

PHYSICS



EXAM QUESTION PACK

MODULE 3 PHYSICS IN ACTION

SCORE

/439

PERCENTAGE

%

STEMUP

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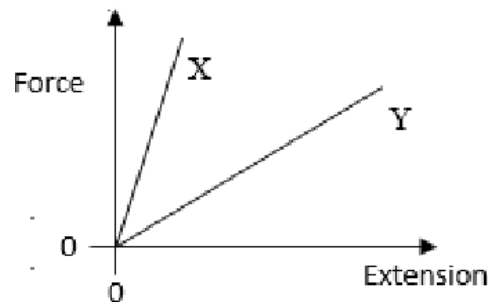
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- 1 This is a force–extension graph for two different materials, X and Y. The materials are stretched up to the point at which they fracture.



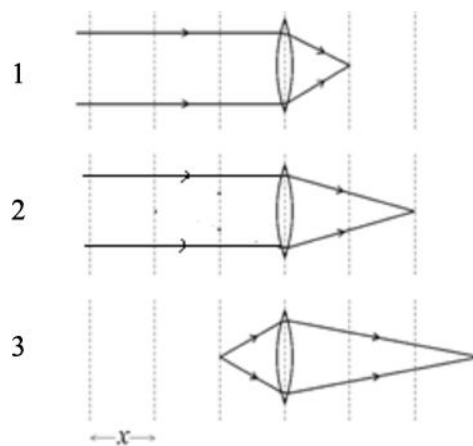
Which one of these statements about the materials is true?

- A Y is stiffer than X
- B both materials are tough
- C X stores more energy than Y
- D X and Y obey Hooke's law

Your answer ☐

[1]

- 2 The diagrams 1, 2 and 3 show three different lenses forming images.
In each diagram, the dotted lines are equally-spaced and separated by the same distance x .



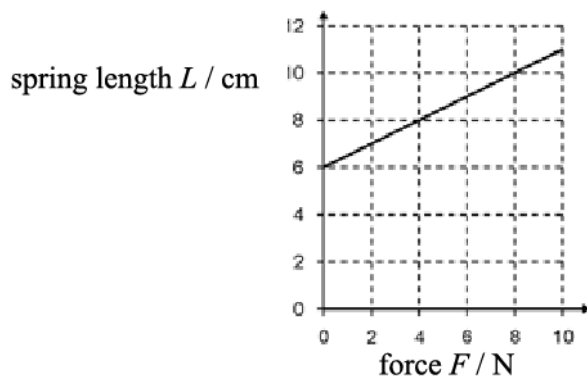
Which, if any, of the lenses have power $P = \frac{1}{x}$?

- A None
- B lens 1
- C lens 2
- D lens 3

Your answer ☐

[1]

- 3 The graph shows the variation of length L of a spring with the stretching force F .



Which is the best estimate of the work done in stretching the spring over the range given by the graph?

- A 0.25 J
- B 0.85 J
- C 85 J
- D 200 J

Your answer

[1]

4 **Fig. 32.1** represents the internal structure of a metal alloy.

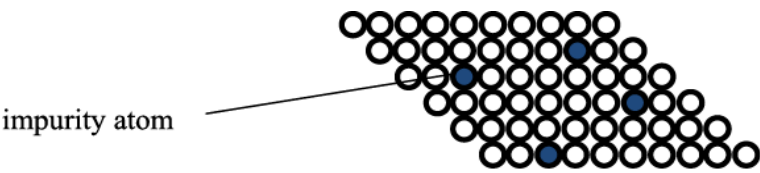


Fig. 32.1

Describe and explain how the presence of impurity atoms makes the metal harder.

[3]

5(a) This question is about sampling sounds. Fig. 41.1 shows part of a waveform. This waveform has been sampled at the points shown by small circles.

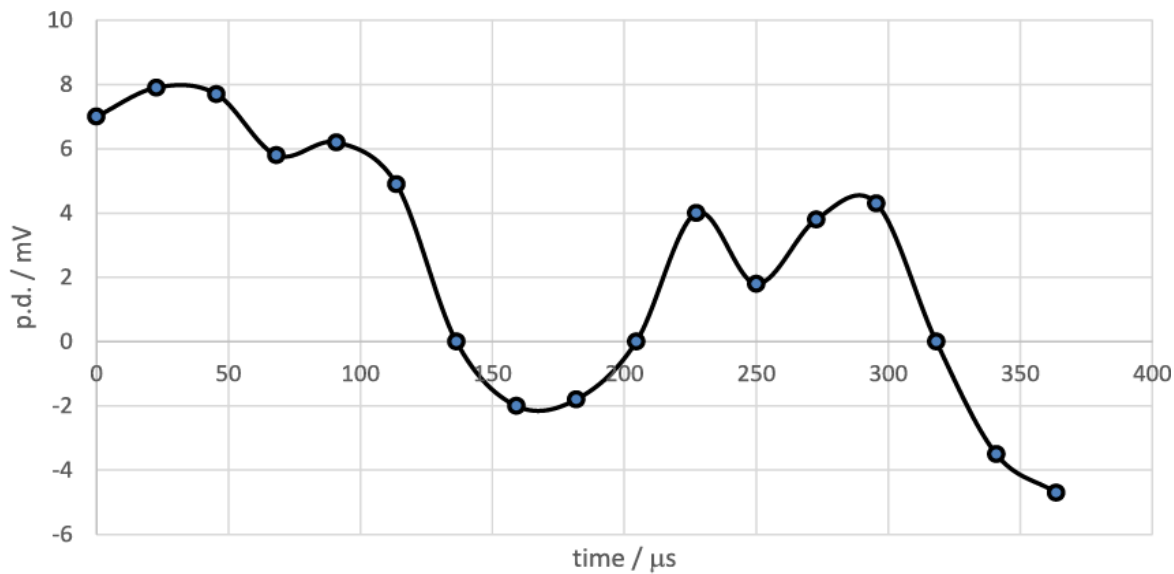


Fig.41.1

The sampling rate is 44 kHz.

On Fig. 41.1 sketch the waveform that would be reproduced if the sample rate is reduced to 22 kHz.
Explain your reasoning and state how the reproduced waveform will differ from the original waveform.

[3]

(b) A student estimates that the system uses 50 000 voltage levels. Calculate how many bits are required to produce this number of levels and suggest a more likely value for the number of voltage levels.

[3]

(c) This system is used for high quality sound. Explain why it is necessary to sample at a frequency of 44 kHz when the highest note that can be heard is about 20 000 Hz.

[2]

(d) Telephone systems are often designed to use 8 bit sampling at 8 kHz instead of the 16 bit sampling at 44 kHz used for music. Suggest and explain why this decision was made in designing those systems and explain why recorded music can sound distorted on a telephone.

[3]

- 6 A student wanted to use a capacitor and a resistor in an electronic timer.
She used the circuit shown in Fig. 4.1 to test a capacitor C and variable resistor R_2 .

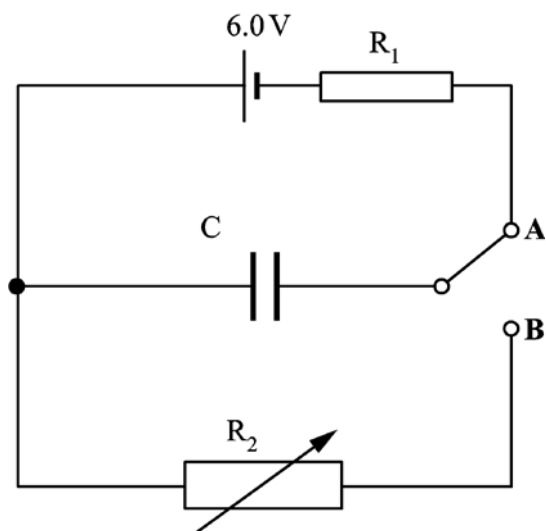


Fig. 4.1

In one test the capacitor was first charged through the fixed resistor R_1 by connecting the switch to A. It was then discharged through the variable resistor R_2 by connecting the switch to B. The student used a data-logger to measure how the voltage across capacitor C varied as it charged and then discharged through the two different resistors. A data table of her results is shown in Fig.4.2.

charging through R_1		discharging through R_2	
t / ms	p.d. ₁ / V	t / s	p.d. ₂ / V
0	0.00	0	6.00
2	0.46	2	5.54
4	0.89	4	5.11
6	1.28	6	4.72
8	1.65	8	4.35
10	1.98	10	4.02
12	2.29	12	3.71
14	2.58	14	3.42
16	2.84	16	3.16
18	3.09	18	2.91
20	3.31	20	2.69
22	3.52	22	2.48
24	3.71	24	2.29
26	3.89	26	2.11

28	4.05	28	1.95
30	4.20	30	1.80

Fig.4.2

Figs. 4.3a and 4.3b show the charge and discharge curves for the data in the table in Fig. 4.2.

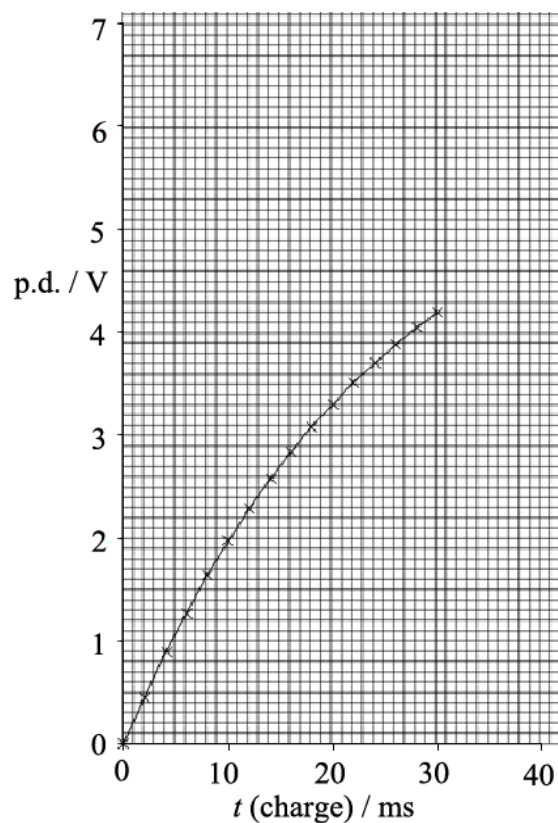


Fig. 4.3a

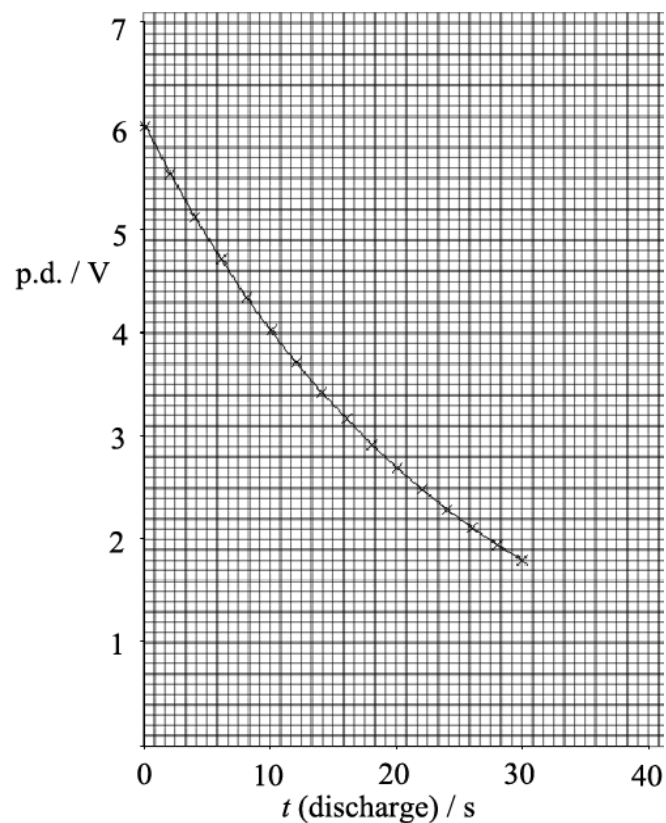


Fig. 4.3b

- (i) Using the graph of Fig. 4.3b, show that the time constant for the discharge is less than 30 seconds.

[3]

- (ii) The capacitor has a value of $4700\ \mu\text{F}$. Show that the initial discharge current would be about $1\ \text{mA}$.

[4]

- (iii) * The student calculated the total amount of charge to flow from the capacitor in the first 30 seconds. She used two methods:

Method 1 – using the relationship $\Delta Q = C \Delta V$

Method 2 – using $I = \frac{V}{R}$ and the area under the $I(t)$ graph where R is $5.0\ \text{k}\Omega$

Show how the total charge flow may be calculated in both cases and comment on how the two methods compare.

[6]

- 7(a) A converging lens is used to form a real image of an object on a screen. The object consists of a black line marked on a sheet of thin white paper illuminated from behind with red light as shown in Fig. 1.1.

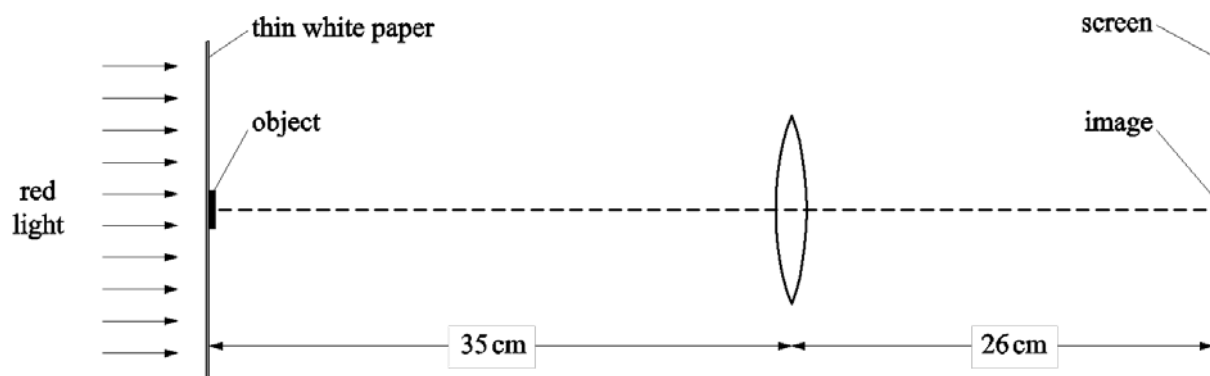


Fig. 1.1

The object is 2.5 cm in height. Using data from the diagram:

- (i) calculate the image height

height = ... cm [2]

- (ii) calculate the power P of the lens.

$P =$ D [2]

- (iii) The ruler used to measure the object and image distances allows measurement to the nearest mm. However, the sharpest position of the image can be judged only to ± 5 mm.

Calculate the uncertainty ΔP in the power of the lens, explaining any assumptions made.

$\Delta P =$ D [3]

(b) When the red light is replaced with violet light, the position of the image moves 2.7 cm closer to the lens.

(i) Show that the power of the lens is about 7% greater for violet light than for red light.

[2]

(ii) Explain how this might affect a person wearing spectacles with lenses made from this glass.

[2]

8(a) A student uses the simple electrical circuit shown in Fig. 4.1 to find the conductivity of a metal alloy.

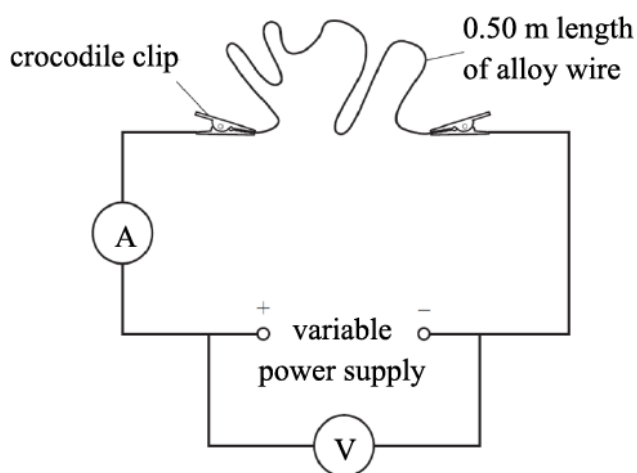


Fig. 4.1

The student uses an alloy wire of length 0.50 m and diameter of 0.213 mm. The student obtains the preliminary readings: $I = 0.18\text{ A}$, $V = 1.4\text{ V}$.

- (i) Calculate the electrical conductivity of the alloy given by the student's readings.

conductivity of alloy = _____ S m^{-1} [3]

- (ii) The accepted value for electrical conductivity of the alloy is significantly larger than the value obtained from the student's data.

Assuming the uncertainties in the student's readings are negligible, suggest and explain a reason for the difference.

----- [2]

- (b) An electromagnetic lock consists of a core and coil attached to a door-frame, and a steel plate attached to the door. In Fig. 4.2 the steel plate is very close to, but not touching, the electromagnetic core.

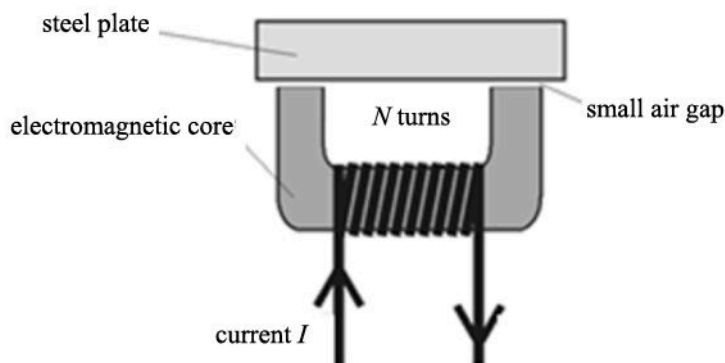


Fig. 4.2

- (i) Draw three lines of magnetic flux on Fig. 4.2 and explain why there is a strong attractive force between the electromagnetic core and steel plate.

[2]

- (ii) Use ideas of permeance to explain why the attractive force becomes much stronger when the core and plate are in contact.

[3]

(c) The experimental diagram of Fig. 4.1 and the door-lock of Fig. 4.2, repeated in Fig. 4.3, are both types of series circuit.

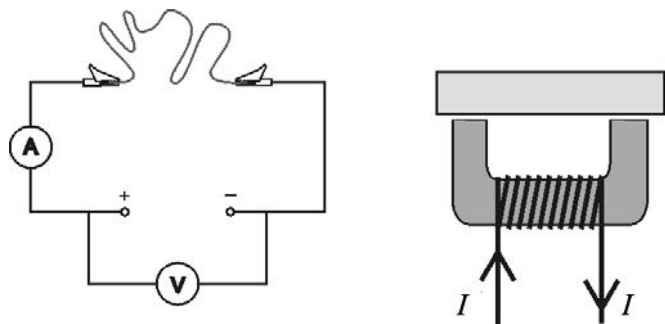


Fig. 4.3

There are analogies between electrical and magnetic circuits.
Complete the table to compare the electrical and magnetic features of the circuits shown in Fig. 4.3.

electrical circuit feature	corresponding magnetic circuit feature
power supply	
e.m.f.	
current in the circuit	
conductance	
the conductance of the connecting leads is greater than that of the alloy metal wire	

[5]

10(a) Fig. 31.1 shows a simple potential divider circuit.

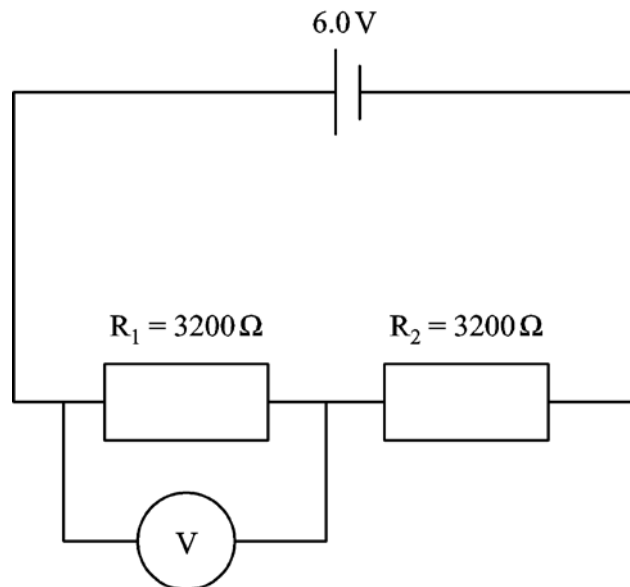


Fig. 31.1

The p.d. across R_1 is 2.9 V.

Show that R_c , the combined resistance of R_1 and the voltmeter resistance R_v , is about $3000\ \Omega$.

Assume that the cell has zero internal resistance.

[2]

(b) Calculate the resistance of the voltmeter, R_v .

resistance = _____ Ω [2]

- 11 A block of mass 0.12 kg is supported by a spring as shown in Fig. 5.1. When displaced vertically from equilibrium and released it makes 5 complete oscillations in 3.0 s .

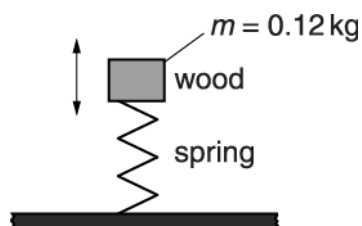


Fig. 5.1

Calculate the force constant of the spring.
Assume that the motion is simple harmonic.

force constant = _____ N m^{-1} [3]

- 12 The top graph of Fig. 6.1 shows how the velocity of an object in simple harmonic motion varies with time. Complete the other two graphs to show how the acceleration and displacement of the object vary with time over the same time interval.

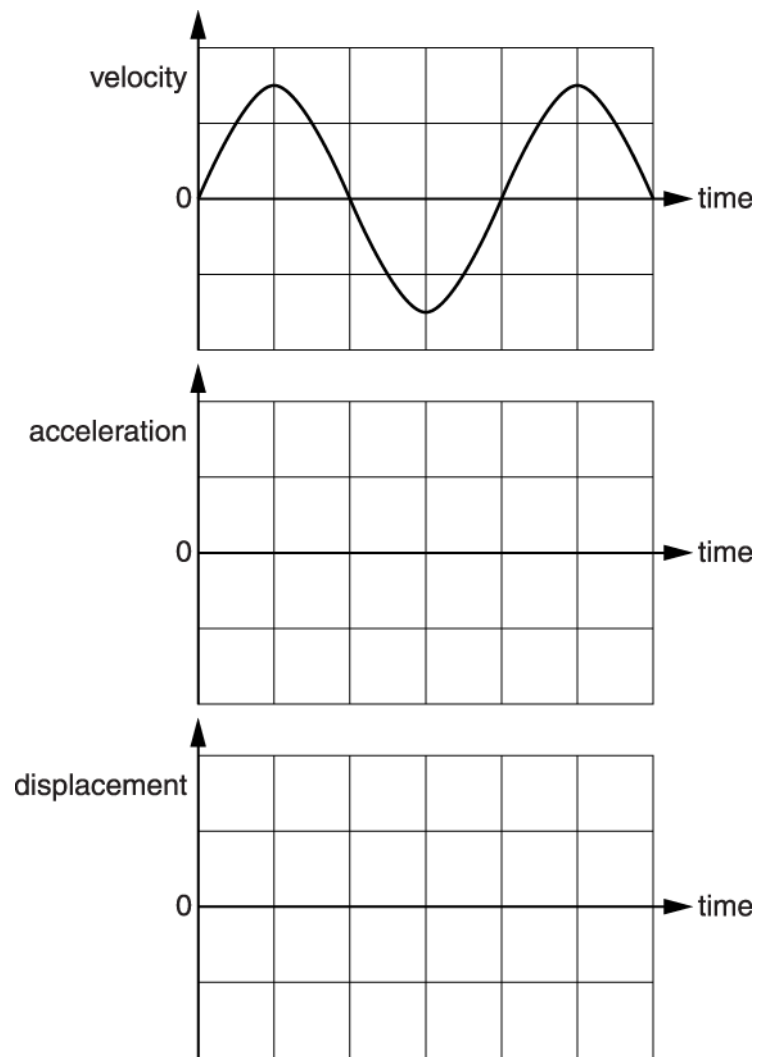


Fig. 6.1

[2]

13(a) This question is based on the Advance Notice *Electricity for Spacecraft*.

The type of battery used to power the first satellite (Sputnik 1) has an energy density of 130 watt-hours per kilogram.

The mass of the battery used in Sputnik 1 was 51 kg. Show that the total amount of energy available from this battery was less than 25 MJ.

[2]

- (b) This battery lasted 22 days (line 8 in the article). Calculate the average power demand of the satellite in that time.

average power = _____ W [2]

14(a) This question is based on the Advance Notice *Electricity for Spacecraft*.

Here are some data concerning the solar panel arrays on the Hubble Space Telescope (HST).

Number of panels	2
Power per panel	2.8 kW
Dimensions of each panel	2.5 m × 7.6 m
Mass of each panel	9.0 kg
Solar radiation intensity received	$1.4 \times 10^3 \text{ W m}^{-2}$

Use data from the table to calculate the power per unit mass of the Hubble solar panel. Compare the value with the value given in the article (line 17).

(b) Show that the **total** amount of solar radiation striking both panels is about 50 kJ per second. [2]

(c) Calculate the percentage efficiency of the panels. [2]

percentage efficiency = _____ % [2]

- (d) Use data from lines 19–22 in the article to calculate the number of orbits for which the onboard battery could power the telescope if the solar panels stopped working completely.

number of orbits = _____ [2]

- (e) Jupiter is 5.2 astronomical units (AU) from the Sun. Show that at this distance, the maximum electrical power produced by a pair of panels like those on the HST is only about 0.2 kW.

Earth-Sun distance = 1.0 AU

[2]

15 This question is based on the Advance Notice *Electricity for Spacecraft*.

Long conducting cables ('tethers') hung from some satellites could be used to generate significant voltages (line 42 in the article).

The choice of metal to be used in a tether depends upon a number of factors. State **two** factors and give a reason for the importance of each.

Factor 1:

Reason:

Factor 2:

Reason:

[4]

16 Which one of the following could **not** be used as a unit of stress?

A Pa

B N m^{-2}

C J m^{-3}

D kg m s^{-2}

Your answer

[1]

- 17 A signal is being digitized by sampling at 2.0 kHz.
The total voltage is 3.0 V and the noise voltage is 5.9 mV.

Which statement is **not** correct?

- A $\frac{V_{\text{total}}}{V_{\text{noise}}} \approx 500$
- B The recommended number of bits per sample is 9
- C The highest frequency in the signal should not exceed 1.0 kHz
- D The voltage resolution of the sampling should be less than 3.0 mV

Your answer

☐

[1]

- 18 Here are some statements about the conduction electrons in a copper wire at room temperature.

- A They are moving freely through the wire.
- B They are moving rapidly and at random making collisions with each other and with the copper ions.
- C They are drifting slowly along the wire making collisions with each other and with the copper ions.
- D They are drifting slowly along the wire but are also moving rapidly and at random, making collisions with each other and with the copper ions.

Which of the above statements best describes the motion of conduction electrons when there is no current in the wire?

Your answer

☐

[1]

19 Here are some statements about the conduction electrons in a copper wire at room temperature.

- A They are moving freely through the wire.
- B They are moving rapidly and at random making collisions with each other and with the copper ions.
- C They are drifting slowly along the wire making collisions with each other and with the copper ions.
- D They are drifting slowly along the wire but are also moving rapidly and at random, making collisions with each other and with the copper ions.

Which of the above statements best describes the motion of conduction electrons when there is a constant current in the wire?

Your answer

[1]

20 Which statement about mechanical properties of materials is **not** correct?

- A Cracks are a common way in which a brittle material can fail mechanically.
- B A material with a high Young modulus will be very stiff.
- C The tensile strength of a stiff material can be relatively small.
- D If a material is tough it will also usually be brittle.

Your answer

[1]

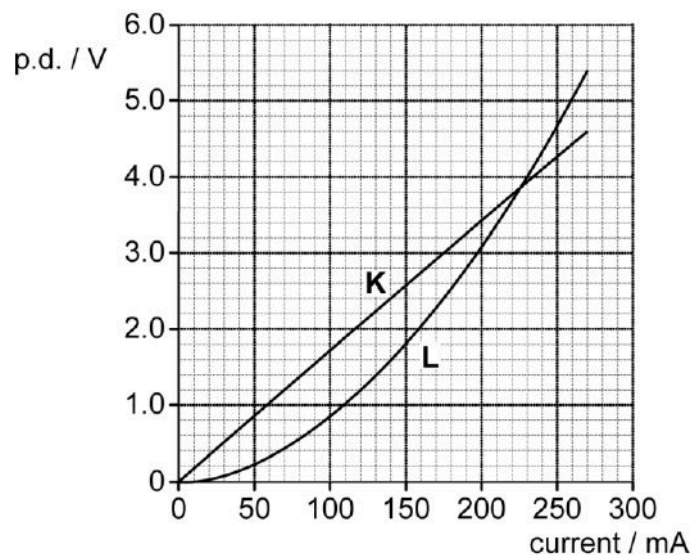
21 For the strain of two different stretched wires to be the same they must have the same ratio of

- A stress to Young modulus.
- B tension to cross-sectional area.
- C tension to extension.
- D tension to original length.

Your answer

[1]

22 The $V - I$ graphs of two electrical components K and L are shown below.



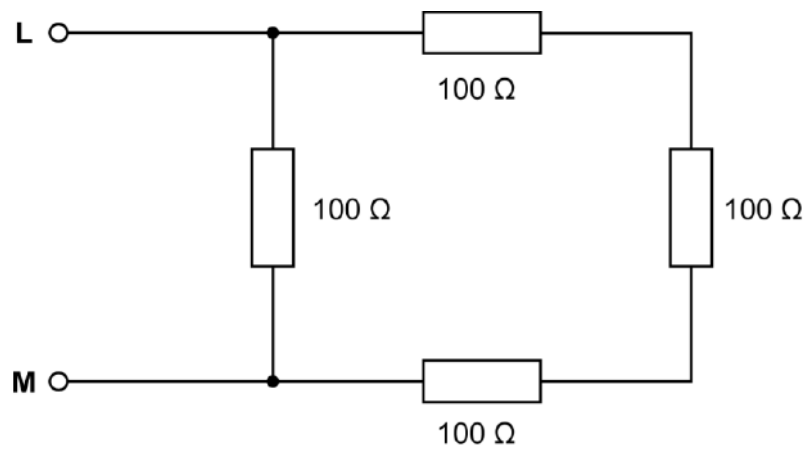
Which statement is **not** correct?

- A K is a resistor and L is a filament lamp.
- B The resistance of L increases as the current in it increases.
- C Up to 3.8 V the conductance of K is larger than the conductance of L.
- D K and L have equal resistance where the graphs intersect at 3.8 V.

Your answer

[1]

23 The diagram shows an arrangement of equal resistors.



What is the total electrical resistance between L and M?

- A less than $10\ \Omega$
- B between $10\ \Omega$ and $100\ \Omega$
- C between $100\ \Omega$ and $300\ \Omega$
- D $400\ \Omega$

Your answer

[1]

24 Kirchhoff's two laws for electric circuits can be derived from conservation laws.

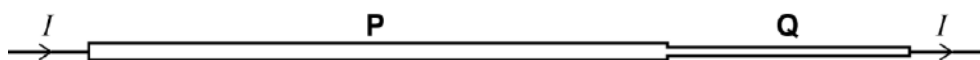
On which conservation laws do Kirchhoff's laws depend?

	Kirchoff's first law	Kirchoff's second law
A	mass	energy
B	current	mass
C	charge	energy
D	energy	current

Your answer

[1]

- 25 A long thick length **P** of tungsten wire is connected in series with a shorter thinner length **Q** of tungsten wire to a variable power supply. The current I in them is adjusted so that when heated by the current their resistances become equal. The wires are not equally hot, **P** is just warm while **Q** glows red.



Which of the following statements about this experiment is/are correct?

- 1 The potential difference across each wire is the same.
- 2 The power dissipated in **P** > power dissipated in **Q**.
- 3 When the current is switched off and the wires have returned to room temperature, the resistances of **P** and **Q** remain equal.

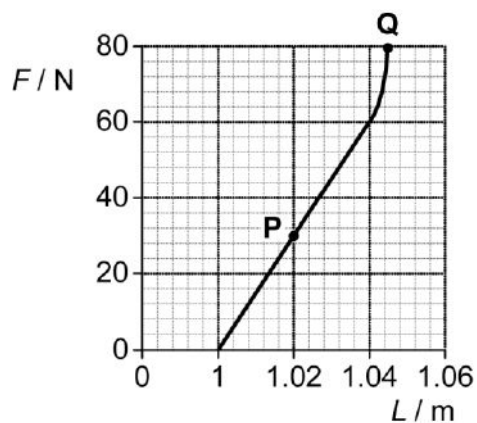
- A 1, 2 and 3 are correct
B only 1 and 2 are correct
C only 2 and 3 are correct
D only 1 is correct

Your answer

☐

[1]

- 26 The graph shows how the length of a perspex strip varies with tension force F .
The strip has a cross-sectional area of 4 mm^2 when it breaks at Q.



Which of the following statements agree with this data?

- 1 The strain at P is 2%.
- 2 The breaking stress is $20 \times 10^6 \text{ Pa}$.
- 3 Hooke's law is obeyed up to a strain of 0.04.

- A 1, 2 and 3 are correct
B only 1 and 2 are correct
C only 2 and 3 are correct
D only 1 is correct

Your answer

[1]

27 Which of the following statements about electromagnetic waves is / are correct?

- 1 It is reasonable to infer that both γ -rays and radio waves are electromagnetic because they both carry energy.
- 2 It is reasonable to expect to be able to polarise electromagnetic waves because they are transverse.
- 3 It is reasonable to expect to observe diffraction of electromagnetic waves of frequency 2×10^8 Hz by an object 1.5 m in diameter since electromagnetic waves travel at 3×10^8 m s⁻¹.

- A 1, 2 and 3 are correct
B only 1 and 2 are correct
C only 2 and 3 are correct
D only 1 is correct

Your answer

[1]

28(a) Fig. 31.1 shows the $V - I$ graph for a potato cell (copper and zinc electrodes stuck in a potato shown in Fig. 31.2).

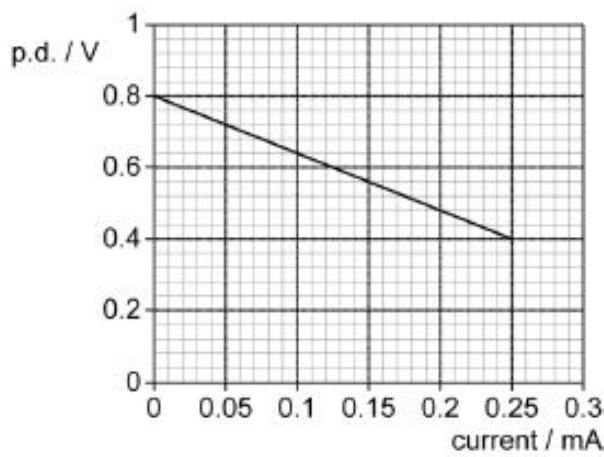


Fig. 31.1

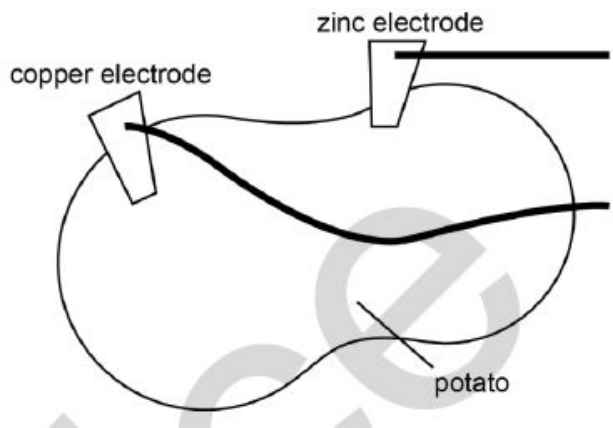


Fig. 31.2

Use Fig. 31.1 to identify the internal resistance of the potato cell. Make your method clear.

internal resistance = _____ Ω [2]

(b)

(i) On Fig. 31.1 draw the $V - I$ graph for a constant resistor of resistance $10\text{ k}\Omega$. [1]

(ii) Using the graph drawn state and explain the current through the $10\text{ k}\Omega$ external resistor when connected across the potato cell.

current = _____ mA

_____ [2]

29(a) Fig. 32.1 shows histograms for a raw image and its processed version.
 The histogram plots the number of pixels against pixel value (0 to 255) for each image.

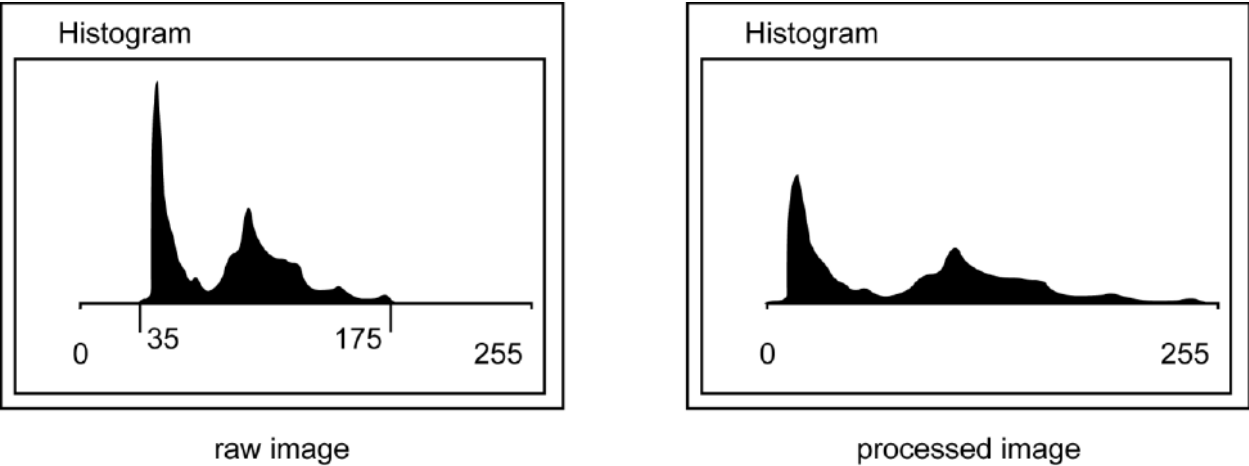


Fig. 32.1

State and describe the process that has been applied to improve the image.

[2]

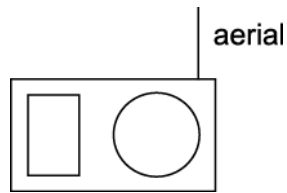
(b) Complete the equation below for calculating the new pixel (grayscale) value from the old value to achieve this image enhancement.

new pixel value = (old pixel value – 35) × (_____) / (_____)

[1]

30(a) A teacher uses a portable radio to demonstrate some properties of waves.
She tunes in to a VHF station.

She obtains the strongest signal when the aerial is vertical as shown below.



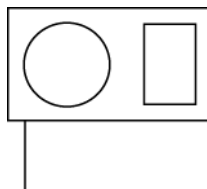
However the signal fades to a minimum when she rotates the radio through 90° as shown below.



State the property of transverse waves that this experiment demonstrates.

----- [1]

(b) The teacher rotates the radio once more through another 90° , as shown below.



State and explain the effect this has on the strength of the received signal.

----- [2]

31(a) A student investigates how the resistance of an LDR varies with light intensity using a lux-meter and an ohm-meter capable of $\pm 1\%$ uncertainty. The teacher also advises her to calculate the conductance G of the LDR, and to plot the graphs shown below. Fig. 39.1, Fig. 39.2 and Fig. 39.3 show her incomplete practical results.

Light Intensity / lux	R_{LDR} / Ω	G / mS
15	13000	0.08
70	3450	0.29
150	1640	0.61
260	1070	0.93
500	530	
1000	270	
1500	186	
2000	150	

Fig. 39.1

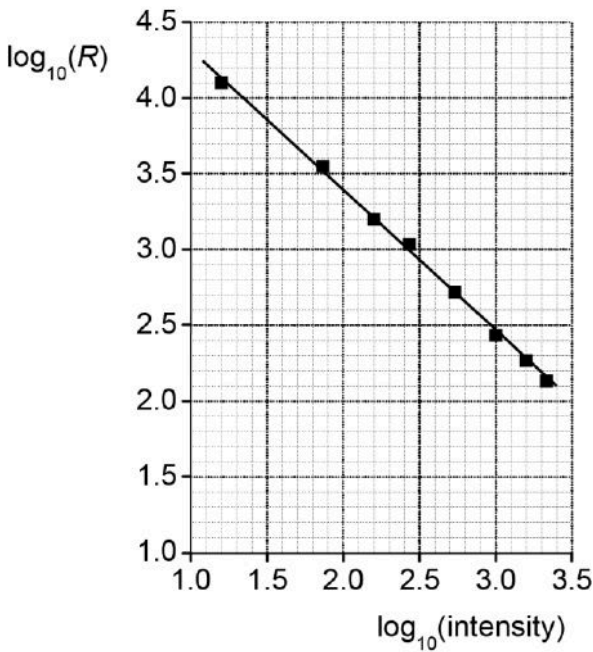


Fig. 39.2

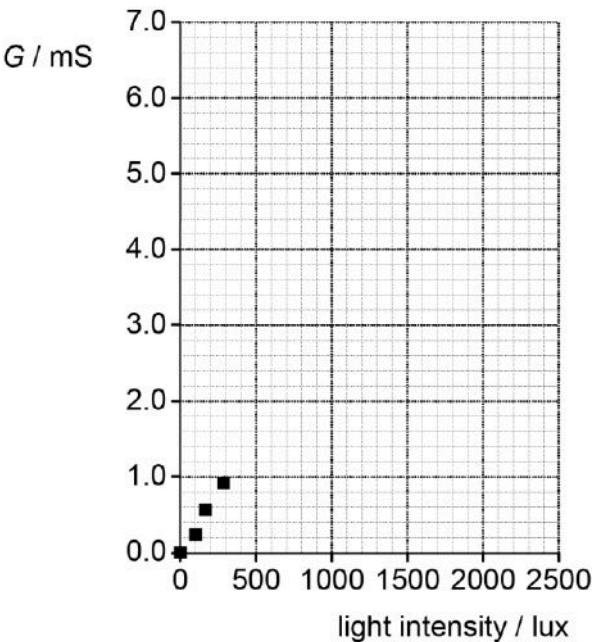


Fig. 39.3

- (i) Complete her table Fig. 39.1 for conductance G in mS.
 Plot the remaining data on her graph of Fig. 39.3 and draw a line of best fit.

[3]

- (ii) Explain why these graphs are more useful than a plot of R against light intensity, and state your conclusion about what they show.

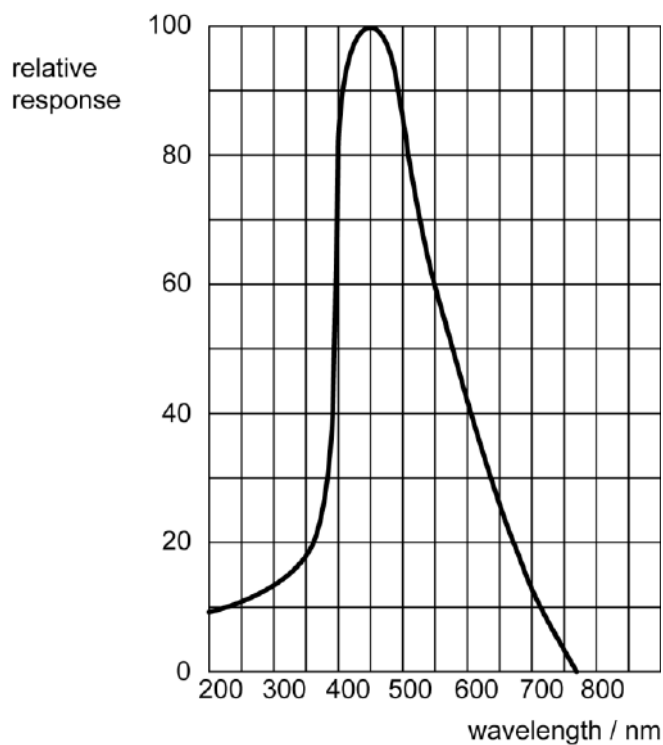
----- [3]

- (iii) The light sensitive material in the LDR is a semiconductor. It is suggested that the charge carrier density in the material is proportional to the light intensity shining on it.

Give a reason for this suggestion and evaluate it using the graphical evidence from part (i).

----- [2]

(b) The graph below shows the relative response to different wavelengths of light for the LDR.



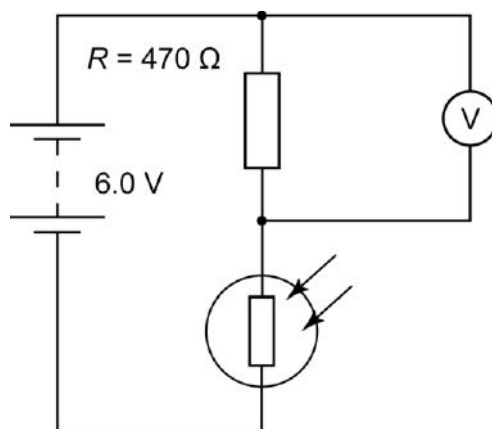
(i) State the feature of the graph that suggests a quantum process might be involved in changing charge carrier density when the LDR is illuminated.

----- [1]

(ii) Use a value from the graph to calculate the minimum energy for the quantum process.

energy = ... J [2]

- (c) The LDR is set up in the potential divider circuit as shown with a 6.0 V supply and a fixed resistor of resistance 470 Ω .



Use data in Fig. 39.1 to calculate the p.d. measured by the voltmeter when the light intensity is 1000 lux.

p.d. = ... V [2]

32 This question is about modelling simple harmonic motion.

Fig.4.1 shows a trolley of mass 1.0 kg tethered between two extended springs. The springs obey Hooke's law.

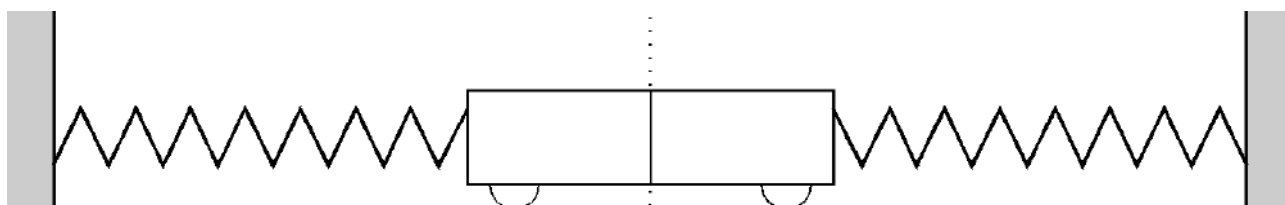


Fig. 4.1

Fig. 4.2 shows the trolley displaced 0.10 m to the right. Both springs are still in tension.

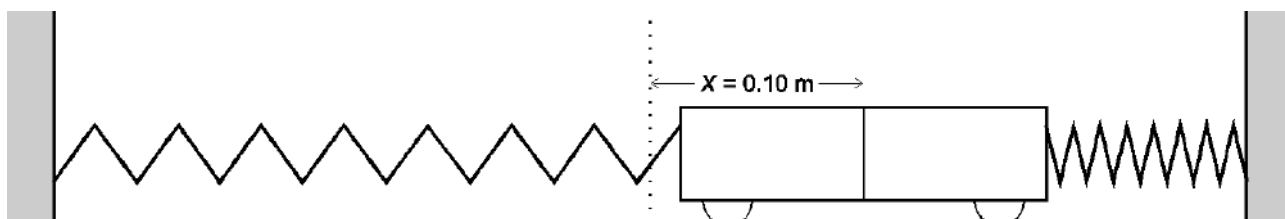


Fig. 4.2

In Fig. 4.2 the resultant force on the trolley is 4.0 N to the left. Calculate the force constant of the spring / trolley system.

force constant = _____ N m^{-1}

[1]

33(a) This question is about a portable, flexible electrical extension cable. The cross-section of the cable is shown in Fig. 6.1

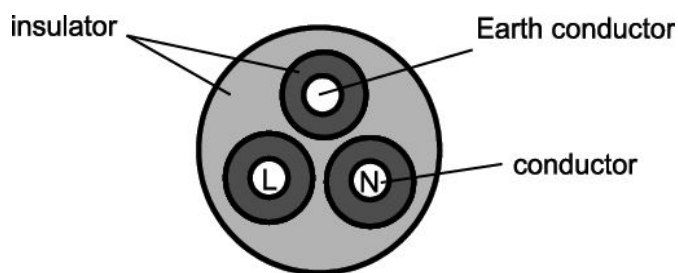
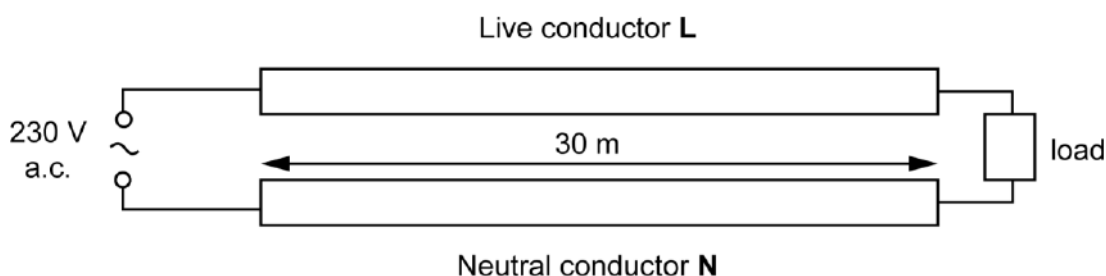


Fig. 6.1

The live **L** and neutral **N** conductors are connected in series with the load and the supply as shown below.



- (i) The cable is 30 m long, so that the total length of conductor is 60 m. The conductor has a diameter of 1.5 mm.

Copper has a conductivity of $5.9 \times 10^7 \text{ S m}^{-1}$.

Calculate the conductance of the cable.

conductance = _____ S [3]

- (ii) Calculate the voltage dropped across the 60 m of cable when it carries a current of 13 A.

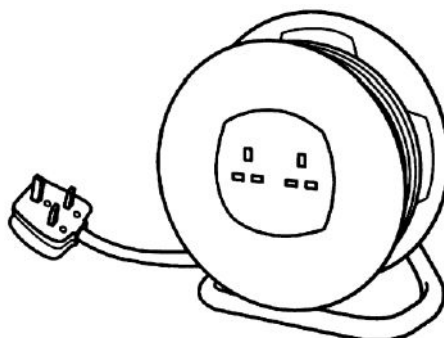
voltage dropped = _____ V [2]

- (iii) Explain why a 2.8 kW 230 V kettle would take slightly longer to boil when connected to the mains supply with

this extension lead, but the performance of a 500 W electric drill would not be significantly affected by using this extension cable.

[3]

- (b) * The cable is stored tightly wound on a reel as shown. The manufacturer recommends that if the cable is used coiled on its reel, the current must be significantly less than 13 A to prevent overheating.



Use your answers to part (a) to calculate the power dissipated by the cable. Make further estimates and calculations to show why the current should be kept significantly less than 13 A when the cable is wound on a reel.

specific thermal capacity of copper = $390 \text{ J kg}^{-1} \text{ K}^{-1}$

density of copper = 9000 kg m^{-3}

[6]

34(a) This question is about the physical properties of cooked and uncooked food. It is based on the Advance Notice article.

The biological molecules found in meat, or in uncooked vegetables, are **long-chain polymer molecules** (lines 6 – 7 in the article).

With the aid of a simple sketch, indicate the basic structure of a long-chain polymer molecule.

[1]

(b) The term ‘tough’ is used rather differently in describing strong materials such as metals.’ (lines 22 – 23 in the article).

(i) State the meaning of the word ‘tough’ as applied to a strong material.

----- [1]

(ii) Referring to the structure of collagen (Fig. 1 and lines 19 – 20 in the article), suggest why raw meat is tough to eat.

----- [2]

(iii) What happens to the structure of collagen during cooking to make meat tender and cause it to fall apart? (lines 20 – 22 in the article)

----- [2]

(c) Jellies are made from gelatine. With reference to the structure of gelatine (Fig. 1 and lines 25 – 29 in the article), explain why the density of a jelly is almost identical to the density of water.

----- [1]

In lines 10 – 12 the article states, ‘The important applications of physics in the kitchen – particularly heat transfer – are ways in which we can control and accelerate these processes.’

Thermal conductivity k is analogous to electrical conductivity σ , with the energy per second P conducted through a conductor (such as the bottom of a pan) of area A and thickness d given by the equation

$$P = \frac{kA}{d} \Delta T$$

where ΔT is the temperature difference between the hot and cold ends of the conductor.

metal	aluminium	steel	copper
thermal conductivity k /W m ⁻¹ K ⁻¹	220	48	380

Saucepans can be made from aluminium, stainless steel or copper. Discuss how the cooking of food in a saucepan can be controlled and accelerated by a suitable choice of materials and dimensions of the pan.

[6]

36(a) This question is about a simple electronic thermometer using a thermocouple (lines 51 – 54 in the Advance Notice article). A thermocouple is made from two different metals, connected at two junctions at different temperatures, as shown in Fig. 10.1. This generates an e.m.f. ε which depends on the temperature difference ΔT between the two junctions

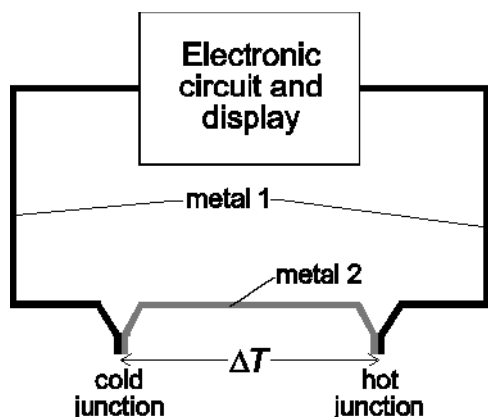


Fig. 10.1

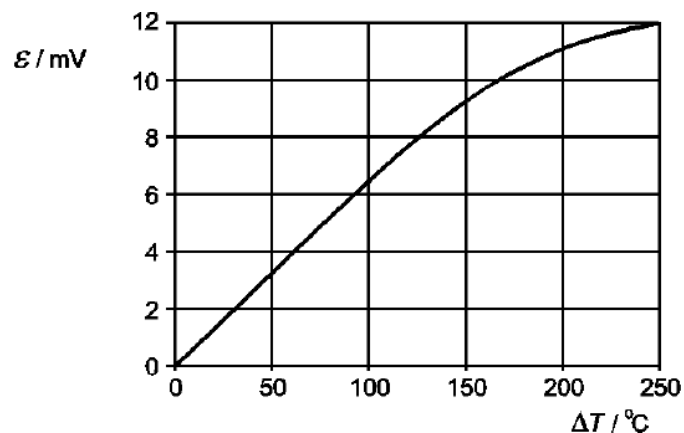


Fig. 10.2

The display for the electronic thermometer is a voltmeter of full-scale deflection 2.50 V. The thermometer is designed to have a range of 0 °C to 250 °C. Look at the graph of Fig. 10.2 and state why an amplifier is needed.

----- [1]

- (b) A temperature difference $\Delta T = 250\text{ }^{\circ}\text{C}$ gives a reading of 2.50 V on the display of the thermometer.

Use the graph of Fig. 10.2 to explain why a temperature difference $\Delta T = 125\text{ }^{\circ}\text{C}$ may not give a reading of 1.25 V.

[2]

37 A $470\ \mu\text{F}$ capacitor is placed in the circuit of Fig. 12.3.



Fig. 12.3

When the switch **S** is opened, the reading on the voltmeter decreases by $0.12\ \text{V}$ in $60\ \text{s}$. This is because the insulator which separates the capacitor plates does not have infinite resistance. Charge is able to flow directly from one plate to another through the insulator, making a *leakage current*.

- (i) Calculate the leakage current in the insulator.

leakage current = _____ μA [2]

- (ii) Leakage current increases with temperature. The Boltzmann factor can be used to predict that the leakage current I is related to the temperature T by the equation $I = Ae^{-\epsilon/kT}$, where A is a constant.

Suggest the meaning of the quantity ϵ in this equation.

[2]

- (iii) The leakage current rises from $1.0\ \mu\text{A}$ to $10\ \mu\text{A}$ as the temperature of the capacitor increases from $300\ \text{K}$ to $400\ \text{K}$. Calculate the value of ϵ .

$$k = 1.4 \times 10^{-23}\ \text{J K}^{-1}$$

$$\epsilon = \text{----- J [2]}$$

38 This question is about avoiding resonant oscillations in an earthquake.

The lift in a skyscraper can be modelled as a mass suspended by a spring from the top of the building. The lift will therefore have a natural frequency of vertical oscillations f_0 . If the value of f_0 lies within the range 2 Hz–0.2 Hz, there is a risk that surface waves from an earthquake will set the lift into resonance.

Fig. 13.1 shows a lift cage suspended by steel cables from the top of a tall building. Here are some data for a typical lift.

mass of empty cage	1500 kg
maximum load of 8 people	640 kg
maximum length of cable	300 m
overall cross-sectional area of cables	$2.5 \times 10^{-4} \text{ m}^2$
Young modulus of steel	$2.0 \times 10^{11} \text{ Pa}$
yield stress of steel	$2.5 \times 10^8 \text{ Pa}$

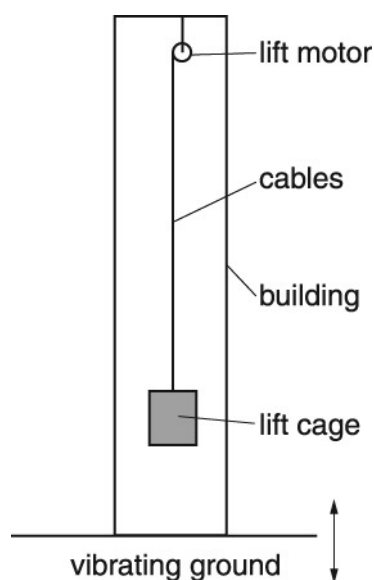


Fig. 13.1

- (i) Show that the force constant k of a cable of length L , cross-sectional area A and Young modulus E is given by

$$k = \frac{EA}{L}$$

[2]

- (ii) Use calculations to show that the lift is in danger of resonance from earthquake waves when it contains a maximum load and the cables are at their maximum length.

[3]

39 This question is about the physical properties of lithium fluoride crystals (TLD 'chips').

The mechanical properties of the material of the chips require them to be handled with some care. Use the internal structure of such ionic crystals (Fig. 15.1) to explain how this structure gives them these properties.

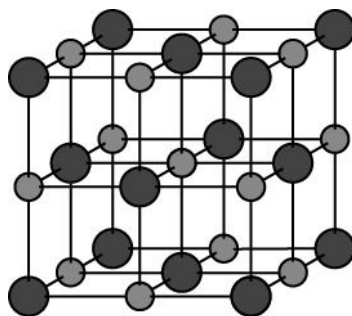


Fig. 15.1



In your answer you should clearly identify the relevant properties and link them to the structure.

40(a) Electrons reach the anode at the far end of the photomultiplier tube to produce a small current.

[3]

For an anode current of 5×10^{-13} A, show that the number of electrons reaching the anode each second is about 3×10^6 .

electronic charge = 1.6×10^{-19} C

[2]

- (b) If three electrons are emitted from each dynode for each incident electron, calculate the number of electrons per second that must be incident upon the first dynode.

number of electrons per second = _____ s⁻¹ [3]

41(a) This question is based on the insert.

Optical microscopes use combinations of glass lenses to produce magnified images (line 10). The objective lens is a short focal length converging lens as shown in Fig. 13.1.

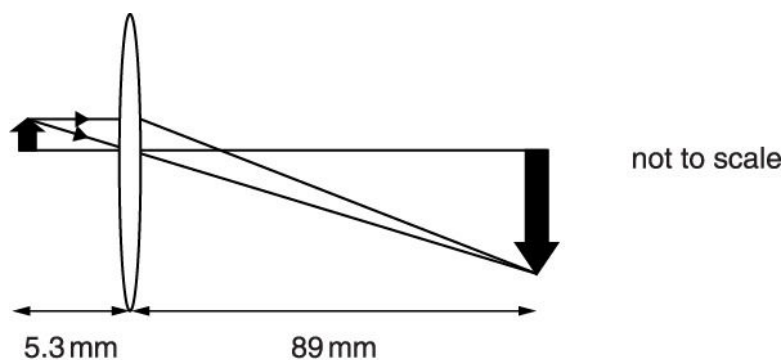


Fig. 13.1

Calculate the magnification of the image.

magnification = ...

[1]

(b) Calculate the power of the lens.

power = ... dioptr

[2]

42(a) This question is based on the insert.

The image shown in Fig. 14.1 is that of part of a fly's eye, obtained with an electron microscope.
The eye consists of a large array of lenses (line 75).

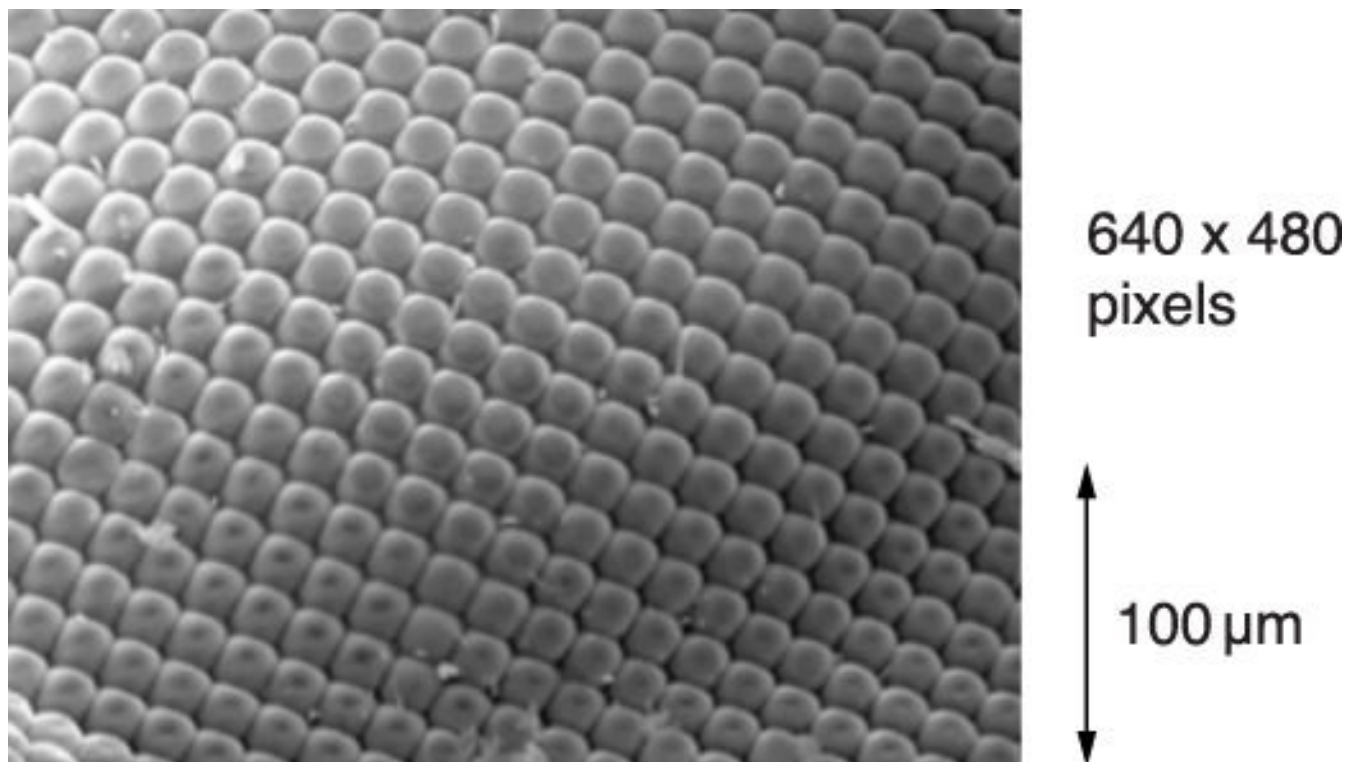


Fig. 14.1

From the information given in Fig. 14.1, calculate the resolution of the image.

resolution = _____ metres per pixel

[2]

- (b) The surface area of the fly's eye covered by the lenses is about $6.2 \times 10^{-6} \text{ m}^2$. Calculate the approximate number of lenses covering one eye.

approximate number of lenses covering one eye = _____

[2]

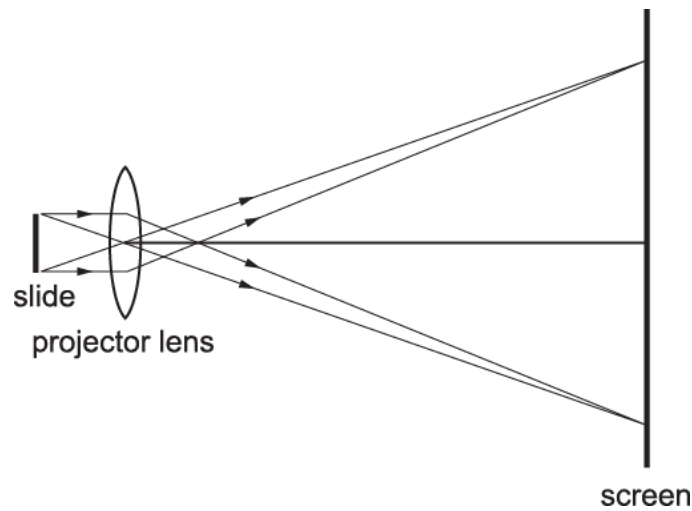
- 43 Which unit could be used for conductance?

- A W A^{-1}
- B $\text{A}^2 \Omega$
- C V A^{-1}
- D A V^{-1}

Your answer

[1]

44 A slide projector is set up to give a focused image on a fixed screen.



Which set of adjustments could give a larger focused image on the screen?

	Movement of slide	Movement of projector
A	away from the lens	away from the screen
B	away from the lens	towards the screen
C	towards the lens	away from the screen
D	towards the lens	towards the screen

Your answer

[1]

45 A thin converging lens of focal length f produces a real image.

Which of the following is correct?

When the object distance is

- A very large the image distance is $2f$.
- B f the magnification M is 1.
- C $2f$ the image distance is f .
- D larger than f but smaller than $2f$ the magnification M is larger than 1.

Your answer

[1]

46 An analogue signal with a maximum frequency of 6 kHz is to be digitised.

For the signal $\frac{V_{\text{Total}}}{V_{\text{Noise}}} = 2000$ what is the best estimate of the bit rate needed for the digitised signal?

- A 12 Mbit s⁻¹
- B 24 Mbit s⁻¹
- C 66 kbit s⁻¹
- D 132 kbit s⁻¹

Your answer

[1]

47 Two wires of the same length and the same material are connected in parallel across the same battery of negligible internal resistance. Wire X has double the diameter of wire Y.

What is the ratio $\frac{\text{current in X}}{\text{current in Y}}$?

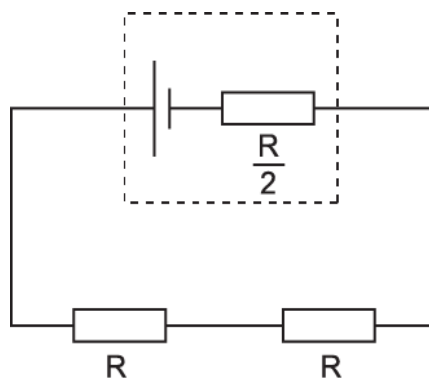
- A $\frac{1}{4}$
- B $\frac{1}{2}$
- C 2
- D 4

Your answer

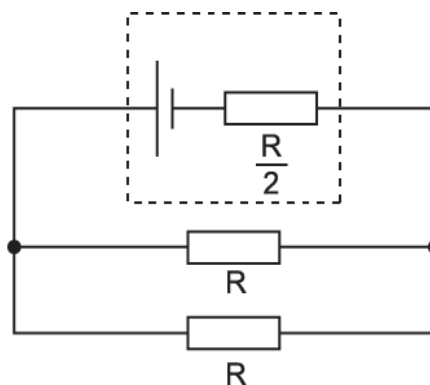
[1]

48 These two circuits have identical components.

The cells have internal resistance $r = \frac{R}{2}$.



circuit 1



circuit 2

What is the ratio $\frac{\text{total resistance of circuit 1}}{\text{total resistance of circuit 2}}$?

- A $\frac{5}{2}$
- B $\frac{2}{5}$
- C $\frac{3}{2}$
- D $\frac{2}{3}$

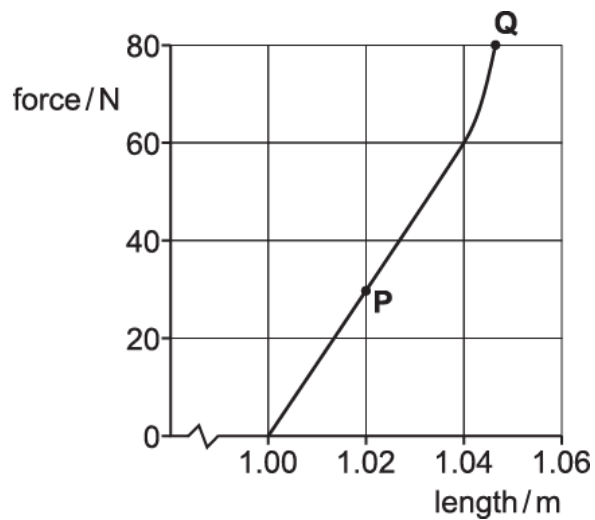
Your answer

[1]

The following information is for use in questions 8 and 9.

The graph shows how the length of a plastic rod varies with the force in it.

The rod snaps at Q, when its cross-sectional area is $2 \times 10^{-6} \text{ m}^2$.



49 What is the best estimate for the Young modulus of the plastic?

- A 10^3 Pa
- B 10^6 Pa
- C 10^9 Pa
- D 10^{11} Pa

Your answer

[1]

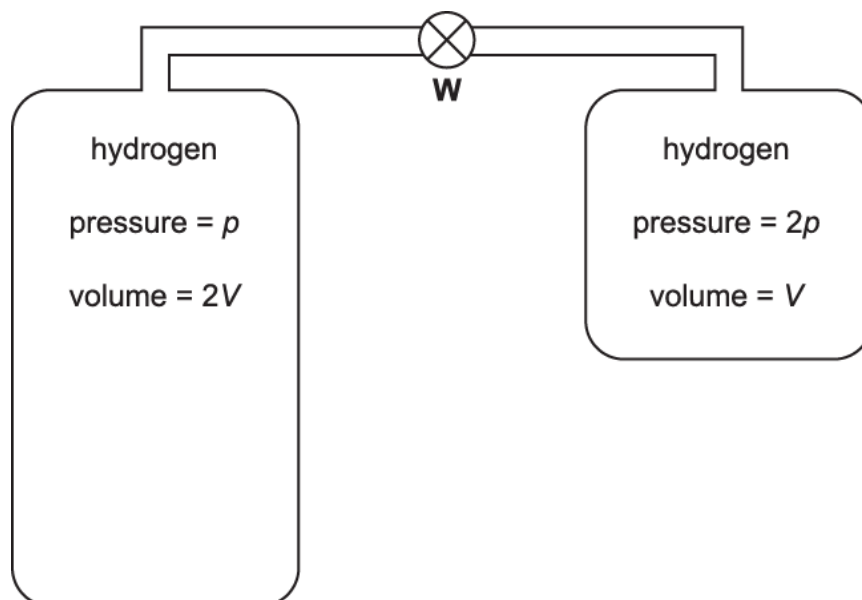
50 Which of the following statements is correct?

- A The breaking stress is $4.0 \times 10^7 \text{ N m}^{-2}$.
- B Hooke's Law is obeyed up to a force of 60 N.
- C The stress at P is 0.2%.
- D The strain at P is 0.02%.

Your answer

[1]

51 Two large gas bottles are connected by a tube of negligible volume as shown.



Initially the valve **W** is closed.

Valve **W** is opened so that gas can slowly flow, but remain at room temperature.

What is the new gas pressure in the bottles when flow has stopped?

- A $\frac{2}{3}p$
- B $\frac{4}{3}p$
- C $\frac{3}{2}p$
- D $\frac{5}{3}p$

Your answer

[1]

- 52 Fig. 35.1 shows two hydrogen spectra, on the same wavelength scale. One is from a laboratory reference frame and the other from a distant, receding cloud of hydrogen gas.

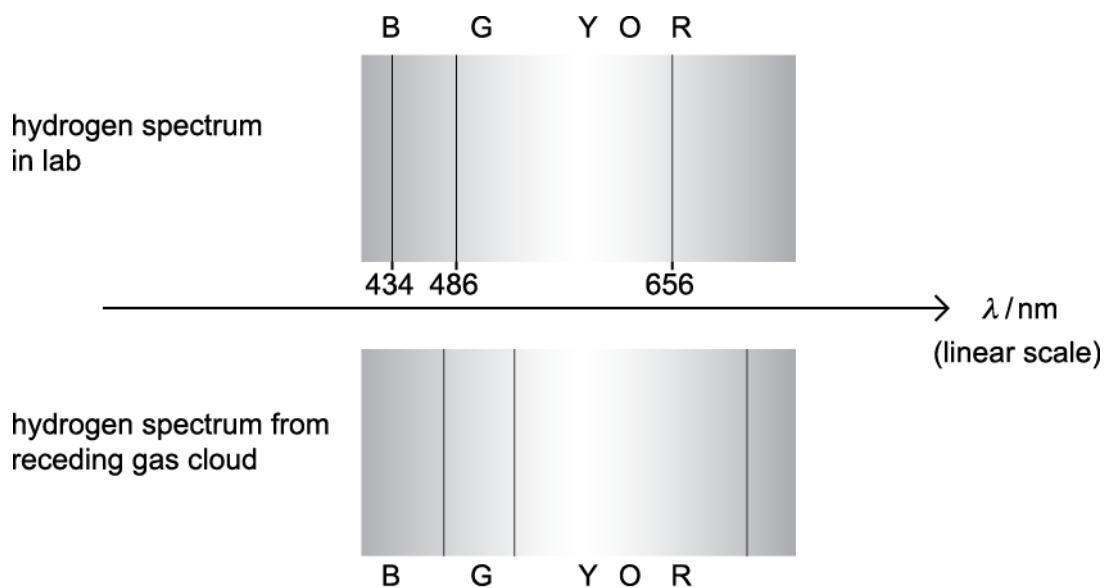


Fig. 35.1

Use the non-relativistic Doppler shift equation $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$

to show that the recession velocity v of the distant hydrogen gas cloud is about $0.1 c$.

[3]

53(a) Fig. 37.1 shows a toy rocket of mass 0.030 kg about to be launched vertically from a compressed spring that obeys Hooke's Law.

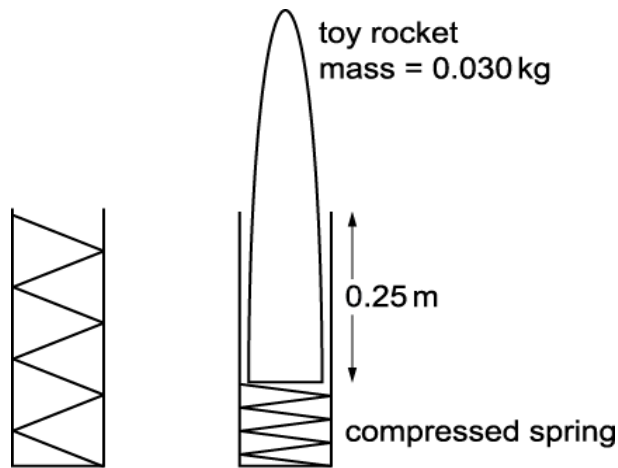


Fig. 37.1

The spring is compressed by 0.25 m by a force of 18 N.

Calculate the maximum height that the toy rocket could reach.
State any assumptions you make.

maximum height = _____ m [3]

- (b) In reality the toy rocket would not reach as high as you calculated in (a).
Suggest and explain one possible reason for this shortfall.

_____ [2]

- (c) The spring vertically launches a ball bearing of mass equal to the rocket.
Suggest and explain how the height reached by the ball bearing might be different to the rocket.

_____ [2]

54(a) This question is about strain gauges that can be fixed to an object to measure its extension or compression.

Fig. 38.1 shows a strain gauge. It is made of strips of **very thin** metallic foil in a series **zig-zag** format.

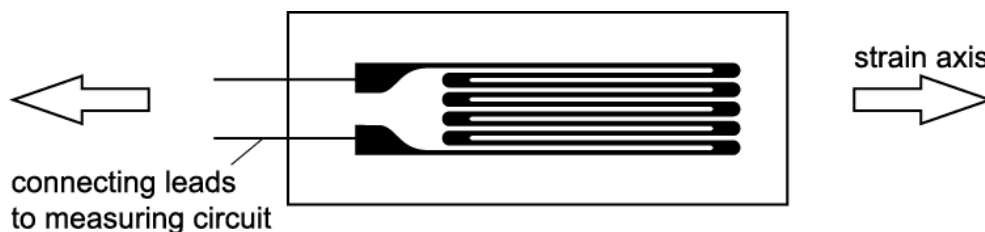


Fig. 38.1

- (i) State why the foil gauge is made in this shape.

----- [1]

- (ii) The strain gauge has a resistance R of $350.0 \pm 0.05 \, \Omega$.

A student measures the resistance R using connecting leads and an ohmmeter, as shown in Fig. 38.2. The ohmmeter reading is accurate to 5 s.f. and measures $350.90 \, \Omega$.

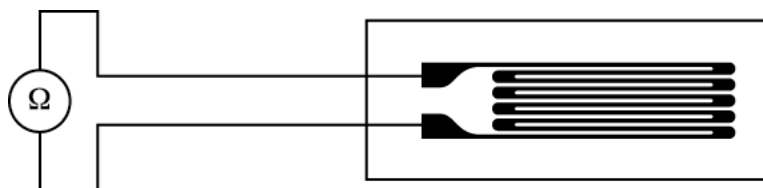


Fig. 38.2

Suggest an explanation for this systematic error.

----- [1]

- (b) To make a sensing circuit, a student connects a potential divider circuit with the strained gauge X connected in series with another identical, unstrained strain gauge Y as shown in Fig. 38.3.

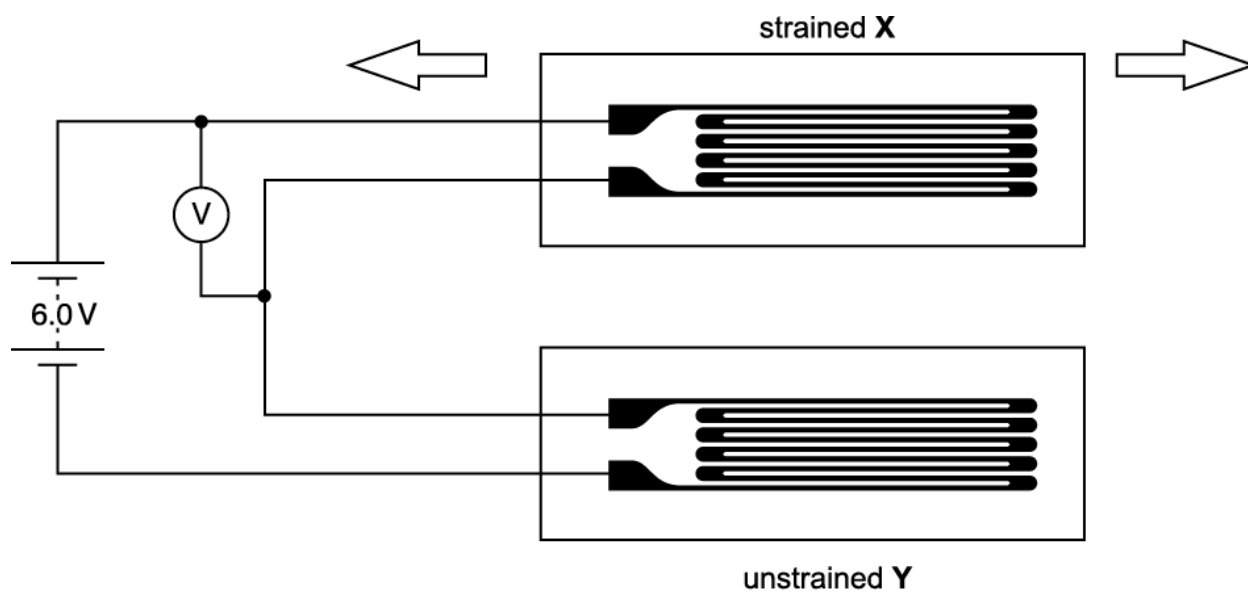


Fig. 38.3

- (i) Fig. 38.4 shows the calibration graph for this strain sensor.

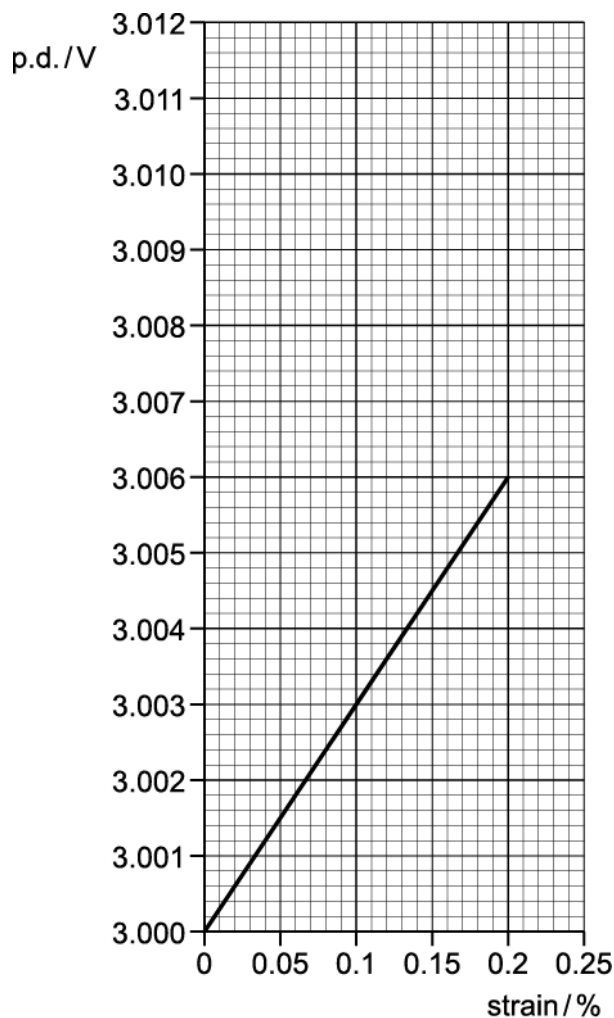


Fig. 38.4

Use data from Fig. 38.4 to calculate the sensitivity of the strain gauge sensor.

sensitivity = _____ V unit strain⁻¹ [2]

- (ii) Explain how there can be a systematic error in strain measurement if the strained gauge X is in a hotter environment than the unstrained gauge Y.

Use these order of magnitude statements about metal properties to help you answer:

fractional change in resistivity per kelvin $\frac{\Delta\rho}{\rho\Delta T} \approx +10^{-3} \text{ K}^{-1}$ and

fractional change in length per kelvin $\frac{\Delta L}{L\Delta T} \approx +10^{-5} \text{ K}^{-1}$.

[4]

- (iii) In the case of a bending beam the upper surface is stretched and the lower surface is compressed as shown in Fig. 38.5.

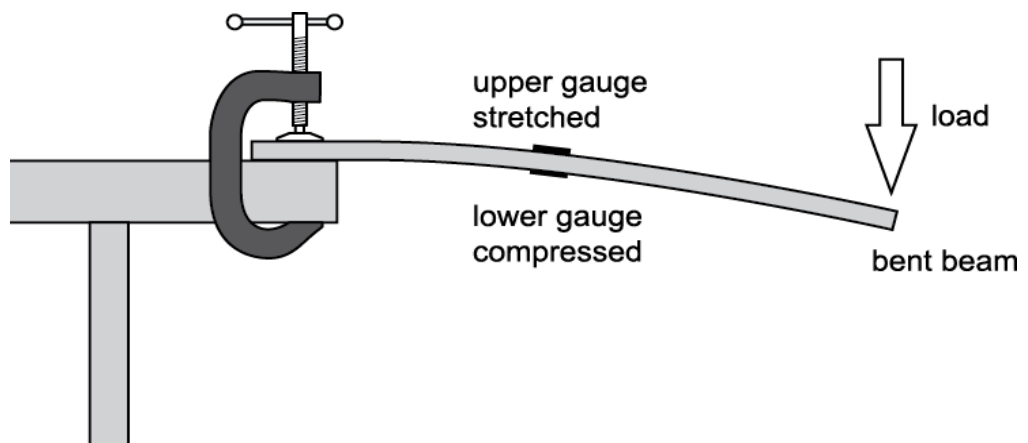


Fig. 38.5

The circuit in Fig. 38.3 is used with the strain gauge X attached to the upper surface of the beam, and strain gauge Y on the lower surface.

Draw on Fig. 38.4 the calibration graph you would expect for this arrangement of gauges.

[1]

55(a) Juno is a satellite mission to Jupiter. Fig. 39.1 shows an image it captured as it passed the Earth.

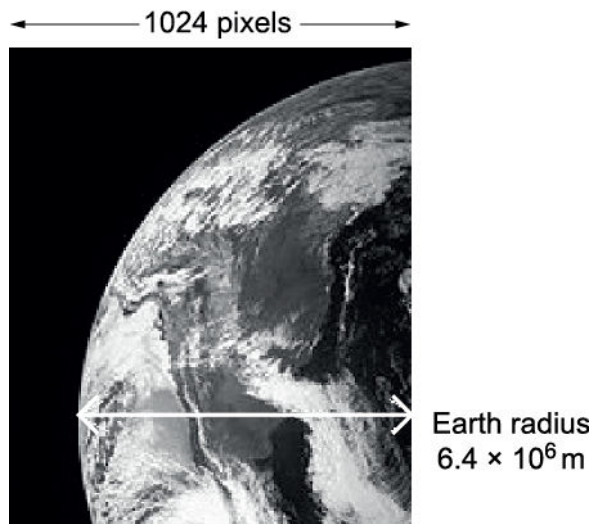


Fig. 39.1

The camera forms an image on a sensor of 1224×1024 pixels. It records three-colour (RGB) intensity using 10 bits per colour per pixel.

- (i) Show that the information in a full uncompressed image is less than 40 Mbits.

[1]

- (ii) An Earth radius ($= 6.4 \times 10^6 \text{ m}$) is indicated on the image.

Estimate the resolution of the image in Fig. 39.1. Make your method clear.

resolution = _____ m pixel^{-1} [2]

- (b) *The JunoCam contains an image processor chip so that images can be enhanced and data downloaded efficiently. Some of the image processing techniques are: **noise reduction**, **changing contrast** or **brightness** of the image and **edge detection**. The data representing the image can also be **compressed** into a smaller number of bits.

Describe how the data from the camera is manipulated in these processes. Suggest advantages and problems of image processing, and explain why compressing the image data is useful.

This image shows a blank sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

[6]

- (c) The satellite transmits information at 340 bit s^{-1} .

Calculate the amount of information in bytes that can be transmitted in 24 hours.

information = _____ Mbytes [2]

56(a) This question is about the behaviour of a pure metal and an alloy.

Fig. 3.1 shows the stress against strain graphs to breaking point for samples of a pure metal and one of its alloys.

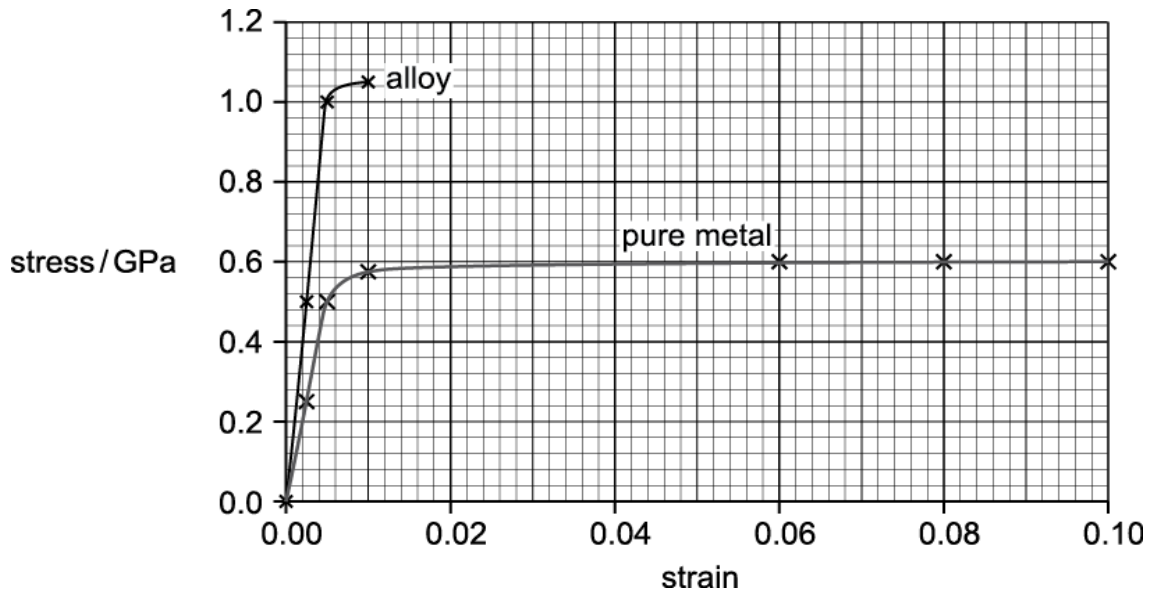


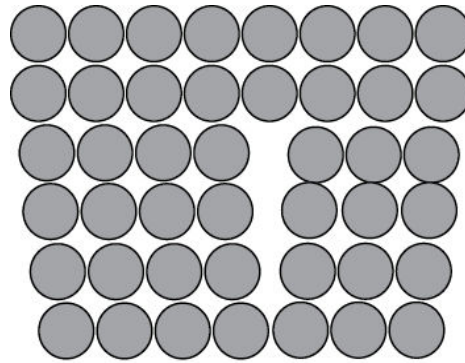
Fig. 3.1

- (i) Use the graph to calculate the Young modulus of the metal alloy. Make your method clear.

Young modulus = _____ GPa [3]

- (ii) Use the graphs to compare the stiffness, strength and ductility of the metal and the metal alloy. Explain your reasoning.

- (b) The microstructure of the pure metal is shown in Fig. 3.2. State how the microstructure of the alloy is different from that in the pure metal and explain how this effects the properties you have discussed in part (a)(ii).



pure metal

Fig. 3.2

57(a) This question is about the determination of the specific thermal capacity of aluminium.

An electrical heater is used to raise the temperature of a 1.0 kg aluminium block in the circuit shown in Fig. 1.1.

The switch is closed, switching the heater on for ten minutes before the switch is opened, which turns the heater off.

The temperature of the block is recorded at one minute intervals for fifteen minutes.

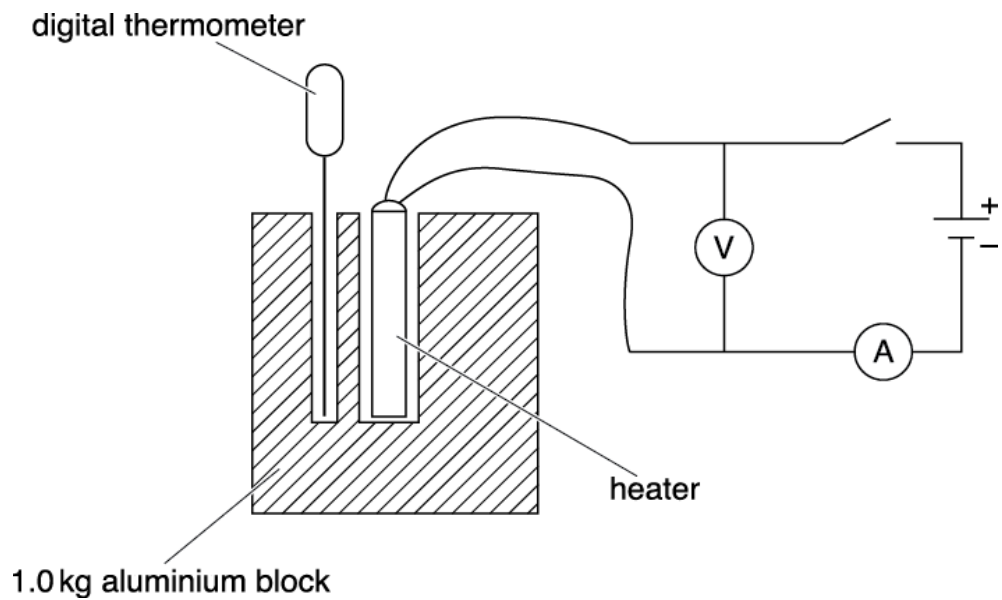


Fig. 1.1

Readings are taken of potential difference across the heater and current through the heater every two minutes. The results are shown in the table.

Time t / minutes	Potential difference V / V	Current I / A	Power P / W
0		2.30	19.8
2	8.67	2.35	20.4
4	8.74		20.3
6	8.75	2.42	21.0
8	8.69	2.39	20.8
10	8.70	2.41	

(i) Complete the missing values in the table.

(ii) Calculate the mean power. Include the uncertainty in the value.

mean power = _____ $\pm$ _____ W [2]

Fig. 1.2 shows a graph of temperature against time.

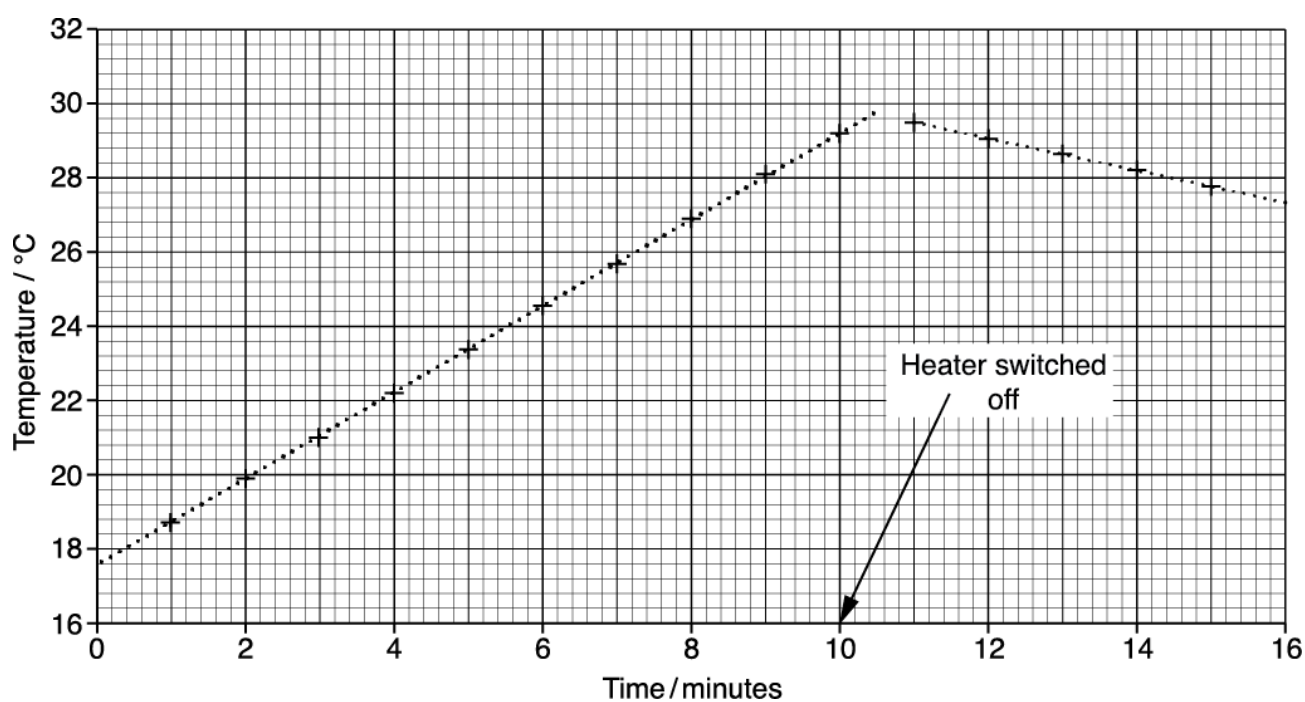


Fig. 1.2

(b)

- (i) Use data from the first ten minutes of the graph and your answer to (a)(ii) to show that the specific thermal capacity of aluminium is about $1000 \text{ J kg}^{-1}\text{K}^{-1}$.

[3]

- (ii) Use Fig. 1.2 to estimate the maximum rate of cooling when the switch is opened.

maximum rate of cooling = _____ K min^{-1} [2]

- (c) The total percentage uncertainty in the investigation is found to be 5 %. The accepted value of the specific thermal capacity of aluminium is $897 \text{ J kg}^{-1} \text{ K}^{-1}$.

Calculate the percentage difference between your calculated value from (b)(i) and the accepted value and use this to comment on the accuracy of the investigation. Suggest reasons for the difference between the investigation value and the accepted value.

[4]

58 This question is about an experiment to determine the Planck constant using LEDs.

Fig. 3.1 shows the circuit which is used in a school laboratory.

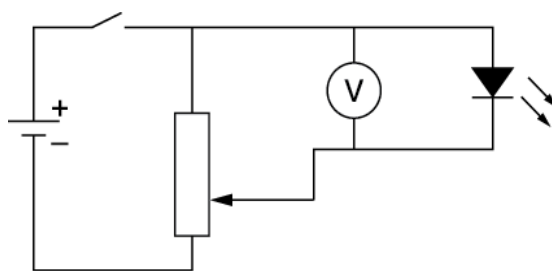


Fig. 3.1

The voltage across each LED is increased until the light emitted from the LED is just visible. This voltage V_t recorded. V_t is found for seven LEDs emitting light of different wavelengths.

V_t for a red LED is measured as 1.35 V. Calculate the energy change of an electron passing through the LED.

energy change = ... J [1]

59 This question is about charging a capacitor in a circuit with two resistors in series.

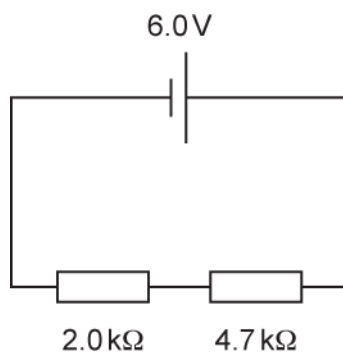


Fig. 2.1

Show that the p.d. across the $4.7\text{ k}\Omega$ resistor in the circuit in Fig. 2.1 is about 4 V , assuming that the cell has zero internal resistance.

[2]

- 60 (See Insert for H557/02, Scientific literacy in physics (AS/A level), June 2017) The density of silver is $10\,500\text{ kg m}^{-3}$. The mass of one silver atom is $1.8 \times 10^{-25}\text{ kg}$.

Use this data to calculate an estimate for the diameter of an atom of silver, explaining your reasoning and assumptions.

diameter of silver atom = ... m [4]

61 The unit of electrical resistance is the ohm Ω . 1Ω is the same as

- A 1 C V^{-1}
- B 1 S^{-1}
- C $1 \text{ C}^2 \text{ J}^{-1} \text{ s}^{-1}$
- D 1 A V^{-1}

Your answer

[1]

62 A signal is being digitised by sampling at 12 kHz.
The total voltage is 5.0 V and the noise voltage is 4.9 mV.

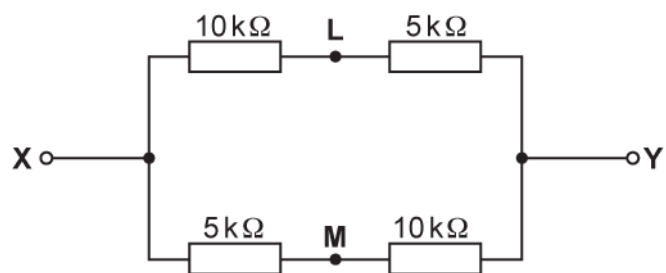
Which statement is correct?

- A $\frac{V_{\text{total}}}{V_{\text{noise}}} \approx 10^3$
- B The highest frequency in the signal should not exceed 24.0 kHz.
- C The recommended number of bits per sample is 8.
- D The voltage resolution of the sampling should be about 1 mV.

Your answer

[1]

63 The diagram shows a combination of four resistors.



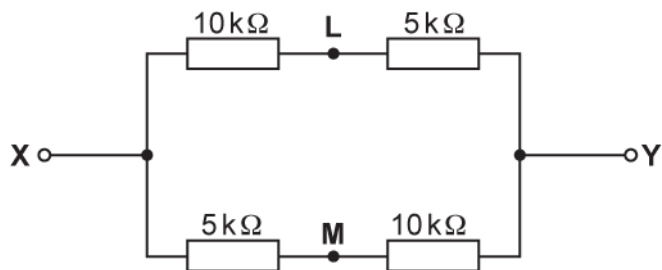
What is the resistance between X and Y?

- A $5\text{ k}\Omega$
- B $7.5\text{ k}\Omega$
- C $15\text{ k}\Omega$
- D $30\text{ k}\Omega$

Your answer

[1]

64 The diagram shows a combination of four resistors.



A battery of e.m.f. 12 V and negligible internal resistance is connected across XY .

What is the magnitude of the p.d. between L and M ?

- A 2 V
- B 4 V
- C 6 V
- D 8 V

Your answer

[1]

- 65 Two heater coils X and Y dissipate the same power when coil X runs at 12 V and coil Y runs at 6 V. The coils are made from equal lengths of wire of the same material, but different diameter.

Which one of A to D below is equal to the ratio $\frac{\text{resistance of X}}{\text{resistance of Y}}$?

A $\frac{1}{4}$

B $\frac{1}{2}$

C 2

D 4

Your answer

[1]

- 66 Two heater coils X and Y dissipate the same power when coil X runs at 12 V and coil Y runs at 6 V. The coils are made from equal lengths of wire of the same material, but different diameter.

Which one of A to D below is equal to the ratio $\frac{\text{diameter of wire X}}{\text{diameter of wire Y}}$?

A $\frac{1}{4}$

B $\frac{1}{2}$

C 2

D 4

Your answer

[1]

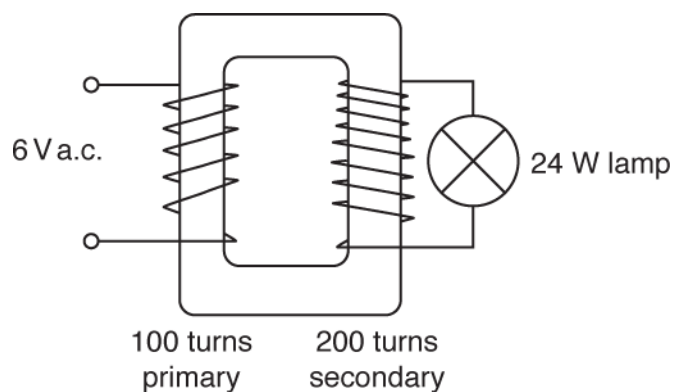
67 Which of the following changes doubles the flux in a magnetic circuit?

- 1 doubling the permeance
- 2 doubling the current-turns
- 3 halving the circuit length
- A 1, 2 and 3 are correct
- B only 1 and 2 are correct
- C only 2 and 3 are correct
- D only 1 is correct

Your answer

[1]

- 68 A 6 V a.c. supply is connected to the 100 turn primary coil of an ideal transformer. The 200 turn secondary coil runs a lamp which dissipates 24 W.



Which is the best estimate of the current in the secondary coil?

A $\frac{1}{4}$ A

B $\frac{1}{2}$ A

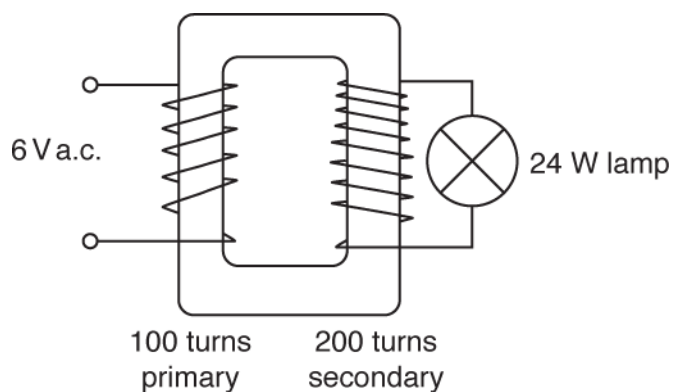
C 2 A

D 4 A

Your answer

[1]

- 69 A 6 V a.c. supply is connected to the 100 turn primary coil of an ideal transformer. The 200 turn secondary coil runs a lamp which dissipates 24 W.



Which is the best estimate of the current in the primary coil?

- A $\frac{1}{4}$ A
- B $\frac{1}{2}$ A
- C 2 A
- D 4 A

Your answer

[1]

- 70(a) The main bolt of a lightning strike flows through air already ionised by a “leader” strike.

State why air needs to be ionised to carry an electric current.

[1]

- (b) The current in a main strike is 30 kA and lasts for 250 μs .
Show that the charge delivered by this strike is less than 8 C.

[2]

71(a) An electric shower runs at 230 V and 46A.
In summer it increases the water temperature from 22 °C to 39 °C.

(i) Calculate the thermal energy used to increase the temperature of 1 kg of the water.

Specific thermal capacity of water = 4200 J kg⁻¹ K⁻¹

energy = _____ kJ [2]

(i) Calculate the time it will take the heater to deliver this amount of thermal energy.

time = _____ s [2]

(b) In winter the inlet water temperature drops to 5 °C, but the final temperature remains at 39 °C.

State and explain the change to the water flow rate for this shower in winter compared to summer.

-----[2]

72(a) This question is about using a thermistor in a temperature sensing circuit.
The graph, Fig. 1.1, shows how the resistance R of a thermistor varies with temperature T .

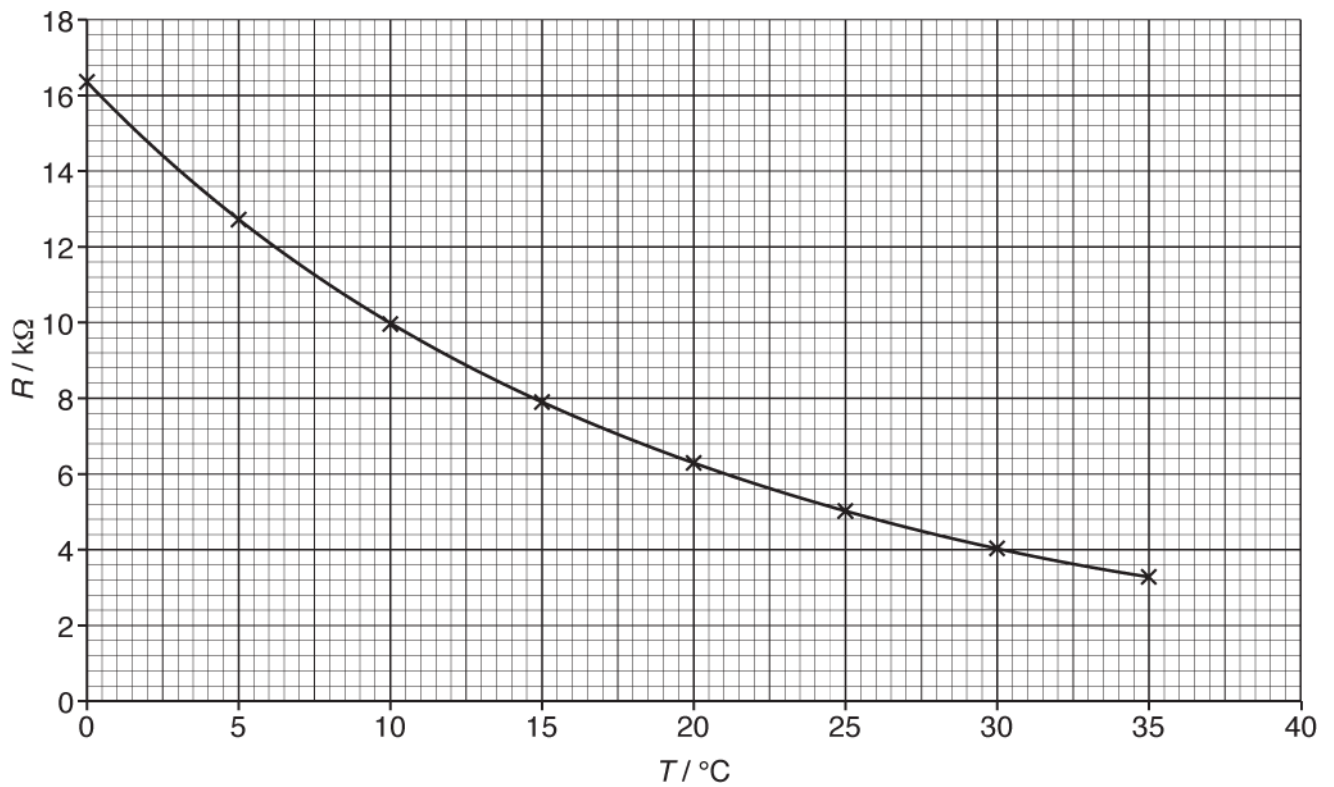


Fig. 1.1

The resistance of the thermistor can be measured with a multimeter on the resistance range.
Suggest how you might vary and measure the temperature of the thermistor so that the data, for Fig. 1.1, could be collected.

[2]

The thermistor is used in the potential divider shown in Fig. 1.2.

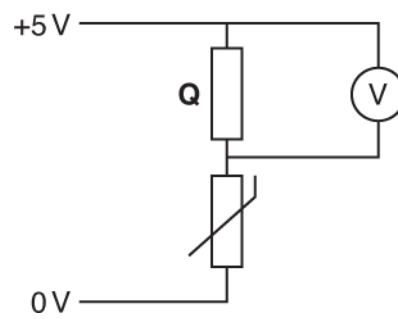


Fig. 1.2

- (b) Suggest why the voltmeter is connected across the fixed resistor **Q** rather than the thermistor in this temperature sensing circuit.

----- [1]

- (c) Readings of voltage V_{out} against temperature T are recorded using an analogue voltmeter. The uncertainty in the voltmeter readings is $\pm 0.1 \text{ V}$ and the uncertainty in the temperature readings is $\pm 1 \text{ }^\circ\text{C}$. The data is shown in Fig. 1.3 in the form of a graph.

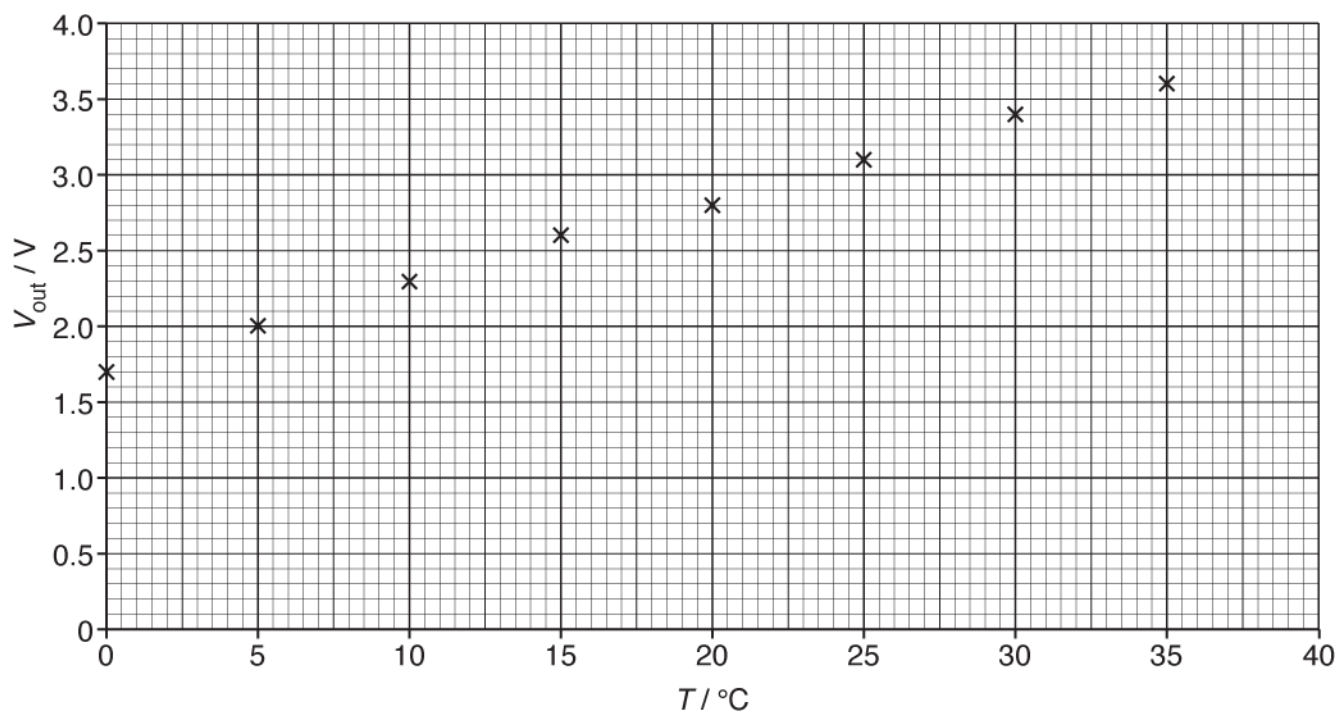


Fig. 1.3

- (i) It is suggested that V_{out} varies linearly with T . By adding uncertainty bars to Fig. 1.3 use the graph to show that this is true over the temperature range tested. State your reasoning.

[3]

(ii) Explain how you could calibrate the analogue voltmeter scale to read temperature directly.

----- [2]

(d)



Discuss the effect of changing the fixed resistor **Q** to a higher **and** a lower value on the performance of the temperature sensing circuit over the range of temperatures 0 – 35 °C. Use data from Fig. 1.1 and Fig. 1.3 to perform calculations to support your ideas.

[illegible]

73(a) This question is about determining the focal length of a converging lens using the apparatus shown in Fig. 4.1.

u is the distance between the lens and the object and v is the distance between the lens and the image.

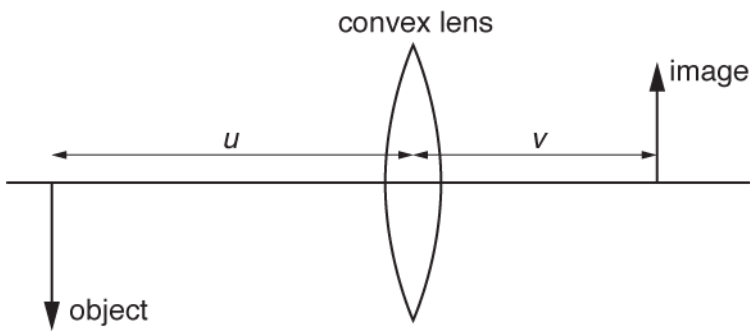


Fig. 4.1

Fig. 4.2 shows some data taken by a student.

$u / \text{m} \pm 1 \text{ mm}$	$v / \text{m} \pm 5 \text{ mm}$
-0.500	0.220
-0.475	0.230
-0.450	0.230
-0.425	0.240
-0.400	0.250
-0.375	0.260
-0.350	0.270
-0.325	0.290
-0.300	0.310
-0.275	0.340
-0.250	0.390
-0.225	0.480
-0.200	0.660

Fig. 4.2

(i) State which measurement, u or v , has the greatest absolute uncertainty and suggest why this is the case.

[1]

To assess the reliability of the experiment, the student decided to repeat one measurement (with value of u equal to -0.250) multiple times. These data are shown below in Fig. 4.3 in a dot-plot, the points at 0.330 and 0.430 are potential outliers.

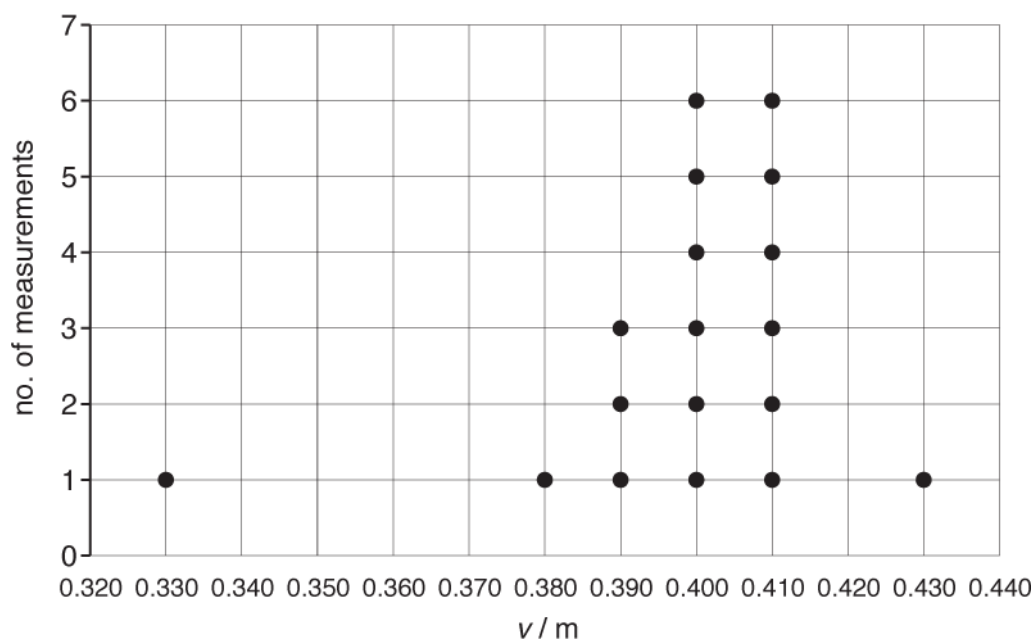


Fig. 4.3

(ii) Ignoring the two potential outliers, calculate the range of the typical values on the dot-plot.

range = _____ m [1]

(iii) Calculate the mean of the values within the range calculated in (a)(ii). Mark this on the dot-plot above.

mean = _____ m [2]

- (iv) The spread of data is given by; $spread = \pm \frac{1}{2} range$. A measurement can be considered to be an outlier if it is more than twice the spread from the mean. State whether you consider either of the points; 0.330 or 0.430 to be outliers and explain your reasoning.

[2]

(b) This question is about determining the focal length of a converging lens using the apparatus shown in Fig. 4.1.

u is the distance between the lens and the object and v is the distance between the lens and the image.

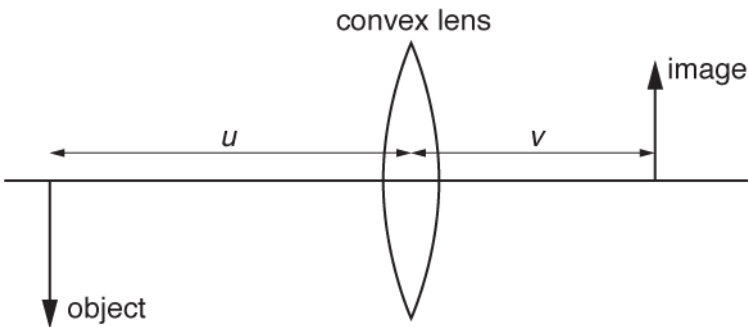


Fig. 4.1

Fig. 4.2 shows some data taken by a student.

$u / \text{m} \pm 1 \text{ mm}$	$v / \text{m} \pm 5 \text{ mm}$
-0.500	0.220
-0.475	0.230
-0.450	0.230
-0.425	0.240
-0.400	0.250
-0.375	0.260
-0.350	0.270
-0.325	0.290
-0.300	0.310
-0.275	0.340
-0.250	0.390
-0.225	0.480
-0.200	0.660

Fig. 4.2

Fig. 4.4 shows a plot of magnification m against v for the data from Fig. 4.2. The last two points are missing from the graph. The uncertainties are too small to be shown on this graph.

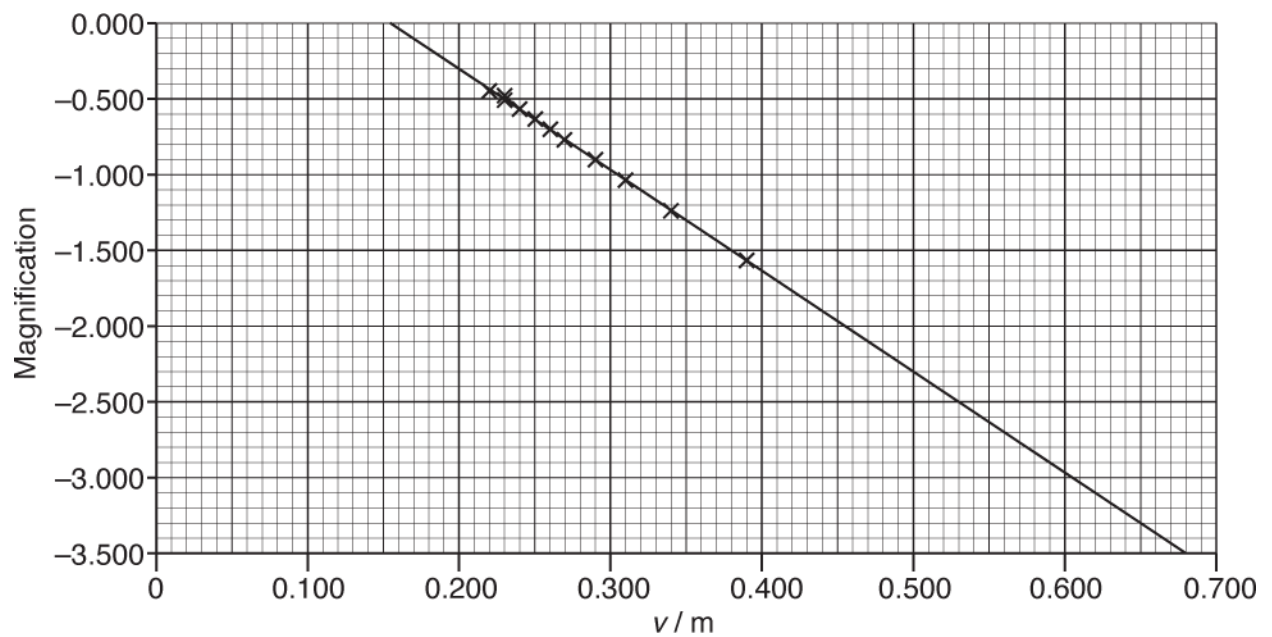


Fig. 4.4

- (i) The last two points from Fig. 4.2 have not been plotted. Complete Fig. 4.5 below, adding the last two magnification values.

u / m	v / m	m
-0.225	0.480	
-0.200	0.660	

Fig. 4.5

[2]

- (ii) Add the remaining points to the graph.

[1]

- (iii) Use $\frac{1}{v} = \frac{1}{u} + \frac{1}{f}$ to show that $m = -\frac{v}{f} + 1$.

[2]

(iv) Use data from the graph to calculate the focal length f of the lens.

$f =$ _____ m [2]

(c) A second converging lens of different focal length is used to form an image. Data for the second lens is displayed in Fig. 4.6.

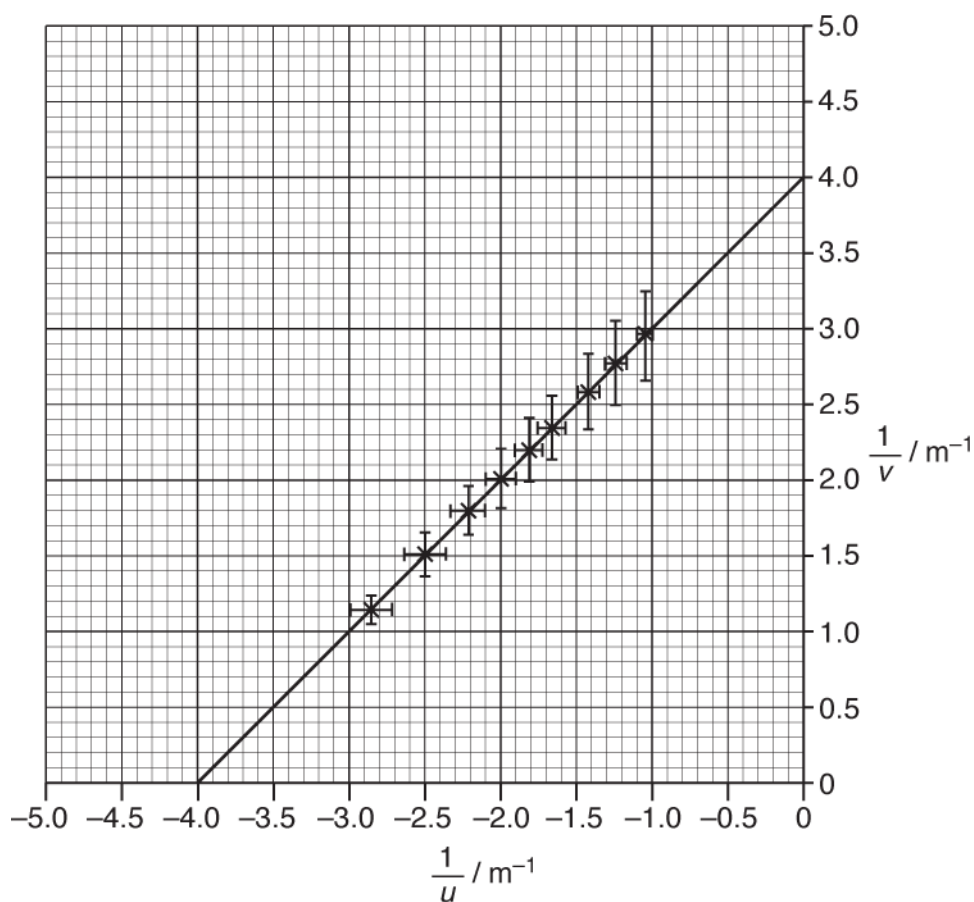


Fig. 4.6

(i) Use Fig. 4.6 to determine the power of this lens.

Power = _____ dioptre [1]

- (ii) Use the uncertainty bars on Fig. 4.6 to determine the maximum and minimum values for the power of the lens. Use these values to determine the percentage uncertainty in the power of the lens.

Maximum power value = _____ diopter

Minimum power value = _____ diopter

Percentage uncertainty = _____ %

[4]

74(a) This question compares the properties of pure aluminium with Aluminium Strong Alloy. Fig. 40.1 and Fig. 40.2 show stress against strain graphs for these metals. Fig. 40.2 shows that both metals have the same initial elastic regions.

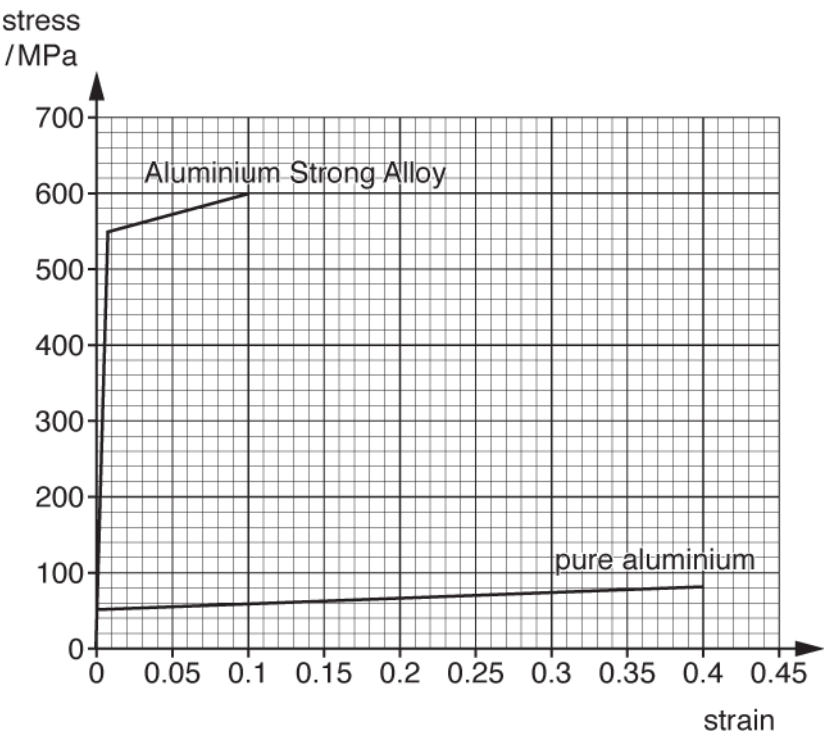


Fig. 40.1
pure aluminium and
Aluminium Strong Alloy

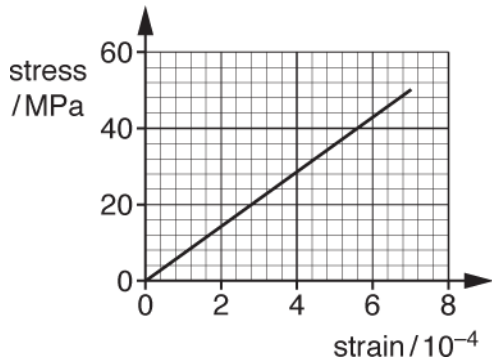


Fig. 40.2

Calculate the Young modulus for the metals using data from Fig. 40.2.

Young modulus = _____ Pa [1]

(b) State and justify which of the metals you would use for the crumple zone of a car.

[2]

(c) Fig. 40.3 shows a TEM (transmission electron microscope) image of atoms in a metal with a scale marker of 1 nm.

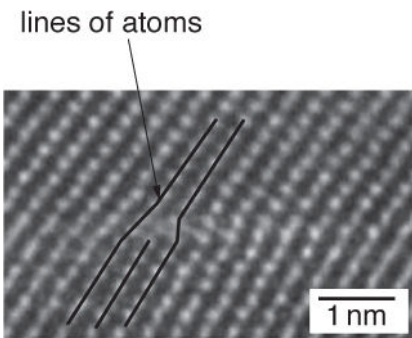


Fig. 40.3

(i) Use the Fig. 40.3 to estimate the diameter of a metal atom.

diameter = _____ m [2]

(ii) Name the feature represented by the lines of atoms added to the image.

name of feature _____ . [1]



[6]

[6]

75 This question is about the New Horizons spacecraft mission to the dwarf planet Pluto.

In July 2015, the Long Range Reconnaissance Imager (LORRI) sent the image shown in Fig. 4.1a.



Fig. 4.1a

The square image is 1024 pixels wide. The diameter of Pluto is 2700 km.

(i) Calculate the resolution of the image in km pixel^{-1} .

resolution = ----- km pixel^{-1} [3]

(ii) The image in Fig. 4.1a was taken at a distance of 770 000 km. The **angular** resolution of LORRI is 5×10^{-6} radian per pixel. This means that each pixel covers an angle of 5×10^{-6} radian. By calculating how many radians Pluto subtends (angle θ in Fig. 4.1b), test whether the value for angular resolution agrees with your value for the resolution in (b)(i). Comment on your answer.

[4]

$$RC = 10 \text{ s.}$$

time lapsed / s	charge Q on capacitor / C	charge ΔQ leaving capacitor in time interval $\Delta t = 1$ s / C	charge Q remaining after time interval Δt / C
t	Q	$\Delta Q \approx \frac{Q\Delta t}{RC}$	$\Delta = (Q - \Delta Q)$
0	5	$\frac{5 \times 1}{10} = 0.5$	$5 - 0.5 = 4.5$
1	4.5		

[2]

(b)

(i) Explain the physics behind the approximation in the third column of the table $\Delta Q \approx \frac{Q}{RC}$

[21]

(ii) State the assumption made in using this approximation and explain how its effect can be made insignificant.

[21]

77(a) This question is about the behaviour of a mass on a spring.

The table below shows how the extension x of a spring varies as the mass m suspended vertically from it alters.

m / g	x / cm
100	2.5
200	5.1
300	7.5
400	9.9
500	12.5
600	15.0

Fig. 2.1

- (i) Apply a test to the data to see if the extension of the spring is proportional to the applied force. Explain your method and state your conclusion.

[3]

- (ii) Calculate the spring constant k of this spring.

$$g = 9.8 \text{ N kg}^{-1}$$

$$k = \text{-----} \text{ N m}^{-1} \text{ [1]}$$

- (b) In order to investigate the behaviour of an oscillating mass and spring system, the spring is suspended vertically below a vibration generator. A mass is added to the bottom of the spring. The arrangement is suspended above an ultrasound distance sensor as shown in Fig. 2.2.

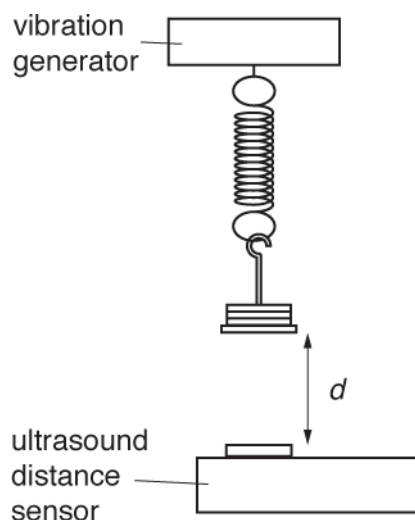


Fig. 2.2

With the vibration generator switched off, the mass is given a small vertical displacement then released. A few oscillations later the ultrasound distance sensor is started and the trace shown in Fig. 2.3 is displayed on a computer.

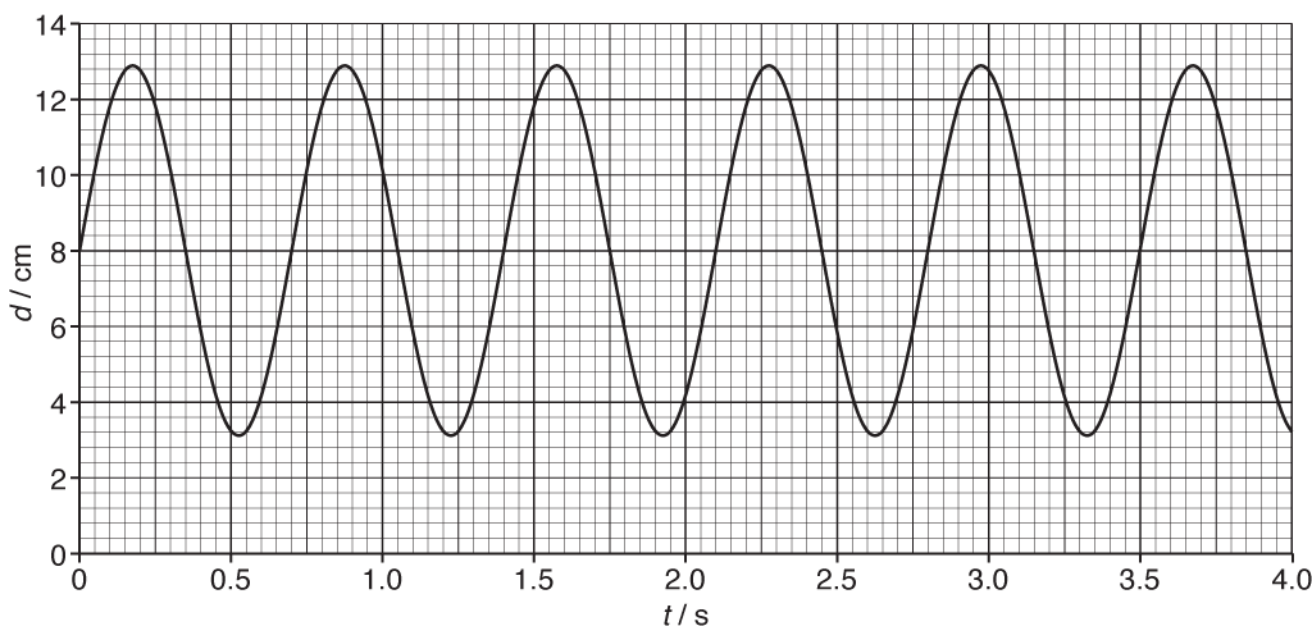


Fig. 2.3

(i) Mark **two** points on the curve shown in Fig. 2.3, to indicate where the speed of the oscillating mass is at its maximum. Label each point with a letter **V**. [1]

(ii) Use data from the trace shown in Fig. 2.3 to calculate the natural frequency f of the mass and spring system.

$f =$ _____ Hz [2]

(iii) Show that the mass m supported by the spring is about 500 g.

[2]

78(a)

A student uses the circuit shown in Fig. 1 to investigate the characteristics of a filament bulb.

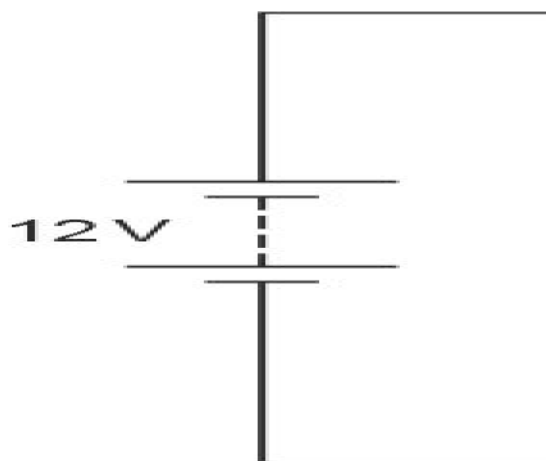


Fig. 1

- (i) Show that the resistance R of the filament bulb Y in this circuit is approximately $2\ \Omega$.

[2]

The bulb is broken and the diameter of the filament wire is measured. The diameter is found to be $0.046 \pm 0.002\text{ mm}$.

- (ii) Calculate the cross sectional area A of the wire and the uncertainty.

$$A = \text{-----} \pm \text{-----} \text{ m}^2 \text{ [3]}$$

- (iii) The filament is removed from the bulb housing and the length is measured to be 20 cm. Using your answer from (a)(i) calculate the conductivity σ of the filament of the bulb stating any assumption(s) that you make.

$$\sigma = \text{-----} \text{ Sm}^{-1}$$

Assumption(s): -----

----- [3]

(b)



A new working **identical** bulb is put in the circuit in Fig. 1. The resistor **X** is changed to one with a resistance of 6.9Ω . A student calculates that the voltage across resistor **X** will now be 6.0 V .

Using ideas about current, temperature and the structure of metals explain whether or not the student is correct.

----- [6]

79(a) This question is about an experiment to determine the Young modulus of a copper wire.

The diameter D of the wire was measured using a micrometer screw gauge in several places along the length of the wire. The values obtained are shown in the dot-plot shown in Fig. 4.1. Each dot represents one reading.

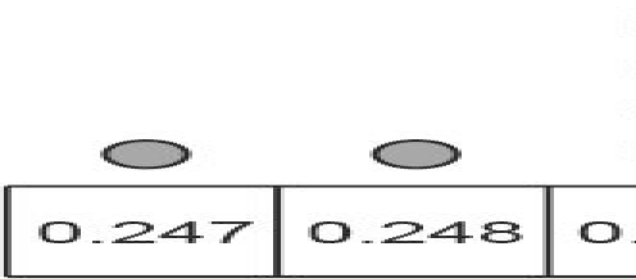


Fig. 4.1

- (i) Use the information in the dot-plot to find the mean D . Use the spread to determine the percentage uncertainty.

mean D = ----- mm $\pm$ ----- % [3]

- (ii) Calculate the cross sectional area A of the wire and include the uncertainty.

A = ----- $\pm$ ----- m² [3]

(b) A marker is placed to give an original length of the wire as 4.00 ± 0.02 m.

Fig. 4.2 shows the extension x of a metal wire at different applied loads F . x is measured to ± 0.5 mm and F is measured to ± 0.2 N. Fig. 4.2 shows the force–extension graph for the wire.

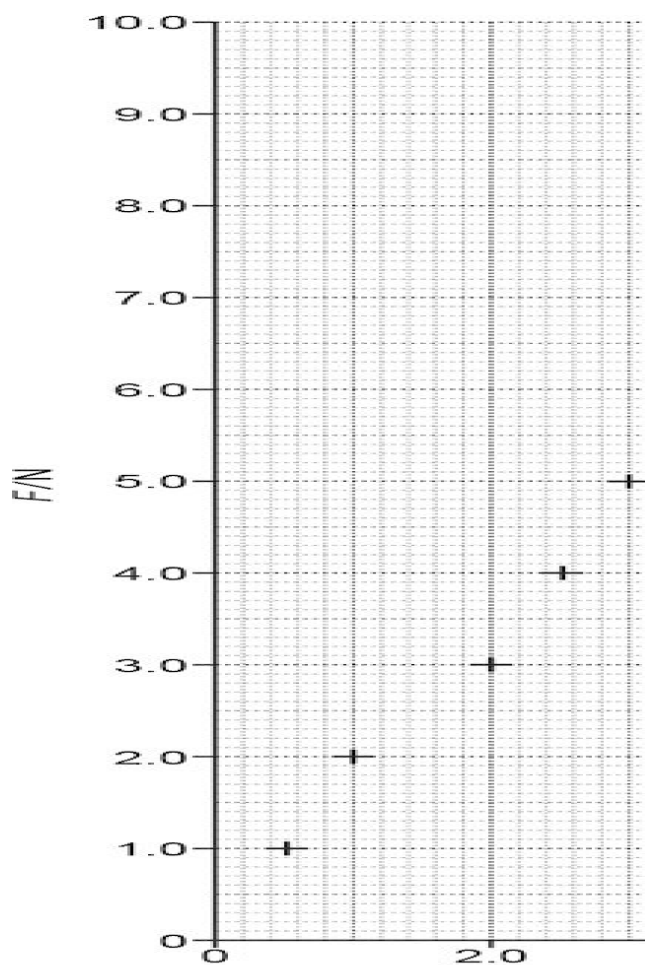


Fig. 4.2

(i) On Fig. 4.2

- 1 complete vertical and horizontal error bars on each of the plots
- 2 label the regions of elastic and plastic deformation
- 3 draw a line of best fit through the straight section of the graph.

[4]

- (ii) Use the graph and the data given to calculate the value of the Young Modulus E . Include the appropriate unit.

$E =$ ----- unit ----- [5]



[6]

[illegible]

80(a) This question is about investigating the polarisation of light.

A student takes two polarising filters as shown in Fig. 1.1.

Unpolarised light is incident on the filter 1.

Filter 2 is initially set up to allow all the light passing through the first filter to be transmitted.
The filter 2 is then rotated through 360° .

Describe and explain how the intensity of the transmitted light changes during the rotation of the second filter.

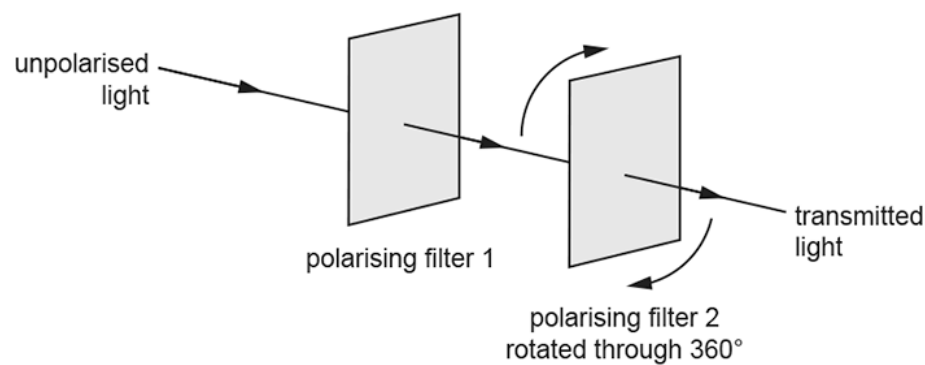


Fig. 1

[2]

(b)

The transmitted light strikes an LDR in the circuit shown in Fig. 1.2.

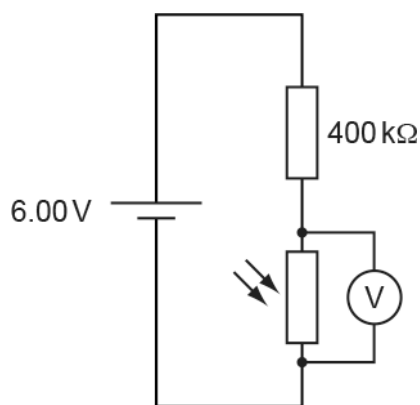


Fig. 1.2

- (i) Describe and explain how the p.d. across the LDR changes as the second filter is rotated through 360° from its original orientation.

You do not need to give values for the p.d. but you should indicate the orientation of the filters which produce maximum and minimum p.d.s.

[4]

(ii) The highest p.d. recorded by the voltmeter is 3.00 ± 0.01 V.

Calculate the **maximum** value of the resistance of the LDR at this point.

Assume that there is no uncertainty in the p.d. of the cell.

maximum value of resistance = ----- Ω [2]

81(a) This question is about conduction in metals and in semiconductors.

A copper wire of length 1.5 m and radius 2.5×10^{-4} m has a resistance of $0.13 \, \Omega$ at $20 \, ^\circ\text{C}$.

Calculate the conductivity of copper at this temperature.

conductivity at $20 \, ^\circ\text{C}$ =----- Sm^{-1} [3]

- (b) A copper wire of length 1.5 m and radius 2.5×10^{-4} m has a resistance of $0.13 \, \Omega$ at $20 \, ^\circ\text{C}$.

A simple model of conduction suggests that each copper atom in the wire contributes one or more electrons to a cloud of free electrons that behave rather like particles in a gas. These electrons drift through the wire under the influence of an electric field.

The current I is given by the equation $I = nave$ where:

n is the number of free electrons in the material per m^3

a is the cross-sectional area of the wire

v is the drift velocity of the electrons

e is the electronic charge.

Calculate the drift velocity of the electrons when the copper wire carries a current of 2.3 A. The number of free electrons per m^3 in copper = $8.5 \times 10^{28} \, \text{m}^{-3}$ Calculate the drift velocity of the electrons when the copper wire carries a current of 2.3 A. The number of free electrons per m^3 in copper = $8.5 \times 10^{28} \, \text{m}^{-3}$

drift velocity =----- ms^{-1} [2]

- (c) The conductivity σ of semiconductors such as ntc thermistors increases dramatically with temperature T . The relationship is given by the equation

$$\sigma = C e^{-E/kT}$$

where C is a constant, k is the Boltzmann constant and E is the energy required to ionise an atom in the semiconductor.

Use the relationships given in the question to explain the effect of increasing temperature on the conductivity of metals and semiconductors, referring to the microscopic structure of the materials. No calculations are required.

[6]

82 Which expression gives a quantity that can be expressed in joules?

- A $F v$ where F is the force causing a body to move and v is its speed
- B $I^2 R$ where I is the current flowing through a resistance of value R
- C $m v$ where m is the mass of a body moving with velocity v
- D $V I t$ where V is the potential difference across a conductor and I is the current in it for time t .

Your answer

[1]

83 How many bits are required to code for 1300 different levels?

- A 3
- B 4
- C 10
- D 11

Your answer

[1]

84 An image sent from Pluto to Earth is 1024×1024 pixels. Each pixel is coded by 12 bits.
The data is transferred at a rate of 200 bytes per second.

How long does it take to transmit the data?

- A 11 minutes
- B 87 minutes
- C 131 minutes
- D 1049 minutes

Your answer

[1]

85 A weight of 20 N is suspended from a steel wire.

What is the extension of the wire?

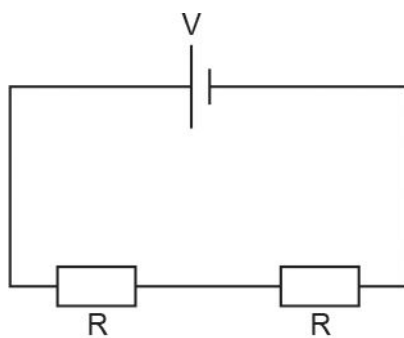
Data: original length of wire = 2.5 m
cross-sectional area of wire = $7.0 \times 10^{-8} \text{ m}^2$
Young Modulus of the wire material = $2.1 \times 10^{11} \text{ Pa}$

- A 0.0030 m
- B 0.0034 m
- C 0.030 m
- D 0.034 m

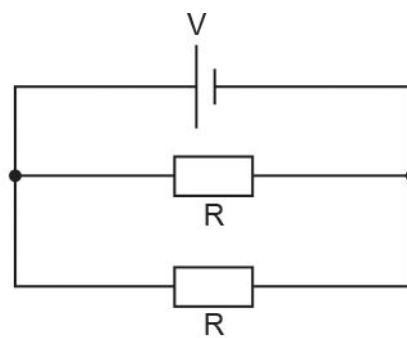
Your answer

[1]

- 86 These two circuits use identical components.
The cells have zero internal resistance.



circuit 1



circuit 2

What is the ratio $\frac{\text{power dissipated in circuit 1}}{\text{power dissipated in circuit 2}}$?

A $\frac{1}{4}$

B $\frac{1}{2}$

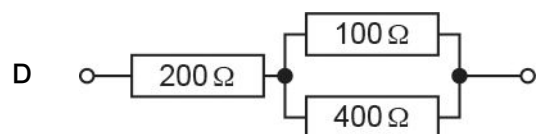
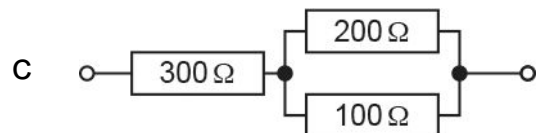
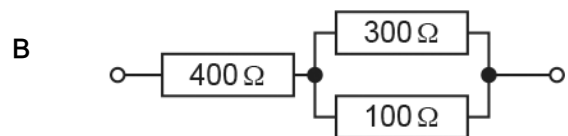
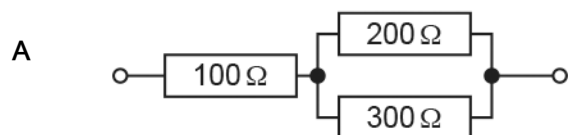
C 2

D 4

Your answer

[1]

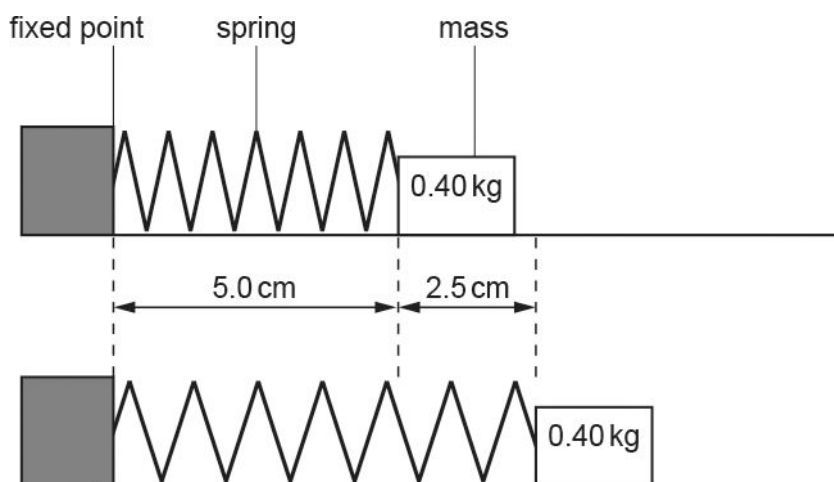
87 Which combination of resistors gives the **lowest** total resistance?



Your answer

[1]

- 88 The spring in this diagram has a spring constant of 20 N m^{-1} .
The mass is pulled away from the fixed point. The spring stretches by 2.5 cm .
The mass is then released.



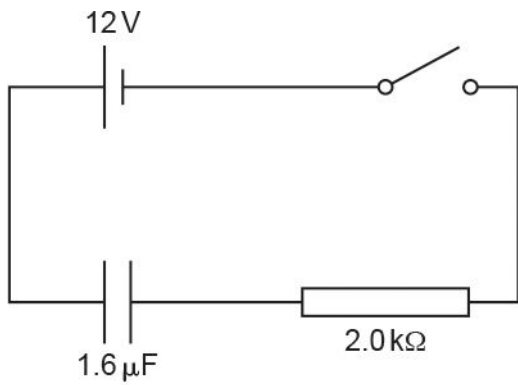
What is the maximum speed reached by the mass?

- A 0.18 m s^{-1}
- B 0.53 m s^{-1}
- C 1.25 m s^{-1}
- D 3.75 m s^{-1}

Your answer

[1]

89 An uncharged capacitor and a resistor are connected in this circuit.



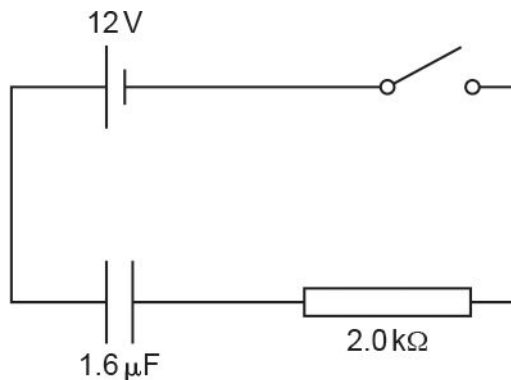
	current / mA	p.d. across the capacitor / V	p.d. across the resistor / V
A	0	12	0
B	2	8	4
C	3	6	6
D	6	0	12

Which set of values **A** to **D** above, most closely represents the situation immediately after the switch is closed?

Your answer

[1]

90 An uncharged capacitor and a resistor are connected in this circuit.



	current / mA	p.d. across the capacitor / V	p.d. across the resistor / V
A	0	12	0
B	2	8	4
C	3	6	6
D	6	0	12

Which set of values **A** to **D** above, most closely represents the situation 3 seconds after the switch is closed?

Your answer

[1]

91 A liquid flows through a tube containing an electrical heater with a constant voltage.
At a steady state of flow, the liquid leaves the tube at temperature $\Delta\theta$ higher than the liquid entering.

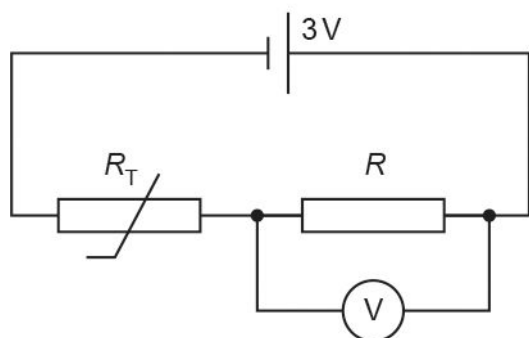
Which change will increase $\Delta\theta$ with no other changes?

- A Increasing the flow rate of the liquid.
- B Changing the liquid to one with a higher specific heat capacity.
- C Using a heating element of lower resistance.
- D Decreasing the supply voltage.

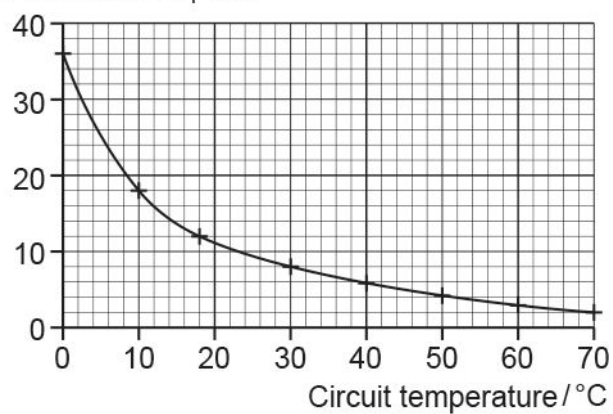
Your answer

[1]

92 A thermistor is used in a potential divider circuit.



thermistor resistance $R_T / \text{k}\Omega$



When the circuit temperature is 10°C the reading on the voltmeter is 1.0 V.

What is the resistance of the resistor R ?

- A $6\text{k}\Omega$
- B $9\text{k}\Omega$
- C $18\text{k}\Omega$
- D $36\text{k}\Omega$

Your answer

[1]

93(a) The lens in a digital clock projects the time onto a wall 1.5 m away as shown in Fig. 31.

The digital display is 0.030 m from the lens.

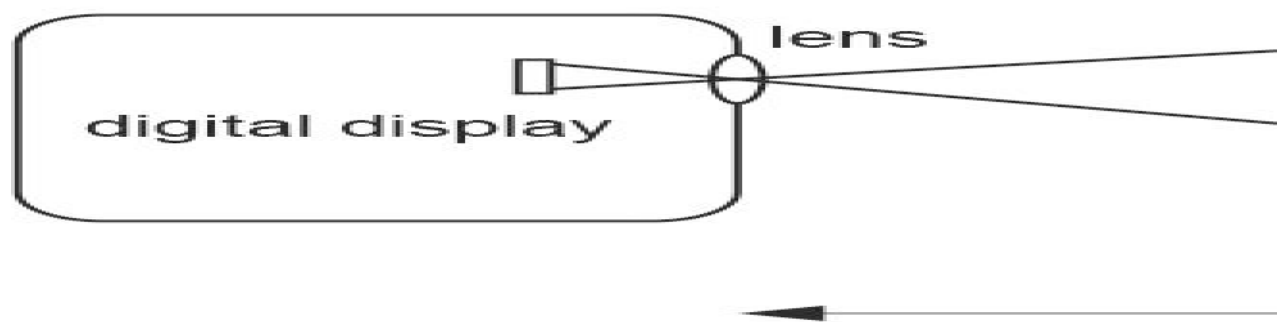


Fig. 31

Calculate the power of the lens.

power of the lens =----- D [3]

(b) State the magnification of the lens in this example.

magnification =----- [1]

94(a)

A video file is downloaded at a rate of 24 Mbit s^{-1} .
The video file is 1.2 Gbytes in size.

Show that the time taken for the file to download is greater than 6 minutes.

[2]

(b) The video file contains a soundtrack sampled at 16.0 kHz.

State and explain the highest frequency of sound that can be recorded on the soundtrack.

highest frequency -----kHz

[2]

95(a) A solar panel is charging a rechargeable battery, with a resistor R in series.

The values of the internal resistances r , the external resistance R and the e.m.f.s $\mathcal{E}$ at the start of the charging process are shown in Fig. 34.

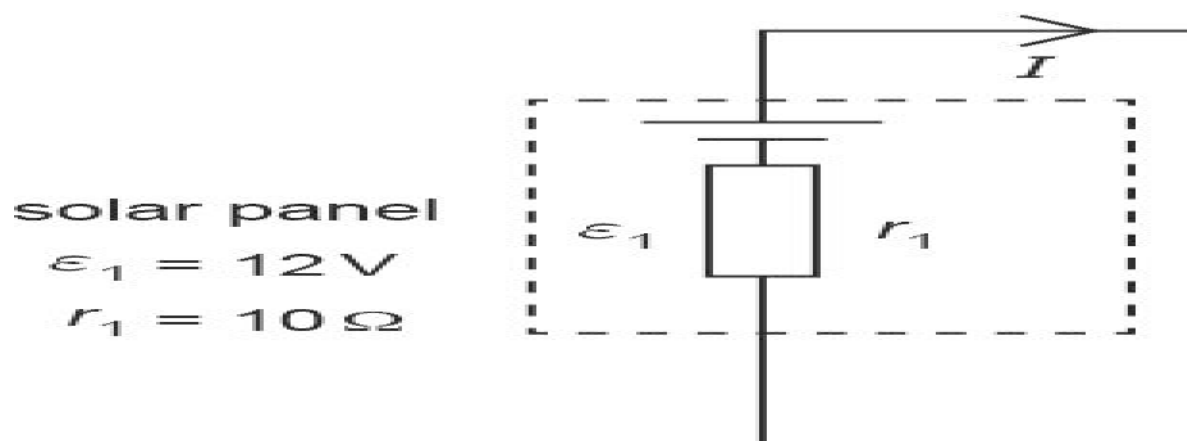


Fig. 34

Show that the initial current charging the rechargeable battery I is less than 0.2 A.

- (b) When fully charged, the rechargeable battery has enough charge to deliver an average current of 500 mA for an hour before it is fully discharged. [2]

Estimate the time needed to recharge the battery at the mean charging current of 0.12 A.

time = ----- hours [2]

An ion drive uses the momentum of ions for propulsion. It ionises a gas and uses an accelerating field to accelerate the positive ions to a high velocity.



Fig. 37.2

- (i) A positive ion of charge Q and mass m is accelerated through a p.d. V . Show that the momentum per unit mass $\frac{p}{m}$ it gains is given by the expression

$$\frac{p}{m} = \dots$$

[2]

- (ii) Discuss an advantage of using ions of hydrogen $^1\text{H}^+$ as propellant instead of xenon $^{130}\text{Xe}^+$.

[2]

- (iii) An ion drive with accelerating p.d. $V = 2000 \text{ V}$ must produce a thrust of 0.24 N .

Show that the mass flow rate $\frac{\Delta m}{\Delta t}$ is less than $4 \times 10^{-7} \text{ kg s}^{-1}$.

$$\frac{Q}{m} \text{ for } ^1\text{H}^+ \text{ ions} = 9.6 \times 10^7 \text{ C kg}^{-1}.$$

[2]

- 97 Fig. 40.1 shows a simplified diagram of a d.c. motor with permanent magnets.
 Fig. 40.2 shows the graph of current in the coil against frequency of rotation for this motor.

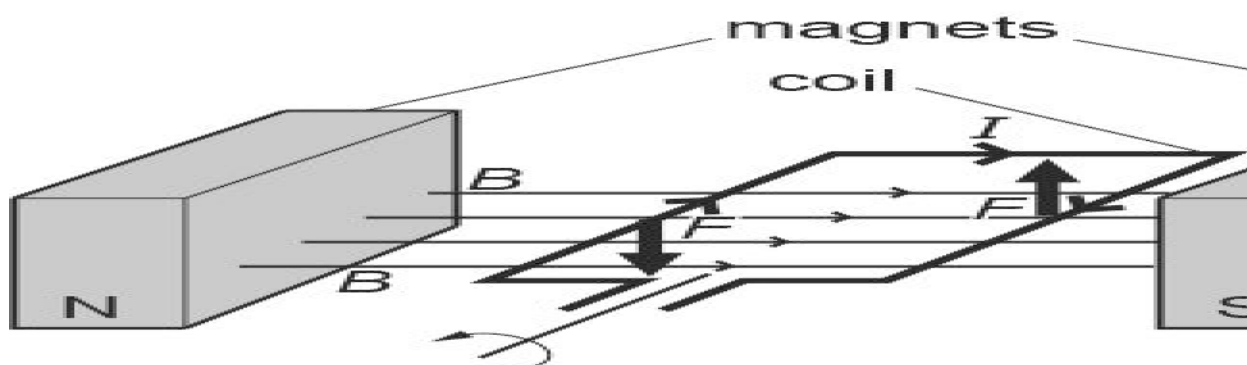


Fig. 40.1

Fig. 40.2

The coil is connected to a 12.0 V supply of negligible internal resistance shown in Fig. 40.1. This produces the force to keep the motor turning against a mechanical load.

Draw a **straight line** of best fit on Fig. 40.2 and use it to predict the current in the coil when the motor is not rotating.

Use your prediction to calculate the resistance of the coil.

resistance = ----- Ω [3]

98(a) Fig. 2.1 shows a potential divider circuit using cells with very low internal resistance.

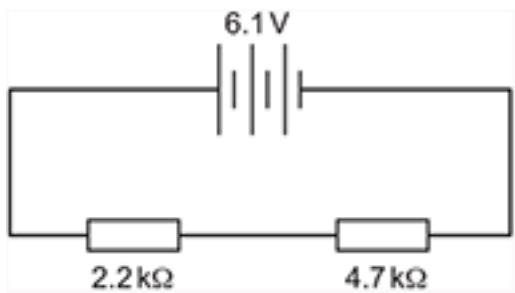


Fig. 2.1

Show that the potential difference across the 4.7 kΩ resistor is 4.2 V to 2 significant figures.

[1]

(b) An analogue voltmeter connected across the 4.7 kΩ resistor reads 3.2 V.

Show that the resistance of the voltmeter is about 5 kΩ.

[3]

- (c) A cell is made by inserting a zinc strip and a copper strip into a potato. When the same analogue voltmeter is connected to the cell as shown in Fig. 2.2, it registers a potential difference of 0.50 V.

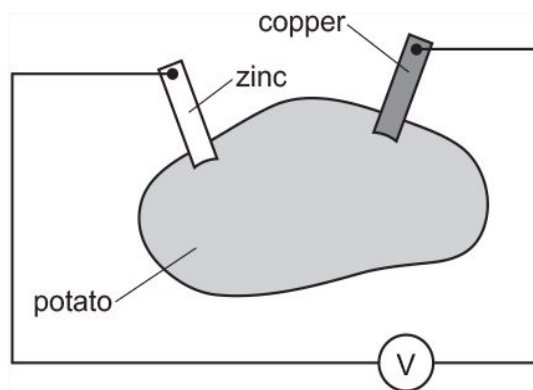


Fig. 2.2

- (i) Using your answer to (b), calculate the current in the circuit.

current = ... A [1]

- (ii) When a digital voltmeter of resistance $1.0\text{ M}\Omega$ replaces the analogue voltmeter in Fig. 2.2, it registers a potential difference of 0.93 V. Use the readings from the two meters to calculate an estimate for the internal resistance of the potato, stating any assumptions you make.

internal resistance = ... Ω [3]

- (i) An electron is accelerated through a p.d. of 4.3 kV. Calculate the velocity of the accelerated electron. Ignore relativistic effects.

velocity = ... m s^{-1} [2]

- (ii) Explain whether it is reasonable to ignore relativistic effects in the calculation in (i). Include a calculation in your explanation.

[3]

- (iii) Calculate the de Broglie wavelength of the accelerated electron.

wavelength = ... m [1]

100 Fig. 7.1 is an image from Mariner 9. It shows most of the crater at the top of Olympus Mons. (See Article in Insert for H557/02, June 2019.)

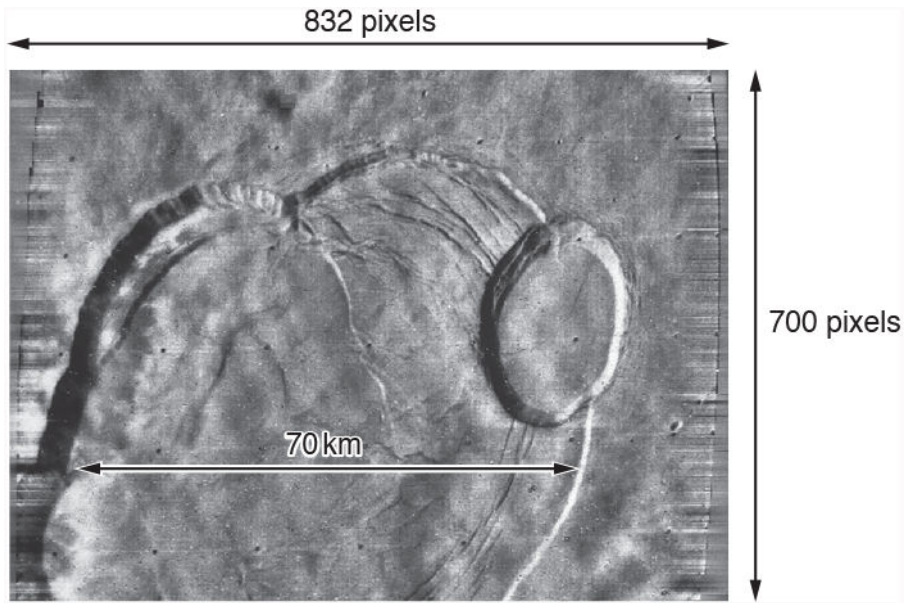


Fig. 7.1

Use data from Fig. 7.1 to calculate the resolution of the image.

resolution = ... km pixel⁻¹ [2]

END OF QUESTION PAPER

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
1			D	1	
			Total	1	
2			B	1	
			Total	1	
3			A	1	
			Total	1	
4			Any three from: less ductile Plastic flow reduced Alloying atoms pin (AW) dislocations or dislocations less mobile Reducing distance planes of atoms slip over one another or less slip	3	
			Total	3	
5	a		(straight) line passing through every second point (1) Reasoning: half the frequency, twice the time interval between sample AW (1) Effect: detail in the waveform lost e.g. high frequency components lost (1)	3	Ignore shape of line between points
	b		Number of bits used = $\log_2$ (number of levels) (1) = 15.6 (therefore 16) (1) More likely to use 65536 (or rounded value) (1)	3	$65536 = 2^{16}$, accept 64k
	c		Need to have sampling frequency of at least $2 \times$ frequency of highest note (1) Higher frequency components of music give overall sound (1)	2	musical knowledge NOT required

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	d		Any three from: • Smaller information transfer rate required • Accurate reproduction of voices not needed for understanding telephone conversations • Conversations uses a more limited frequency range than music • Only 256 voltage levels • Only frequencies up to about 4000 Hz can be accurately reproduced • Music requires higher sampling rate to show different instruments • Music requires 16 bit sampling to give smoother changes in dynamics	3	
			Total	11	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
6		i	Time constant is the time taken for the voltage to fall to 1/e of original value or $0.37 \times 6 \checkmark$ $= 2.2 \text{ V} \checkmark$ Shown on graph to be about 25 seconds $\checkmark$	3	ORA accept answers using initial tangent at $t = 0$ accept answers in range 24.5 to 25.5 s
		ii	$R = \tau / C \checkmark$ $R = 25 / 4700 \times 10^{-6} = 53(2)0 \Omega \checkmark$ Then $I = V/R = 6 / 5320 \checkmark$ $= 1.1 \times 10^{-3} \text{ A} \checkmark$	4	Credit correct answers based on own value of time constant from part (a) OR $I = \Delta Q / \Delta t = C \Delta V / \Delta t$ with $\Delta V = 0.50 \text{ V}$ gives 1.2 mA for full marks

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	* Level 3 (5–6 marks) Performs both calculations correctly and appreciates the strengths and limitations of both. Principally: for Method 1 relies on $Q \propto V$ which is valid; for Method 2 the y-axis needs to be re-interpreted and the area being measured (integration by counting squares) gives an approximate estimated answer. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Performs both calculations successfully but method may not be completely clear or does not compare them sufficiently well. <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Attempts one or both calculations but does not successfully compare the two methods. <i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i> 0 marks No response or no response worthy of credit.	6	expected comparison of two methods - method 1 does not depend on the time variation of $V(t)$, only on the accuracy of start and end p.d.s. and the R and C values. It is a calculation based on theory. - method 2 depends on counting squares and fractions of squares under the exponential decay curve which is an approximation to the area under the graph leading to an estimate of the charge flow. points worthy of credit: - method 1 calculation: $\Delta Q = C\Delta V$ with $\Delta V = (6 - 1.8) \text{ V}$ - gives 19.7 mC - method 2 estimation: re-scaling of y-axis to represent current - area under $I(t)$ represents $\Delta Q = I \Delta t = V\Delta t/R$ - each 1 cm square $1 \times 10/5000 = 2 \text{ mC}$ - between 0 and 30 s there are about 10 squares - so total charge flow = $10 \times 2.0 \times 10^{-3} = 20 \text{ mC}$ accept answers in range 18 to 22 mC
			Total	13	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
7	a	i	$h_{\text{image}} = (v/u) \times h_{\text{object}}$ or $= (26 / 35) \times 2.5$ ✓ $= 1.9$ (cm) ✓	2	1.9 (cm) gains both marks
		ii	$(P = 1/f = 1/v - 1/u) = 1/(0.35) - 1/(-0.26)$ ✓ $(= 2.86 + 3.85) = 6.7$ (D) ✓	2	method mark for adopting the correct method and evaluation mark for getting the correct answer. 6.7 (D) gets both marks
		iii	Justifies ignoring Δu as Δv is much greater ✓ uses $v = 26.5$ or 25.5 ✓ evaluation $\Delta P = 0.08$ (D) from 25.5 or 0.07 (D) from 26.5 ✓	3	allow $\Delta P/P = \Delta v/v$ giving $\Delta P = 0.1$ (D) <i>alternative method</i> This method makes no simplifying assumption Attempt to find P_{max} or P_{min} using $\Delta u = 0.1$ & $\Delta v = 0.5$ ✓ in same direction, both to increase P or both to decrease P (e.g. 35.1 cm & 26.5 cm or 34.9 cm & 25.5 cm) ✓ evaluation $\Delta P = 0.09$ (D) ✓
	b	i	New $P = 1/0.35 - 1/(-0.26 - 0.027) = 7.2$ D ✓ Percentage increase $= [(7.2 \text{ D} - 6.7 \text{ D})/6.7 \text{ D}] \times 100\% = 7.5\%$ ($\approx 7\%$) ✓	2	Allow use of unrounded figures for both P s, gives 6.6% 7.46 or 7.5 gains both marks
		ii	different colours will be imaged at different places ✓ so objects emitting / reflecting light of several colours will not be seen sharply / will be fuzzy / will have coloured edges ✓	2	
			Total	11	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
8	a	i	$G = I/V = 0.18 / 1.4 = 0.129 \text{ (S)} \checkmark$ $G = \sigma A/L \Rightarrow \sigma = GL/A = 0.129 \times 0.5 / (\pi \times [\frac{1}{2} \times 0.213 \times 10^{-3}]^2) \checkmark$ $= 1.8 \times 10^6 \text{ (S m}^{-1}\text{)} \checkmark$ <i>alternative method</i> $R = V/I = 0.18 / 1.4 = 7.8 \text{ (}\Omega\text{)} \checkmark$ $R = \rho L/A \Rightarrow \rho = RA/L = 7.8 \times (\pi \times [\frac{1}{2} \times 0.213 \times 10^{-3}]^2) / 0.5 = 5.54 \times 10^{-6} \text{ (}\Omega\text{m)} \checkmark$ $\sigma = 1/\rho = 1/(5.54 \times 10^{-6}) = 1.8 \times 10^6 \text{ (S m}^{-1}\text{)} \checkmark$	3	If done through resistance, the method mark for finding σ must include inversion of ρ. correct answer gains 3 marks
		ii	(σ too low means that is G also too low so) either I should be larger or V should be smaller $\checkmark$ there are p.d. losses across ammeter or croc clips / places where clips grip wire $\checkmark$ <i>alternative</i> Resistance R increases or G decreases $\checkmark$ current heats wire due to increased atomic vibrations hindering electron transport $\checkmark$	2	1st mark is for the suggestion and the 2nd for the explanation
	b	i	Three complete continuous loops through core, air gap and plate (not crossing) $\checkmark$ Flux lines tend to contract or straighten $\checkmark$	2	
		ii	Air has a much lower permeability than steel or the core $\checkmark$ Overall permeance of the magnetic circuit is much lower when air is present $\checkmark$ Giving smaller flux and so less force with air gap $\checkmark$	3	allow suitable alternative terms
	c		Power supply ~ current carrying coil $\checkmark$ emf ~ NI $\checkmark$ I ~ flux or ϕ $\checkmark$ conductance ~ permeance $\checkmark$ value for circuit leads / electromagnet core is greater than that for the alloy wire / steel plate $\checkmark$	5	award 1 mark for each correct row
			Total	15	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
9			*Level 3 (5–6 marks) Relates desirable and undesirable properties of aluminium during the launch and in the space environment with explanation in terms of physics principles. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Recognises some desirable qualities of aluminium and some disadvantages with some details relating to the launch or space environment but lacks explanation of either. <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Recognises that toughness, strength and low density are advantageous as these qualities make it durable and light but does not relate properties to details of the context. <i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i> 0 marks No response or no response worthy of credit.	6	Indicative scientific points may include: Properties of aluminium • Low density so light • Strong to withstand stresses e.g. in launch • Tough so will not crack easily • May conduct charge from solar wind into sensors • Changing magnetic field induce emfs in the satellite body which may damage electronics Demands of environment • Vacuum of space • Exposed directly to solar storms or solar wind • Changing magnetic fields • Irradiated by UV etc. from Sun • Cannot be repaired once in position • Need to manoeuvre easily • Great stresses during launch
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
10	a		$2.9 = 6.0 \times (R_c / (R_c + 3200))$ (1) $R_c = 2994 \Omega$ (1)	2	Accept RA: $V = 6 \times (3000/6200)$ $= 2.90 \text{ V}$ (1) Correct answer gains 2 marks. (1)
	b		$1/2994 = 1/3200 + 1/R_v$ (1) $R_v = 46500 (\Omega)$ (1)	2	Bald answer acceptable. Look for working from 3000Ω and working using conductance.
			Total	4	
11			$T = 3/5 = 0.60 \text{ s} / f = 1.67 \text{ Hz} / \omega = 10.5 \text{ rad/s};$ $k = \frac{4\pi^2 m}{T^2} / k = 4\pi^2 m f^2 / k = m\omega^2;$ $13(.2) \text{ N m}^{-1};$	1 1 1	correct period / correct frequency / correct angular frequency [1] correct rule transposed correctly or EOR [1] Accept any final answer that rounds to 13 for [3] No ECF for incorrect T Examiner's Comments This question produced a wide variety of answers but usually, gave the right answer if it was started correctly. Many incorrect answers were indicated by the candidate creating a mess of formulas and then (almost) randomly calculating anything. This question is a good example of a 'multistage problem' that was not approached as such by many candidates.
			Total	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
12				1 1	correct acceleration graph (Cosine) for [1] Correct displacement graph (-Cosine) for [1]. Accept ECF for acceleration graph reflected about time axis. Note: The tolerance on both graphs is... Time axis: To within $\frac{1}{4}$ square for the peaks, troughs and zero points. y-axis: to within $\frac{1}{4}$ square for the amplitudes. THE LINE MUST COVER THE FULL WIDTH OF THE x-axis. Examiner's Comments This aspect of graphical analysis, where the link between the diagrams is a differential is quite common, yet many candidates find it difficult. It was clear that for many, the link between d, v and a is not clear. Beyond the problem of getting the phase right, candidates were generally quite poor at drawing curves that look like sinusoids – frequently, the answer bordered on a triangular wave, which is not good – more practice with this kind of question is clearly needed. It was also interesting to note that a large number of candidates chose to have their amplitudes at values 'between' the x-gridlines, rather than use the major horizontal lines given. This increased the risk of losing a mark for an inconsistent amplitude.
			Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
13	a		$130 \times 51 \times 3600$ (1) $= 24 \times 10^6 \text{ J}$ (1)	2	Must see working Own answer required Calculation of intermediate value accepted. Examiner's Comments This question about the power supply of Sputnik 1 was a gentle opening question which most candidates found accessible.
	b		$P = E/t = 24 \text{ MJ} / (22 \times 24 \times 3600 \text{ s})$ (1) $= 12.6 \text{ W}$ (13 W) (1)	2	25 MJ gives 13.15 W 23.9 MJ gives 12.6 W Allow ecf from (a) on values less than 25 MJ Correct bald answer gains two marks Examiner's Comments This question about the power supply of Sputnik 1 was a gentle opening question which most candidates found accessible.
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
14	a		$2800 \text{ W} / 9 \text{ kg} = 311 \text{ W kg}^{-1}$ (1) which is similar to the “typical” value of 300 in line 24 (1)	2	310 allowed as 2 sf answer Any statement suggesting that the calculated value is near the typical value eg small (4%) difference gains the mark. Accept ‘same to one sf.’ Second mark dependent on correct first mark.
	b		$\text{power} = (\text{power/area}) \times \text{total area of panels}$ $= 1400 \times (2.5 \times 7.6 \times 2)$ (1) $= 53.2 \times 10^3 \text{ W}$ i.e. about 50 kJ per sec (1)	2	Working required Own value needed
	c		$(2 \times 2.8) \text{ kW} / 50 \text{ kW}$ (1) = 0.11 $0.11 \times 100 = 11\%$ (1)	2	Using 53.2 kW gives 10.52% = 11% Acceptable alternative approach: output power = mass of panel $\times$ answer to (a) no credit for only using one panel (giving 5.5 %) Allow $2.8 \text{ kW} / 26.6 \text{ kW} = 11\%$ (or 10.52 %) for two marks.
	d		$(7 \times 60) / 97$ (1) $= 4.3$ orbits (1)	2	Allow 4
	e		Inverse sq law so $5.6 \text{ kW} \times 1^2 = P \times 5.2^2$ (1) So $P = 5.6 \text{ kW} / (5.2^2) = 0.21 \text{ kW}$ (1)	2	Or: $14000 / 5.2^2 = 52 \text{ W m}^{-2}$ (1) $52 \text{ W m}^{-2} \times 38 \text{ m}^2 \times 11\% = 0.21 \text{ kW}$ (1) Accept: $300 \text{ W kg}^{-1} \times 18 \text{ kg}$ power calculation giving 199.7 W Own value needed Examiner's Comments This question, about the Hubble solar panel proved a little more discriminating, with some candidates considering the power from one panel rather than the pair of panels. Part (d) was more challenging although it was clear that many Centres had discussed the inverse-square relationship mentioned in the article with the candidates during the preparation for the examination leading to confident and clear responses.
			Total	10	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
15			Any two pairs from: Factor: conductivity/resistivity (1) Reason: high conductivity/low resistivity produces smaller heating effect/bigger current (1) Factor: density (1) Reason: low density reduces mass (1) Factor: UTS (1) Reason: high UTS won't break easily (1) Factor: toughness (1) Reason: tough material will absorb energy when deforming/won't shatter (1)	4	Not permeance/permeability Or any other sensible factor + reason Not conductance/resistance but can still access reason mark Accept arguments about voltage drop across the resistance of the cable. Not low mass Accept 'strength' Examiner's Comments This was about electromagnetic tethers. This required candidates to suggest factors affecting the choice of a metal for the tether. Many candidates considered factors of a particular specimen rather than a material. (For example, the conductivity of the material is a possible factor in choosing the material, whereas conductance is not a property of a material but of a specimen.) Only the best responses clearly linked the factor with the reason. Once again, many candidates relied on common-sense thinking (e.g. the weight of the tether in space) in a situation where common-sense ideas are not necessarily applicable.
			Total	4	
16			D	1	
			Total	1	
17			D	1	
			Total	1	
18			B	1	
			Total	1	
19			D	1	
			Total	1	

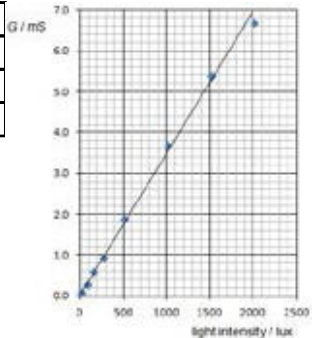
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
20			D	1	
			Total	1	
21			A	1	
			Total	1	
22			C	1	
			Total	1	
23			B	1	
			Total	1	
24			C	1	
			Total	1	
25			D	1	
			Total	1	
26			A	1	
			Total	1	
27			C	1	
			Total	1	
28	a		$r_{\text{internal}} = \{ \epsilon - V \} / I$ or e.g. $= \{0.8 - 0.4\} / 0.25 \times 10^{-3}$ ✓	1	method read from graph intercept and another point
			$= 1600 \text{ } (\Omega)$ ✓	1	evaluation
	b	i	proportional graph through e.g. (0.10 mA, 1.0 V) ✓	1	
		ii	current = intercept = 0.07 (mA) ✓	1	read from graph
		ii	R is across cell so shares same p.d. and current ✓	1	explanation accept by calculation $= 0.80 / 11600 = 0.069 \text{ (mA)}$
			Total	5	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
29	a		contrast stretch / improvement / ✓	1	
			the raw image only uses a limited range of 140/1 pixel values, these are shifted and stretched to use all 255/6 levels of the greyscale ✓	1	
	b		(255) / (140) ✓	1	accept (255) / (175 – 35)
			Total	3	
30	a		polarisation ✓	1	accept oscillations at 90° to direction of propagation if stated that aerial points at transmitter (when rotated)
	b		(signal) increases / returns to original intensity ✓	1	AW
			receiving aerial is parallel to direction of oscillation again / aerial is back in plane of polarisation ✓	1	accept E or B vector
			Total	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
31	a	i	✓✓	1	G / mS values in table allow 2 or 3 S.F.
			1.89 or 1.9	1	G values plotted correctly allow ecf on wrong values
			3.70 or 3.7	1	best fit line must show proportionality for mark
			5.38 or 5.4	1	
			6.67 or 6.7	1	
					
		ii	R vs Intensity both variables change over about 2 orders of magnitude / by about $\times 100$ / graph is highly curved ✓	1	accept log / log graphs compress large ranges of data
		ii	both graphs give linear best fit graph / test a functional relationship ✓	1	accept straight line graphs are only function that can be judged by eye
		ii	straight log / log graph shows a power law $R \propto I^n$ (gradient = $n \approx -1$) ✓	1	accept $R \propto 1 / I^n$ ($n \approx 1$) or $G \propto I$
		iii	photons give energy to electrons and free them into the conduction band ✓	1	reason
		iii	$G \propto$ carrier density and $G \propto I$ so expect $I \propto$ carrier density (provided electrons drop back into bonds / recombine with holes) ✓	1	evaluation
	b	i	threshold λ above which process of freeing electrons does not occur or ✓ threshold f or E below which electrons are not freed from bonds	1	
		ii	$E = hc / \lambda = 6.6 \times 10^{-34} \times 3 \times 10^8 / 770 \times 10^{-9}$ ✓	1	must have threshold λ not peak λ
		ii	$= 2.6 \times 10^{-19} \text{ (J)}$ ✓	1	
	c		$V = 6 \times R / (R + R_{\text{LDR}})$ or $6 \times 470 / (470 + 270)$ ✓	1	method
			$= 3.8 \text{ (V)}$ ✓	1	evaluation
			Total	14	
32			$k = F/x = 4.0 \text{ N} / 0.10 \text{ m} = 40 \text{ N m}^{-1}$ ✓	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
33	a	i	$A = \pi r^2 = \pi \times (0.75 \times 10^{-3} \text{ m})^2 = 1.77 \times 10^{-6} \text{ m}^2 \checkmark$ $G = (5.9 \times 10^7 \text{ S m}^{-1} \times 1.77 \times 10^{-6} \text{ m}^2) / (60 \text{ m}) \checkmark$ $= 1.7 \text{ S} \checkmark$	3	Stages can be implicit
		ii	$V = I/G = 13 \text{ A} / 1.7 \text{ S} \checkmark$ $= 7.8 \text{ V} \checkmark$	2	ecf from a i
		iii	any three points from: 2.8 kW means $I \approx 13 \text{ A}$ as in (a)(ii) - p.d. across kettle reduced from 'normal' 230 V (to 223 V) reducing the current (to $\approx 223/230$ of 'normal') so power is reduced (to $\approx (223/230)^2$ of 'normal') 500 W drill draws smaller current ($\approx 2 \text{ A}$), so fewer 'lost volts' ($\approx 1.3 \text{ V}$) than for kettle - p.d. across / current in drill not significantly different when using extension cable	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b		* Level 3 (5 – 6 marks) Marshals argument in a clear manner linking calculated power to temperature rise with little thermal transfer to surroundings. Makes sensible estimates throughout. Correctly calculates the thermal capacity of the cable <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3 – 4 marks) Makes a clear argument explaining the manufacturers' recommendation but does not use all available data to support the argument. <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i> Level 1 (1 – 2 marks) Makes some correct calculations but these are not linked to the central argument and the incomplete nature of the argument significantly weakens it. <i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i> 0 marks No response or no response worthy of credit	6	Indicative scientific points may include: • Correct calculation of power dissipated (100 W to 1 s.f.) • Correct calculation of mass of cable (1 kg to 1 s.f.) • Sensible choice of time of current flowing in a wound state • Correct calculation of temperature rise • Statement about thermal loss in wound cable • Statement about thermal loss in unwound cable • Statement about consequences of high temperature in wound cable • Statement about effect of reducing current
			Total	14	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
34	a		Any long random linear molecular structure ✓	1	Chemical type chains OK, or just zigzags
	b	i	Not brittle / doesn't crack / deforms before breaking/ absorbs energy on breaking/ AW✓	1	
		ii	Molecules tightly wound ✓ ; Strongly bonded / difficult to separate helical 'strands' ✓	2	Force or energy argument acceptable for (ii) and (iii)
		iii	Molecules separate ✓ ; Less strongly bonded ✓	2	
	c		Virtually all water ✓	1	
			Total	7	
35			* Level 3 (5 – 6 marks) Data used make quantitative comparisons of metals related to speed of cooking and temperature control. The size and shape of the pan is considered in terms of conduction through the base. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3 – 4 marks) Data used make qualitative comparisons of metals related to use in a pan with some consideration of their use in the pan base. <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1 – 2 marks) Data from the table used to decide on a suitable metal with little or no consideration of the pan design. <i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i>	6	Indicative scientific points may include: structure of pan • large area of base • constrained by size of heating plate / burner • (relatively) thin bottom • only the bottom needs to conduct well comparing metals • copper is the best conductor • iron is a poor conductor • aluminium is nearly as good as copper
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
36	a		12 mV is much too small to read on 2.5 V scale ✓	1	
	b		Gradient not constant ✓ ; Show/ calculate that emf > 1.25 V ✓	2	
			Total	3	
37		i	$\Delta Q = C\Delta V = 470 \times 10^{-6} \times 0.12 = 5.64 \times 10^{-5} \text{ C};$	1	no ecf on incorrect ΔQ
		i	$I = \frac{\Delta Q}{\Delta t} = \frac{5.64 \times 10^{-5}}{60} = 9.4 \times 10^{-7} \text{ A} = 0.94 \mu\text{A};$	1	
		ii	energy required;	1	not just to get from one plate to the other
		ii	for an electron to break free (from an atom) / enter the conduction band / become a free electron / move freely within the insulator;	1	
		iii	use of $\ln I = \ln A - \frac{\epsilon}{kT}$ to eliminate A; $\epsilon = 3.9 \times 10^{-20} \text{ J};$	1	look for method which will eliminate A [1]
		iii			correct answer for [2] Examiner's Comments Less than half of the candidates could calculate the leakage current for part (i), mostly because they failed to distinguish between Q and ΔQ . Many candidates correctly identified ϵ as energy for an electron, most wrongly assumed that it was to force the electron across the capacitor rather than allow it to move freely through the dielectric. The calculation of part (iii) was another stretch-and-challenge question, with only stronger candidates able to successfully solve the simultaneous equations with the help of logs.
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
38		i	use of $k = \frac{F}{x}$ or $F = kx$;	1	accept $k = \frac{F}{\Delta L}$
		i	use of $\frac{F}{A} = E \frac{x}{L}$ to obtain required expression	1	
		ii	$k = \frac{2.0 \times 10^{11} \times 2.5 \times 10^{-4}}{300} = 1.67 \times 10^5 \text{ Nm}^{-1}$	1	no ecf on incorrect k allow ecf if mass is just 1500 kg (1.7 Hz) or 640 kg (2.6 Hz) for [2] Examiner's Comments Many had difficulty with the synoptic element from G491 in part (i). Many candidates were unable to do this, often confusing the length of the cable with its extension in their attempts to derive the required rule. The calculation of part (ii) discriminated very well, with weaker candidates often selecting the wrong mass for the lift cage and confusing the period of the oscillation with its frequency.
		ii	$T = (2\pi \sqrt{\frac{m}{k}} = 2\pi \sqrt{\frac{1500 + 640}{1.67 \times 10^5}}) = 0.711 \text{ s}$	1	
		ii	$f = \frac{1}{T} = \frac{1}{0.711} = 1.4 \text{ Hz}$	1	
Total				5	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
39			LiF brittle - so snapping risk/cracks will propagate (1) due to LiF being an ionic lattice structure/ has directional bonds (1) so there is a lack of (mobile) dislocations (1)	3	Brittle alone does not gain mark. Accept fractures as alternative to cracks propagating Award three marks only if there is a clear link from micro properties via dislocations to brittle behaviour (QWC) Examiner's Comments This question was about the mechanical properties of LiF. Most candidates identified the crystal as brittle and correctly recalled a consequence of this property to gain the first mark. The majority of candidates correctly described the ionic lattice structure or the directional bonds within the crystal to gain the second mark. The third mark proved less accessible.
			Total	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
40	a		$n = 5 \times 10^{-13} / 1.6 \times 10^{-19} \text{ (1)}$ $= 3.1 \times 10^6 \text{ (1)}$	2	Need own value Examiner's Comments This simple 'show that' question proved accessible to all but the weakest candidates.
	b		10 stages so $3^{10} \times N$ per second (1) $N = 3.1 \times 10^6 / 3^{10} \text{ (1)}$ $= 52 \text{ (1)}$	3	Ecf 2 marks max for choosing 9 or 11 stages (3^9 gives 159, 3^{11} gives 17) Other number of stages score zero Accept 51 , 53 to allow for different values of number of electrons reaching anode. Allow non-integer values (as the final answer is an average) Give two marks max if response suggests that 4 electrons (3 new + incident) emitted for each incident electron. Examiner's Comments The question was of a higher demand and it was encouraging to see that over half the candidates gained all three marks for reaching the correct answer of between 51 and 53 electrons incident on the first dynode. (The range covers the various values used for the number incident on the anode.)
			Total	5	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
41	a		$M = 89/5.3 = 16.8$ or 17 (1)	1	Ignore sign and spurious unit. Allow 17 × (for 17 times) Don't allow 16 or 16.7 (RE) Examiner's Comments This question proved straightforward.
	b		$(1/f = 1/v - 1/u) = 1/0.089 + 1/(5.3 \times 10^{-3})$ (1) = 200 dioptre (1)	2	Correct bald answer 2 marks 0.2 dioptre POT 1 Zero marks for 1/200 on answer line (or calculated value) Examiner's Comments This was expected to be equally accessible, but this was not the case; only about half the candidates reached the correct value. This is an area of the course they meet early in the AS year and it was clear that many candidates had forgotten that object distances are negative in the Cartesian convention. If a candidate chose to use a different convention full marks could still be gained for a correct answer.
			Total	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
42	a		$(5.0 \text{ cm} / 2.0 \text{ cm}) \times 100 \times 10^{-6} / 480$ (1) $= 5.2 \times 10^{-7} \text{ m} / \text{pixel}$ (1)	2	Accept +/- 1 mm on each measurement Acceptable range = 5.6×10^{-7} to 4.8×10^{-7} m / pixel Correct, in-range bald answer 2 marks Examiner's Comments This is a straightforward calculation and the majority of candidates gained both marks.
	b		Area of single lens in range $250 - 350 \mu\text{m}^2$ (1) Number in eye = total area / area of single lens = range 17000 – 25000 lenses (1)	2	Alternative methods e.g. $30 - 40 \text{ lenses per } (100 \mu\text{m})^2$ (1) $= > 17000 - 25000 \text{ lenses on the whole eye}$ (1) In range bald answer worth one mark only. No ecf from incorrect single lens area or number of lenses in any given area Examiner's Comments This calculation is less straightforward and many candidates lost marks through confusing units and inaccurately calculating the area of a single lens.
			Total	4	
43			D	1	
			Total	1	
44			C	1	
			Total	1	
45			D	1	
			Total	1	
46			D	1	
			Total	1	
47			D	1	
			Total	1	
48			A	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
49			C	1	
			Total	1	
50			B	1	
			Total	1	
51			B	1	
			Total	1	
52			Use of measurement and scaling to get a value for λ ✓ {720-656} c / 656 ✓ = 0.098 c ✓	L H H	Teachers should check measurements from their printed papers. This solution is based on scale of 36 mm $\equiv$ 222 nm applied to any spectral line { red is best: shifted to $\approx$ 720 nm } accept their value of λ evaluation accept v in range 0.090 c to 0.110 c
			Total	3	

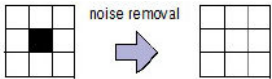
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
53	a		gravitational E_p gained = elastic E_p in spring ✓	L	principle make conservation of energy clear accept correct ref to E_k or to work done
			$h = Fx / [2mg] = 18 \times 0.25 / [2 \times 0.030 \times 9.81]$ ✓	M	accept $mgh = (\frac{1}{2} mv^2) = \frac{1}{2} Fx$
			= 7.7 (m) ✓	M	evaluation
	b		spring contains some E_k at point of launch / some E_k of rocket transferred to air by air resistance / friction against walls of tube results in temperature increase ✓	L	not just all energy is not transferred must identify the energy transfer
			So less energy transferred to E_p and so height less ✓	L	accept work done against air resistance.
	c		EITHER ball bearing reaches higher ✓ because smaller surface area / less air resistance / less energy transferred to air by air resistance ✓	M	ignore has same launch velocity
			OR lower because larger surface area / less streamlined ✓ more air resistance / more energy transferred or work done against air resistance ✓	M	
			Total	7	

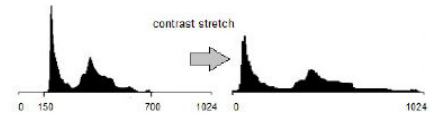
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
54	a	i	to create a metal resistor of reasonable resistance in a small sized device ✓	L	accept to get a long length / small x-sectional area in a compact device
		ii	resistance of connecting leads / contact resistance ✓	L	accept contact / thermal e.m.f. offsets Ohmmeter reading not within the limits of experimental accuracy
	b	i	sensitivity = $\Delta V / \Delta \epsilon$ OR = 0.006 / 0.002 ✓	M	method accept in numbers / gradient
		i	= 3.0 (V per unit strain) ✓	H	evaluation allow 1 mark for 0.030 POT
		ii	T increases ρ and R ✓	L	not just T affects ρ and R
		ii	T increases dimensions of wire ✓	L	accept % increase in A is $2 \times$ % increase in L ($R \propto L / A$)
		ii	R would decrease due to expansion alone because % increase in L is $\frac{1}{2}$ % increase in A ($R \propto L / A$) ✓	S&C	
		ii	fractional change in $\rho \text{ K}^{-1} \approx$ strain OR fractional change L in the gauge so this effect could be important ✓ OR fractional change in $\rho \text{ K}^{-1} \gg$ fractional change $L \text{ K}^{-1}$ so expansion is a less important temperature than change in ρ	S&C	accept % expansion $\text{K}^{-1} \approx 1/100$ % increase $\rho \text{ K}^{-1}$ so could be ignored to first approximation
		iii	Fig. 37.4 $\propto$ line added of $2 \times$ gradient of original ✓	M	expect line through {0, 3.000} and {0.2, 3.012}, gradient = 0.0060
			Total	9	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
55	a	i	$1024 \times 1224 \times 3 \times 10 = 37.6 \text{ Mbits} \checkmark$	L	accept 38 Mbits
		ii	$R_{\text{EARTH}} = (45 \text{ mm} / 53 \text{ mm}) \times 1024 = 870 \text{ pixels} \checkmark$	L	Teachers should check measurements from their printed papers. This solution is based on earth radius of 45 mm and image width 53mm.
		ii	$6.4 \times 10^6 \text{ m} / 870 \text{ pixels} = 7.4 \times 10^3 \text{ (m pixel}^{-1}) \checkmark$	M	evaluation accept in range $\{7.2 \text{ to } 7.6\} \times 10^3 \text{ (m pixel}^{-1})$
	b		Level 3 (5–6 marks) Clear description of the three strands: • noise reduction • changing contrast or brightness • edge detection AND Gives advantages and problems of image processing and explains why compressing the image is useful <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Describes at least two of the three strands above OR covers all three at a superficial manner. AND Gives an advantage OR problem of image processing OR explains why compressing the image is useful <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i>	S&C H M L	Indicative scientific points may include: Noise reduction: • smoothing, by replacing the pixel value with the median of the values of that pixel and its 8 neighbours • the median value of the nine is the middle one(s) when placed in rank order  • filtered image is built up in new array so that original pixel values are always used for rank filter Edge detection: • enhance edges by subtracting average value of pixels neighbour's from each pixel. • Removes uniform areas of brightness and highlights places where gradient of brightness changes abruptly.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
	Level 1 (1–2 marks) Makes at least two independent points that are relevant <i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i> 0 marks No response or no response worthy of credit	L L	Changing contrast or brightness: Example (with 10 bits, could be 8 bits) 10 bits means $2^{10} = 1024$ levels of brightness - increase brightness by increasing the value on each pixel by the same amount until brightest pixel in image coded 1024 - whole range of levels may not be used so increase contrast by stretching to cover full 0 to 1024 range  $\{\text{value-lowest}\} \times 1024 / \{\text{highest} - \text{lowest}\}$ $\{\text{value-lowest}\} \times 1024 / \{\text{highest} - \text{lowest}\}$ Advantages and problems of image processing and why compressing image is useful - minimizing the size in bytes of an image file without degrading the quality of the image to an unacceptable level. - large areas of one pixel value / colour coded by colour value followed by number of consecutive pixels in the row with that colour - noise or spurious artefacts can be introduced to image OR real artefacts removed - reduces the time / bandwidth required for image transmission - reduction in file size allows more images to be stored in a given amount of disk or memory space. accept clearly labelled diagrams throughout

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c		(info = rate × time) = $340 \text{ bits}^{-1} \times 24 \times 3600 \text{ s} / 8 \checkmark$ = 3.7 (Mbytes) $\checkmark$	L L	method evaluation
			Total	11	
56	a	i	Young modulus is the gradient of the linear portion of graph $\checkmark$ Gradient = $(1.0 \times 10^9 \text{ Pa} - 0) / (0.005 - 0.000) \checkmark$ = $2 \times 10^{11} \text{ Pa}$ (200 GPa) $\checkmark$	3	Other ranges acceptable Accept values between 1.9×10^{11} and $2.2 \times 10^{11} \text{ Pa}$
		ii	Alloy stiffer shown by steeper gradient $\checkmark$ Alloy stronger shown by higher stress at breaking $\checkmark$ Pure metal more ductile with wider plastic region $\checkmark$	3	
	b		Any four from: • Pure metal has regular planes which can slip over one another • by mobile dislocations • producing plastic flow • Alloy has atoms of different metals within the microstructure • These 'pin' dislocations AW • reducing plastic behaviour/increasing strength	4	Accept 'foreign atoms'
			Total	10	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
57	a	i	top row: 8.61 (V) ✓	1	Accept 20.97 to 4 sf
		i	Third row: 2.32 (A) ✓	1	
		i	Bottom row: 21.0 (W) ✓	1	
		ii	Mean Power = 20.6 W ✓	1	
		ii	Uncertainty (half range), (21.0 – 19.8)/2 = ± 0.60 W ✓	1	
	b	i	Use of $E = m c \Delta\theta$ and $P = E/t$ to give $c = P t / m \Delta\theta$ ✓	1	Allow ECF from (a)(ii) $t / \Delta\theta = \text{gradient} = \text{cm} / P$
i		Use two readings off the graph and substitute. ✓ e.g. $c = 20.6 \times (10 - 2) \times 60/ 1 \times (29.1 - 19.9)$ $= 1070 \text{ J Kg}^{-1} \text{ K}^{-1}$ ✓	1		
i			1	Ignore sign	
		ii	Find gradient of cooling line of best fit from graph $= -0.45 \text{ K min}^{-1}$ ✓	1	Acceptable range = -0.43 to -0.47 K min^{-1}
		ii	Two plots read off correctly, at least half the length of the line apart. ✓	1	
	c		Percentage difference = $(1070 - 897) \times 100/897 = 19 \%$ ✓	1	Allow ecf from (b)(i)
			Percentage difference is larger than the percentage uncertainty so experiment is not very accurate ✓	1	
			Any two from: ✓ ✓ The block is cooling at rate calculated in b(ii), which means that it should have had a larger temp difference; Heater not 100 % efficient; Energy has gone into heating heater/wires/digital thermometer; Temperature of the block may not have been uniform; Etc.	2	
			Total	14	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
58			$E = V q = 1.35 \times 1.6 \times 10^{-19} = 2.16 \times 10^{-19}$ J ✓	1	
			Total	1	
59			p.d. across resistor = $6.0 \text{ V} \times (4.7 \times 10^3 \Omega / 6.7 \times 10^3 \Omega)$ ✓ = 4.2 V ✓	2	Need own value and working shown Calculator value = 4.21 V Examiner's Comments This question was about discharging and charging capacitors. This part of the question was answered correctly by the majority of the candidates.
			Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
60			Cube Method: Number of atoms / $\text{m}^3 = (10\,500\text{ kg m}^{-3}) / (1.8 \times 10^{-25}\text{ kg}) = 5.8 \times 10^{28} \checkmark$ Volume occupied by one atom = $1/5.8 \times 10^{28}\text{ m}^{-3} = 1.7 \times 10^{-29}\text{ m}^3 \checkmark$ diameter (length of side of cube) = $(1.7 \times 10^{-29}\text{ m}^3)^{1/3} = 2.6 \times 10^{-10}\text{ m} \checkmark$ Assumption: atoms are in simple cubic lattice $\checkmark$ Sphere method: Number of atoms / $\text{m}^3 = (10\,500\text{ kg m}^{-3}) / (1.8 \times 10^{-25}\text{ kg}) = 5.8 \times 10^{28} \checkmark$ Volume occupied by one atom = $1/5.8 \times 10^{28}\text{ m}^{-3} = 1.7 \times 10^{-29}\text{ m}^3 \checkmark$ This gives radius = $1.6 \times 10^{-10}\text{ m}$, therefore diameter = $3.2 \times 10^{-10}\text{ m} \checkmark$ Assumption: volume between spheres can be ignored. $\checkmark$	4	Correct bald answer gains 3 marks Accept: no gaps between atoms, atoms are cubes. It is not enough to give 'atoms are spheres' as an assumption. Examiner's Comments This question was about estimating the size of an atom. The majority of the candidates scored at least 3 marks out of 4, gaining the marks for the calculation but not always being sufficiently clear about the assumption made. A significant minority of the candidates failed to give an assumption.
			Total	4	
61			B	1	Examiner's Comment Candidates had to select an equivalent unit for electrical resistance to the ohm Q. Most successfully chose the unit S^{-1}. A common incorrect answer was D presumably because it involved the units for current and voltage, but in the incorrect inverse ratio.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
62			A	1	Examiner's Comment This question about digitising a sampled signal was well answered by the vast majority of candidates, who picked out the correct statement A.
			Total	1	
63			B	1	Examiner's Comment This pair of questions was about a resistor network. The vast majority got the total resistance of the network correct (Q5), but under half went on (Q6) to correctly select the p.d. between two specified points in the network.
			Total	1	
64			B	1	Examiner's Comment This pair of questions was about a resistor network. The vast majority got the total resistance of the network correct (Q5), but under half went on (Q6) to correctly select the p.d. between two specified points in the network.
			Total	1	
65			D	1	Examiner's Comment This pair of questions was about the resistance and diameter of wires for two equally powered heating coils. The numerical ratios involved scaling reasoning and candidates found this challenging. A common error on Q15 was to get A, the inverse of the correct ratio. In Q16 many forgot that $\text{diameter} \propto \sqrt{(\text{cross-sectional area})}$ and chose A again.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
66			B	1	Examiner's Comment This pair of questions was about the resistance and diameter of wires for two equally powered heating coils. The numerical ratios involved scaling reasoning and candidates found this challenging. A common error on Q15 was to get A, the inverse of the correct ratio. In Q16 many forgot that $\text{diameter} \propto \sqrt{(\text{cross-sectional area})}$ and chose A again.
			Total	1	
67			A	1	Examiner's Comment Candidates found this question on a magnetic flux circuit hard. By far the most common incorrect answer was B. This showed that many candidates did not realise that halving the length of the magnetic circuit would double the flux (by halving the reluctance).
			Total	1	
68			C	1	Examiner's Comment This pair of questions on transformers was well answered by a good majority of candidates, Q24 to calculate the primary coil current being the slightly more discriminating.
			Total	1	
69			D	1	Examiner's Comment This pair of questions on transformers was well answered by a good majority of candidates, Q24 to calculate the primary coil current being the slightly more discriminating.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
70	a		(usually air is not a conductor) having no charge carriers (to support a current) / ✓ the ions and / or electrons provide charge carriers (for the air to conduct)	1	expect concept of charged particles free to move not just air is an insulator or non-conductor / just ions are charged / just charges can conduct allow charge carriers / delocalised or free electrons or charges / charges available to carry current / charges can flow Examiner's Comment In this part most candidates realised that air needs mobile charge carriers in order to conduct electricity. In part (b) affectively all could calculate the charge carried by the bolt (7.5 C) given the current and its duration.
	b		$(\Delta Q = I \Delta t) = 30 \times 10^3 \times 250 \times 10^{-6} \checkmark$ $= 7.5 \text{ (C)} \checkmark$	1 1	bare correct value scores both marks ignore units Examiner's Comment In this part most candidates realised that air needs mobile charge carriers in order to conduct electricity. In part (b) affectively all could calculate the charge carried by the bolt (7.5 C) given the current and its duration.
			Total	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
71	a	i	$\Delta E = m c \Delta \theta \checkmark$ $= 4200 \times 17 = 71.4 \text{ (kJ)} \checkmark$	1	method
				1	evaluation accept 71 (kJ) Examiner's Comment The vast majority of candidates calculated correctly the energy to heat 1 kg of water in summer (71 kJ). The most common error was POT (power of ten) in converting $7.1 \times 10^4 \text{ J}$ into kJ.
		ii	$\Delta t = m c \Delta \theta / IV$ or $= 71.4 \times 10^3 / (230 \times 46) \checkmark$ $= 6.7(5) \text{ (s)} \checkmark$	1	method in rearranged algebra or numbers accept $t = E / P$
				1	evaluation not 6.74 (s) RE allow ecf on value from (a) Examiner's Comment Given the current and voltage to the heater most candidates could calculate the time taken to heat the 1 kg of water by 17° (6.7 s).
	b		$\Delta \theta$ doubled $\checkmark$ so flow (rate) or $\Delta m / \Delta t$ will have to halve $\checkmark$	1	accept mass flow rate drops from 0.15 to 0.075 kg s^{-1}
				1	not ΔE doubles so time doubles / other time reasoning max 1 for just flow (rate) less or slower Examiner's Comment This part was more discriminating, most candidates realised that the flow rate in winter would have to be lower than in summer (1 mark), but few spotted that the temperature rise in winter was doubled, and so the flow rate would be halved (2 nd mark). Weaker candidates missed out all together, by only talking about the time to heat the water being longer, and not considering the flow rate as requested.
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
72	a		Immerse in liquid (eg oil / water) with thermometer and means of changing the temperature. Extra detail: e.g. electrically insulate thermistor from water / allow time for thermal equilibrium to be reached at each temp or method of getting below room temperature or stir.	1 1	Change the temperature by heating water or adding hot water / ice or allowing to cool in room. Examiner's Comments Part (a) was a two mark response on the basic requirements for varying and measuring the temperature of a thermistor for the first mark, with some extra details needed to gain the second mark. Common errors included omitting the use of a thermometer and heating the thermistor by passing current through it. The second mark was often awarded for providing an explanation of how to obtain a temperature of 0 °C such as adding ice.
	b		V_{out} rises as temp increases	1	Examiner's Comments Part (b) was fairly straightforward and many candidates realised that measuring V across the fixed resistor would give a rising output with a rising temperature. Common incorrect responses included keeping the voltmeter away from the heat source or water.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c	i	Appropriate uncertainty bars added to Fig. 1.3 Straight line of best fit drawn within their bars. As <u>straight</u> line can be drawn (results are consistent with V_{out} varying linearly with temperature)	1 1 1	Horizontal bars should be 4 small squares long, vertical bars should be 2 small squares high. Award mark for at majority correctly drawn uncertainty bars. If no error bars drawn, allow line of best fit with even distribution of points either side. Examiner's Comments The first part of (c)(i) was well answered, the majority of candidates correctly adding the error bars and drawing a straight line of best fit within the error bars. The most common error was to have both vertical and horizontal error bars of the same length. For the third marking point of this part required the candidate to say that a straight line could be drawn within the error bars. Many candidates omitted the word 'straight' or used 'linear' instead, but this was included in the question stem and linear does not necessarily imply straight.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Temperature values written on scale to replace voltage values. Extra detail such as: • Linear relationship makes each scale division the same size • Sensitivity is constant across the whole range • A meaningful comment about the conversion of V to °C.	1 1	Ignore reference to measuring V at different T. Accept change the scale to read temperatures. Examples include: • Subtracting intercept (1.7) from V • Dividing V by gradient (0.05 to 0.07 V °C⁻¹) • Multiplying by 1/gradient (14 to 20) Examiner's Comments Many candidates missed the point of (c)(ii) and described the method given in the earlier parts of this question rather than explain how the temperature could be read off the voltmeter directly. Very few candidates explained that the scale should be re-drawn as a temperature scale, but some candidates gained a mark for stating a conversion factor.

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	d	Level 3 (5–6 marks) Detailed and clearly explained calculations to show that sensitivity and range decreases with both increasing and decreasing values of R_Q. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is clear relevant and substantiated.</i> Level 2 (3–4 marks) Some calculations to compare range or V_{out} of existing set up with increasing R_Q and decreasing R_Q. <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Limited use of graphical information and simple calculations linked to comment on sensitivity / performance/output range. <i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i> 0 marks No response or no response worthy of credit.	6	Indicative scientific points may include: Qualitative comments: R_{Th} decreases with increasing temperature. V_{out} varies depending on the ratio of resistance values. - Sensitivity will decrease with increasing R_Q and decreasing R_Q. - Optimum sensitivity will be when R_Q is about the mid-point of range of R_{Th}. Calculations from data shown in graphs: R_{Th} at low temp ($< 5^\circ\text{C}$) is in range 12 – 16 kΩ. R_{Th} at high temp ($> 30^\circ\text{C}$) is in range 3 – 4 kΩ. - Range of $V_{out} = 3.6 - 1.7 \text{ V} = 1.9 \text{ V}$ over 35°C range. - Sensitivity is approx 0.05 to $0.06 \text{ V } ^\circ\text{C}^{-1}$. - Calculate R_Q to be in range 7.5 to 8.6 kΩ. Increasing R_Q: V_{out} will increase as R_Q has larger proportion of total R. - Use of potential divider equation to calculate V_{out} with value of $R_Q > 9 \text{ k}\Omega$ at low temp ($< 5^\circ\text{C}$) and high temp ($> 30^\circ\text{C}$). - Show that range of V_{out} is lower than 1.9 V over 35°C range. - Calculation to show that sensitivity is less than 0.05 to $0.06 \text{ V } ^\circ\text{C}^{-1}$ or their value calculated for existing set up. Decreasing R_Q: V_{out} will decrease as R_Q has smaller proportion of total R. - Use of potential divider equation to calculate V_{out} with value of $R_Q < 7 \text{ k}\Omega$

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					at low temp ($< 5^{\circ}\text{C}$) and high temp ($> 30^{\circ}\text{C}$). • Show that range of V_{out} is lower than 1.9 V over 35°C range. • Calculation to show that sensitivity is less than 0.05 to $0.06 \text{ V } ^{\circ}\text{C}^{-1}$ or value calculated for existing set up. Examiner's Comments Part (d) was a complicated level of response question requiring both calculations and qualitative comments. Candidates could gain low level marks for correct qualitative statements or for reading data from the graphs, but the higher levels required several calculations. Many candidates used the data from both graphs to find an approximate value for the initial resistance of Q. Candidates then went on to work out the range of voltage outputs for both a higher value and a lower value of Q. If candidates chose values which were too close to the initial value of Q, the range of voltage may not have changed much, giving an incorrect trend in sensitivity. Some candidates only worked out a voltage output for one temperature, and some candidates discussed uncertainties in readings rather than sensitivity.
			Total	14	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
73	a	i	v has largest uncertainty because it is difficult to judge where the image is (perfectly) in focus.	1	Ignore answers relating to % uncertainty. Not just more difficult to measure image distance.
		ii	Range = 0.03(0) m	1	
		iii	mean = 0.401m Marked correctly on plot by eye - [in the first quarter of the square to the right of the 0.400 grid line]	1 1	Average calculated excluding the two suspected outliers. Allow ecf from incorrect mean. y-position not important.
		iv	Minus x2 spread from mean = 0.371 so 0.330 is an outlier OR mean - 0.330 = 0.071 which is greater than 2 x spread so is an outlier. Plus x2 spread from the mean = 0.431 so 0.430 is not an outlier OR 0.430 – mean = 0.029 which is less than 2 x spread so not an outlier.	1 1	Allow ecf from mean calculated in (iii) and range calculated in (ii) for both with correct argument. NOT ± 0.015 Examiner's Comments In part (a)(i) many candidates discussed percentage uncertainties rather than the practical consideration of finding the image position. Part (a)(ii) was nearly always correct, but in part (iii) most candidates were able to calculate the mean value correctly many did not realise the importance of using the same number of significant figures as the raw data and consequently quoted their answer as 0.40 or 0.400. The mean value was usually correctly indicated on the grid with either a spot or a line. In part (a)(iv) some candidates used incorrect values for 2x spread – usually either 0.015 or 0.060. Some candidates calculated different values of range which included the potential outliers instead of the value calculated in part (ii).

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b	i	m = v / u Both values correct -2.13 and -3.30 Correct sign and consistent number of SF	1 1	
		ii	Points plotted correctly ± ½ square	1	ECF from (b)i but v should be at 0.48 and 0.66
		iii	Multiply $\frac{1}{v} = \frac{1}{u} + \frac{1}{f}$ by v to get $1 = \frac{v}{u} + \frac{v}{f}$ Substitute in $m = \frac{v}{u}$ to give $1 = m + \frac{v}{f}$ and rearrange (to give $m = 1 - \frac{v}{f}$) OR Rearrange $\frac{1}{v} = \frac{1}{u} + \frac{1}{f}$ to give $\frac{1}{u} = \frac{1}{v} - \frac{1}{f}$ [or $u = \frac{vf}{f-v}$] Substitute into $m = \frac{v}{u} = v (\frac{1}{v} - \frac{1}{f}) = \frac{v}{v} - \frac{v}{f}$ or $m = \frac{v}{\frac{vf}{f-v}}$ (to give $m = 1 - \frac{v}{f}$)	1 1 [1] [1]	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	Gradient = $\frac{-1}{f}$ Calculation of gradient = -6.67 to give $f = 0.15$	1 1	EOR Gradient should be between -6.5 and -6.8. $0.147 \text{ m} < f < 0.154 \text{ m}$. Ignore signs. If correct value for f is given, without evidence of gradient use, then only second marking point awarded. Examiner's Comments The calculations of magnification in part (b)(i) were usually carried out correctly, but some candidates gave the two values to different numbers of significant figures. Only a few omitted the negative sign. The points were invariably plotted correctly. Many candidates demonstrated correct algebra in part (iii), although some followed a rather circuitous route eventually leading to the correct expression. Most candidates calculated the focal length of the lens by substituting data into the expression rather than using the reciprocal of the gradient.
	c	i	4(.00) D	1	From either intercept.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Steepest line drawn <u>within</u> error bars Shallowest line drawn <u>within</u> error bars Maximum and minimum powers = intercepts taken from max and min gradient lines drawn Percentage uncertainty = $(\text{max value} - 4.0) \times 100 / 4.0$ OR Percentage uncertainty = $(4.0 - \text{min value}) \times 100 / 4.0$ OR Percentage uncertainty = $\frac{1}{2} (\text{max value} - \text{min value}) \times 100 / 4.0$	1 1 1 1	Both drawn lines must cross printed line. Accept intercepts from either x or y axes. Correct to $\pm$ half a small square from lines drawn by candidate Intercepts can be taken from either line $\pm 0.05\text{D}$ Eg: Minimum = 3.8D Maximum = 4.2D Common values are usually between 5% to 13% Examiner's Comments Candidates found part (c) more accessible as most were able to give the correct power of the lens in part (i). Most candidates drew acceptable steeper and shallower worst-fit lines through the error bars on the graph and provided they knew to use the intercept were able to gain all four marks in part (ii). If they used some other method to find the power, they were usually able to pick up the final mark for percentage uncertainty using errors carried forward. A few candidates did not draw worst fit lines on the graph.
			Total	18	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
74	a		$(50 \text{ MPa} / 7 \times 10^{-4}) = 7.1(4) \times 10^{10} \text{ (Pa)} \checkmark$	1	evaluation accept in range 7.0 to $7.3 \times 10^{10} \text{ (Pa)}$ Examiner's Comment Part (a) was a Young modulus estimate from the stress against strain graph, and a large majority estimated a value in the acceptable range $(7.0 \text{ to } 7.3) \times 10^{10} \text{ Pa}$.
	b		alloy absorbs more energy (per volume) $\checkmark$ alloy is stronger / has higher breaking stress $\checkmark$	1 1	choice explained accept alloy because it is tougher not stiffer not any credit for pure metal takes greater strain and prolongs time of collision Examiner's Comment Part (b) drew many wrong answers, most candidates believing that pure aluminium is more suitable for crumple-zone construction than aluminium strong alloy, simply because it undergoes more strain. However the energy dissipating capability (area under the graph is proportional to energy per volume) is more important in dissipating crash energy outside the passenger compartment. Many asserted the area under the graph is greater for the pure metal, but measurement would have shown that the strong alloy is more than twice as capable of absorbing energy per unit volume! Candidates should be encouraged to be as quantitative as possible in answering questions.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c	i	method: any {scaled distance ÷ appropriate number of atoms} ✓ evaluation: e.g. 4 atoms per nm gives $0.25 \text{ nm} / 2.5 \times 10^{-10} \text{ (m)}$ ✓ OR 5 atoms per nm gives $0.20 \text{ nm} = 2.0 \times 10^{-10} \text{ (m)}$	1 1	allow atom counting angled to atomic rows not unreal estimates like 10 atoms per 1 nm estimation accept in range { 1.8 to 2.7 } × 10^{-10} (m) credit 2 marks for answer in range with no working Examiner's Comment In part (ci) most candidates attempted to divide a scaled distance by a counted number of atoms and got the method mark. Only the more careful made allowance for the angle of the atomic planes and got an acceptable value for the atomic diameter in the range $(1.8 \text{ to } 2.7) \times 10^{-10} \text{ m}$.
		ii	a dislocation / edge dislocation ✓	1	accept extra half-plane of atoms Examiner's Comment In part (cii) most could identify the dislocation from the STEM image.
	d		Level 3 (5–6 marks) Marshals argument in a clear manner and includes clear explanation of three strands: - metallic bonding - structure of metal and alloy - elastic and plastic deformation <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Shows clear understanding of at least two of the three strands above to the argument or covers all three at a superficial manner and does not include enough indicative points for level 3. <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i>	6	Look for number of strands attempted to help decide the Level, then look at quality. Indicative scientific points may include: Metallic bonding +ve ion lattice in sea / gas of free mobile electrons - non-directional strong electrostatic bond electron glue - similar for pure metal and alloy Structure of metal and alloy - ordered regular stacking of atoms in planes in metal - alloy has a few impurity metal atoms of different size - most metals are polycrystalline with grains and grain boundaries between crystals of different orientation - ions can slip and atomic planes move - dislocations are stacking imperfections e.g. extra half plane reduce stress at which planes slip by localising stress

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Level 1 (1–2 marks) Makes at least two independent points (possibly from one strand) that are relevant to the argument but does not link them together and shows only superficial engagement with the argument. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks <i>no response worthy of credit remember No response at all record NR</i>		Elastic and plastic deformation • elastic behaviour atoms return to original position • when stress removed stretched stiff bonds spring back • metals and alloys are stiff and elastic for small strains • dislocation movement in pure metals allows slip and plastic deformation at relatively low stress this is permanent and ions do not return when stress removed • dislocations are pinned by impurity atoms in alloy • which restricts slip giving a smaller plastic region at higher yield stress • reference to Fig. 40.2 • accept well labelled diagrams throughout for credit if integrated into the explanation Examiner's Comment Part (d) was a LOR (Level of Response question) and worth 6 marks. Candidates had to use ideas about bonding and structure in metals and alloys to explain elastic and plastic behaviour. The most common error was for candidates to miss out on one or more of these elements and thus restrict the level they could achieve. However most candidates could write meaningfully and from knowledge that they understood about metals and alloys and how their different mechanical properties arise, this was most encouraging. Labelled diagrams could have been used more often to advantage. The average response here was at mid Level 2 (3 or 4 marks out of 6), but a significant number of candidates achieved Level 3 (5 or 6 marks out of 6), which was pleasing.
			Total	12	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
75		i	Number of pixels across diameter of Pluto $= (\text{diameter of Pluto on image} / \text{length of square}) \times 1024 \checkmark$ $= \text{range: } 580 \text{ to } 650 \checkmark$ $\text{resolution} = 4.2 \text{ to } 4.7 \text{ km pixel}^{-1} \checkmark$	3	Use of 1024^2 gives 0/3 Bald answer in range 4.2 to 4.7 km pixel⁻¹ gains three marks. Examiner's Comments This question was about imaging Pluto. Parts (a) and (b)(i) were standard calculations involving distance measurement and resolution of digital images. Both parts were answered confidently by the majority of the candidates.
		ii	angle subtended by Pluto at 770 000 km $= 0.0035 \text{ rad} \checkmark$ number of pixels across $\text{Pluto} = 0.0035/5 \times 10^{-6} = 700 \checkmark$ $\text{resolution} = 2700 \text{ km}/700$ $\text{pixels} = 3.9 \text{ km pixel}^{-1} \checkmark$ Sensible comment relating to value from 4 bi e.g. same order of magnitude, difficulty of establishing number of pixels across diameter in Fig. 4.1a✓	4	In calculation, discount use of data from image used in part 4 b i. More needed than 'this answer seems to fit' Examiner's Comments Part b(ii) proved much more challenging. In part this was due to an apparent lack of familiarity with radian measure, in part the difficulty lay in candidates using a circular argument through using data calculated from part (b)(i) rather than calculating the radian angle subtended by Pluto. It was also evident that many candidates were not confident in using radian measure, preferring to calculate the sine or tangent of the angle in degrees. It would be useful to give future candidates practice in the use of radians and give groups of questions where calculators have to be changed from degree to radian mode and vice versa as this was not the only question where problems handling radians cost candidates marks.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Total	7	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
76	a		$(4.5 \times 1/10) = 0.45 \checkmark$	1	ignore 4.1 Examiner's Comment In this part nearly all candidates could predict the next iteration for ΔQ (0.45 C) and the new value of Q (4.05 C).
			$(4.5 - 0.45) = 4.05 \checkmark$	1	
	b	i	$\Delta Q \approx I \Delta t = V \Delta t / R \checkmark$	1	accept algebra expressed in words / = or $\approx$ symbols not credit for any exponential type reasoning Examiner's Comment This part did not elicit the responses intended, few candidates could explain the physics behind the approximation that drives the model. Most discussed rather well, the analytical solution to the problem, i.e. exponential decay, but missed the point and the marks. A few candidates drew out that current $\approx \Delta Q / \Delta t$ depends on V / R (Ohm's Law) and that the p.d. V across the capacitor is given by $V = Q / C$ (definition of capacitance). Hence $\Delta Q / \Delta t \approx Q / RC$.
			and $V = Q / C (\Rightarrow \Delta Q \approx Q \Delta t / RC) \checkmark$	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	assumes current / voltage / charge (on capacitor) is constant during Δt (instead of continuously decaying) ✓ overcome by making Δt smaller / as small as possible (as needed for better approximation) not just make Δt small ✓	1 1	assumption not just rate is constant accept rate of charge flow is constant or rate of discharge is constant how overcome for 1 standalone mark if no answer to assumption Examiner's Comment The majority were back on track in (bii) stating an assumption behind the model's approximation, e.g. charge on capacitor remains constant during the time interval Δt ; and that the model can become more precise by taking smaller time intervals and repeating more iterations. In (bii) a few candidates did not attempt an answer either because they did not feel confident in carrying on from (bi), or perhaps because they had already made the marking points in (bi), where sadly they could not score, as they were not an answer to that part of the question.
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
77	a	i	F is proportional to mass.	1	Could be shown as $F=mg$ or calculations. NOT $F=ma$
			A set (at least 5) of suitable calculations eg: m/x or F/x for each row of table; or Δx for each pair of rows (which have equal $\Delta m = 100g$); Find one value for m/x (or F/x) and then use it to predict values for m for each value of x (or vice versa).	1	m/x will give 40.0, 39.2, 40.0, 40.4, 40.0, 40.0 Δx will give 2.6, 2.4, 2.4, 2.6, 2.5 F/x will give 0.392, 0.384, 0.392, 0.396, 0.392, 0.392 Ignore POT as long as they are consistent. Calculated values should be to at least 2sf.
			$\Delta m/\Delta x$ is constant approximately / within experimental error / uncertainty	1	If no (or insufficient) calculations then this mark can be awarded for describing a valid test to carry out.
		ii	$k = F/x = 0.6 \times 9.8 / 0.15 = 39 \text{ N m}^{-1}$	1	Accept use of data from any row of the table. 38 N m^{-1} if second row is used. Examiner's Comments In part (a) most candidates calculated and compared suitable ratios, but not all of them used sufficient data. Stronger candidates included reference to mass being proportional to force, although those who used $F=ma$ were penalised as the masses were not accelerating at 9.8 ms^{-2} , but experiencing a field strength of 9.8 N kg^{-1} . Usually candidates recognised that the ratios calculated were approximately equal, or referred to experimental uncertainty. There were a few power of ten errors in the calculation of the spring constant in part (ii).
	b	i	Two points marked V where curve crosses $d = 8 \text{ cm}$ within half a small square.	1	Any V in an incorrect position scores zero
		ii	$f (= 5.75/4) = 1.4(4) \text{ Hz}$ Use of $f = n/t$ with $n \geq 2$.	1 1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	Use of $f = 1/T$ and $T = 2\pi\sqrt{(m/k)}$ (to give $m = k / (4\pi^2 f^2)$) $m = 39 / (4 \pi^2 \times 1.43^2) = 4.8 \times 10^{-1} \text{ kg}$	1 1	Credit use of $m = kT^2/4\pi^2$ and $T = 0.7 \text{ s}$. Look for evidence of substitution / evaluation. Answers should be in range 4.7 to $4.9 \times 10^{-1} \text{ kg}$ Do not accept calculations involving amplitude of oscillation = 13 cm. Accept reverse argument. Examiner's Comments In part (b) nearly all candidates recognised where speed was at a maximum on the displacement-time trace. Also the majority of candidates were able to correctly calculate the time period and hence the frequency of oscillation. However many candidates only used the time for one complete cycle, rather than the whole trace. Part (b)(iii) was generally well done, although those candidates who had a power of ten error in their value for spring constant managed to fudge their answer to fit 500g. Some candidates did not realise that they should use the value of frequency calculated to find mass, but instead attempted (unsuccessfully) to use $mg = kx$ using the maximum displacement shown in the graph as extension.
			Total	9	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
78	a	i	Potential divider formula ✓ For example: $R_Y \div R_X = V_Y \div V_X$ or $R_Y \div (R_X + R_Y) = V_Y \div V_T$ $R_Y = (4 \times 3.4) \div 8 = 1.7 \Omega$ ✓ OR Current (through resistor) = $8 \div 3.4 = 2.4 \text{ A}$ ✓ $R_Y = 4 \div 2.4 = 1.7 \Omega$ ✓	2	Potential divider equation with numbers or symbols $R_Y \div 3.4 = 4 \div 8$ or $R_Y \div (3.4 + R_Y) = V_Y \div 12$. Accept reverse argument eg: calculate $V = 4.4 \text{ V}$ for $R = 2 \Omega$ <u>Examiner's Comments</u> Few candidates struggled with this straightforward calculation of resistance in a potential divider circuit. Most used the single step calculation using the ratio of potential difference being equal to the ratio of resistance, whilst a few performed a two-step calculation by first finding the current flowing through resistor X. The actual resistance of the bulb in this question is 1.7Ω

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Area = $\pi d^2 / 4 = 1.7 \times 10^{-9} \text{ m}^2 \checkmark$ EITHER Maximum and/or minimum method $\checkmark$ Maximum = $1.8 \times 10^{-9} \text{ m}^2$ and/or minimum = $1.5 \times 10^{-9} \text{ m}^2 \checkmark$ Absolute error in area = $[\frac{1}{2} (\text{max} - \text{min})$ OR $\text{max} - \text{actual}$ OR $\text{actual} - \text{min}] = 0.1$ or $0.2 \times 10^{-9} \text{ m}^2 \checkmark$ OR % error in diameter measurement = $2 \div 46 = 0.043$ or $4.3\% \checkmark$ % error in area = $2 \times \%$ error in $d = 8.6\%$ or 8.7% giving $0.1(4) \times 10^{-9} \text{ m}^2 \checkmark$	3	Use of $r = 0.046 \text{ mm}$ gives $A = 6.6 \times 10^{-9} \text{ m}^2$. Two marks for uncertainty are independent. ecf incorrect area used to calculate uncertainty. [$\pm 0.6 \times 10^{-9}$ for $A = 6.6 \times 10^{-9} \text{ m}^2$] Ignore sf in final answer but must be rounded correctly. <u>Examiner's Comments</u> Most candidates were able to correctly calculate the cross-sectional area of the wire. Common errors here included power of ten errors because the diameter was not converted from mm to m and of using the diameter as the radius. There were different methods used to find the uncertainty in the area. Many candidates found the percentage uncertainty in the diameter and then multiplied this by 2 to find the percentage uncertainty in area. Others found the maximum possible area and/or the minimum possible area and then worked out the absolute uncertainty. If candidates had an incorrect value for area it was still possible to gain the two marks available for finding the uncertainty. Common errors in finding uncertainty included squaring the percentage uncertainty in diameter, giving the absolute uncertainty in radius (rather than diameter) to be $\pm 0.002 \text{ mm}$ and doubling the absolute uncertainty in diameter instead of the percentage uncertainty.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	Use of [$G = \sigma A/L$ <u>and</u> $G = 1/R$ to give] $R = L/\sigma A$ or $\sigma = L/AR$ ✓ Substitution $\sigma [= 0.2/(1.7 \times 10^{-9} \times 1.7)] = 6.9 \times 10^7 \text{ Sm}^{-1}$ ✓ Assumption: ✓ that the filament provides the only resistance in the bulb the filament is of constant diameter that the filament is at normal (operating) temperature/temperature of filament not affecting resistance/resistivity/conductivity	3	ALLOW $\sigma = 5.9 \times 10^7$, $6(.0) \times 10^7$ or 7.1×10^7. ALLOW ecf of incorrect area calculated in part (ii). ONLY ALLOW ecf of incorrect R from part (i) if it rounds to 2Ω. <u>Examiner's Comments</u> Most candidates were able to calculate conductivity from the data given. Some chose to first find the conductance and then use the equation $\sigma = GL \div A$, whilst others combined equations and used the relationship $\sigma = L \div RA$ instead. There were some power of ten errors where candidates did not use length and area in consistent units, and a few candidates confused conductance and resistance, or resistivity and conductivity. The most common assumption given was that the area, diameter or radius was constant along the length of the wire. Few stated that there was no other resistance in the bulb and some commented on the conductivity or resistivity being unaffected by temperature change. Candidates who stated that there was no change in temperature missed the point in this question.

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
	b	Level 3 (5–6 marks) ✓✓ Clear calculation with reference to student's hypothesis to aid macroscopic explanation AND discussion of microscopic reasons for variation of resistance of a bulb with temperature and current. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) ✓✓ Some macroscopic AND microscopic explanation of variation of resistance with temperature AND current. Correct calculation of either a relevant potential difference or resistance is required as part of the macroscopic explanation. <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1–2 marks) ✓✓ Attempted calculation OR some macroscopic OR microscopic explanation of resistance (relating to temperature OR current). <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.	6	Indicative scientific points may include: Macroscopic explanation. • student's calculation of 6.0 V assumes that resistance of bulb is about 6.9 Ω; • voltage across resistor with $R = 1.7 \Omega$ is 9.6 V (or $R = 2 \Omega$ gives $V = 9.3 \text{ V}$) (accept correct across bulb of approx. 2.5V); • with a higher total resistance in the circuit the current will be less; • lower current means less power/energy dissipated as heat in filament; • filament will be at lower temperature; • higher conductivity / lower resistivity of filament in bulb; • bulb will have R less (than 1.7 Ω); • larger proportion of the p.d. will be across the resistor; • therefore the p.d. across resistor will be larger (than 9.6V). Microscopic explanation (does not to relate to this specific case) • Electrons flowing through lattice of metal atoms/ions; • Electrons collide with metal atoms/ions; • Electrons transfer (kinetic) energy to atoms/ions; • as current is less metal atoms/ions have less KE / vibrate less (ora); • less obstruction to moving electrons (ora); • Temperature of filament reduces due to less frequent collisions of electrons with metal atoms/ions (ora); • metal atoms/ions vibrate less (ora); • fewer collisions between electrons and metal atoms/ions in lattice (ora). Examiner's Comments There was some misinterpretation in this question as a few candidates thought that there were now 2 working bulbs in the series circuit with the larger 6.9Ω resistor.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			These candidates were still able to access all the marks in this LOR question. Most candidates supported their explanation with some simple calculations of potential difference, resistance or current to show that the candidate was incorrect. The potential difference across resistor X should be larger than the 8V in the first circuit, so there was no way it was going to be 6V. Some candidates showed some confusion in their explanations as they attempted to make their correct explanation of how temperature affects resistance in a filament bulb, by then unfortunately stating that this new lower current would cause the temperature in the bulb to increase. There were also a few candidates who described the mechanism for current flow in semiconductors instead of metal wires. In order to gain Level 3 candidates needed to give clear explanation of the mechanism for conductance in filament wires and to state that the candidate was wrong, and the potential difference across the resistor X is likely to be even larger than the 9V calculated using the bulb's resistance calculated in part (a)(i), due to the now lower current flowing through the filament. Exemplar 1 Using ideas about current, temperature and the structure of metals explain whether or not the student is correct. $I = \frac{V}{R}$ and $V_{out} = V_{in} \times \frac{R_x}{R_x + R_y}$ If we are to calculate the theoretical voltage across the resistor X, then $V_{out} = 12 \times \frac{6.9}{6.9 + 9.9} = 9.6V$ However, it is assuming there are no changes due to temperature rises. The current carried around the circuit is proportional to the speed of charge carriers. However, as more current travels through the filament wire the more it heats up by. This causes the metallic structure of the wire to vibrate more which obstructs the movement of charge carriers. This reduces the conductivity of a bulb, and as $G \propto \frac{1}{R}$, the resistance will rise. And as $V = IR$, the rise in R will cause a rise in the V and there will be a higher resistance ratio at the bulb and overall reduces the voltage across X. 12

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					This candidate starts by correctly calculating the potential difference across resistor X when $R_x = 6.9 \Omega$ and the bulb has a resistance of 1.7Ω. This is a correct macroscopic explanation. The candidate then goes on to explain that the resistance of a bulb varies with temperature because of the structure of a metal, and that resistance will be larger at higher temperatures. However, there is no mention of the fact that with a larger overall resistance in the circuit the current in the bulb would be lower and therefore the bulb would be at a lower temperature. This would lead to a reduction in resistance of the bulb, so the potential difference across the resistor would be even higher than the originally calculated 9.6 V.
			Total	14	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
79	a	i	Mean value = $[(0.247 + 0.248 + (4 \times 0.249) + (2 \times 0.250) + (3 \times 0.251) + (2 \times 0.252) + 0.253) \div 14 = 3.501 \div 14] = \underline{0.250} \text{ mm} \checkmark$ Spread = $\pm \frac{1}{2} \text{ range} \checkmark$ $[= \pm \frac{1}{2} (0.253 - 0.247) = 0.003]$ % uncertainty = $(0.003 \div 0.250) \times 100 = \underline{1(2)\%} \checkmark$	3	Mean must be to <u>3sf</u>. ecf incorrect mean used to calculate %uncertainty, but not ecf incorrect spread. Examiner's Comments Most candidates correctly calculated the mean value of D as 0.250 mm and the percentage error. A few left the value for D to only 2 significant figures and some candidates used the whole range of values (0.006) rather than the spread (0.003) to calculate the percentage uncertainty.
		ii	Area = $\pi d^2 \div 4 = \underline{4.9(1) \times 10^{-8} \text{ m}^2} \checkmark$ EITHER % error in area measurement (= $2 \times \%$ error in d) = $2.4\% \checkmark$ Absolute uncertainty = $[4.9(1) \times 10^{-8} \times 0.024 =] \underline{1(2) \times 10^{-9} \text{ m}^2} \checkmark$ OR Maximum = $5.03 \times 10^{-8} \text{ m}^2$ and/or minimum = $4.79 \times 10^{-8} \text{ m}^2 \checkmark$ Absolute error in area = $[\frac{1}{2} (\text{max} - \text{min})$ OR max – actual OR actual – min] $= \underline{\pm 0.1(2) \times 10^{-8} \text{ m}^2} \checkmark$	3	Use of $r = 0.250 \text{ mm}$ gives $A = 1.96 \times 10^{-7} \text{ m}^2$. ALLOW % uncertainty is twice % uncertainty in diameter calculated in (a)(i). ALLOW ecf for uncertainty on incorrect calculation of A. [$\pm 4.8 \times 10^{-9}$ for $A = 1.96 \times 10^{-7} \text{ m}^2$] Examiner's Comments Most candidates were able to correctly calculate the area from the diameter, but there were a number who either forgot to convert to metres, or used the value for diameter as the radius. Similarly to question 1(a)(ii) a number of methods were used to find the absolute uncertainty and similar mistakes occurred.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b	i	x-error bars at ± 0.5 ✓ y-error bars at ± 0.2 ✓ Elastic region labelled at the straight section of the graph ($F \leq 7$ N by eye) AND Plastic region labelled at the curved section of the graph ($F \geq 7$ N by eye) ✓ <u>Straight</u> LoBF drawn with a fair spread of their points above and below the line by eye, extending as least as far as 6 N. ✓	4	At least 6 correct to $\frac{1}{2}$ small square in total line length. At least 6 correct to $\frac{1}{2}$ small square in total line length Both correct for a mark. Can be labelled anywhere on the graph. LoBF should not use top 3 plots. Ignore any line drawn at $F > 7$ N Line drawn should not cross the x axis and there should be similar number of points either side of line. <u>Examiner's Comments</u> Nearly all the candidates correctly identified the elastic and plastic deformations regions of the graph, and many correctly added error bars in both x and y directions. There were more mistakes in the horizontal error bars than vertical bars. Many candidates incorrectly and unnecessarily forced the line of best fit through the origin and ended up with too many plots to the left of the line. In practice it would be rare for the graph obtained from this experiment in a school laboratory would pass through the origin as it is difficult to eliminate all the kinks in the wire before loading.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Calculate gradient using two points on their line which are at least half the length of their line apart. ✓ Use of Young Modulus = F/Ax or stress/strain [= gradient $\times (l/A)$] ✓ Calculate value of Young Modulus using value of A from (a)(ii) and $l = 4.00$ m and <u>gradient</u>. ✓ Correct units (Pa or $N\ m^{-2}$). ✓ Answer has correct POT for their units. ✓	5	Look for $\Delta F \geq 5.0$ if full height line drawn. If a single data point is used to find gradient check drawn line goes through both origin and data point and F is greater than half height of line. Gradient should be in range 1.3×10^3 to 1.7×10^3. Ignore POT in gradient calc. ALLOW ecf from incorrect lbf. If E calculated from data point values or stress over strain; max 3 marks (not first or third marking point). Expect $1 \times 10^{11} \geq E \geq 1.4 \times 10^{11}$ Pa. ALLOW ecf of incorrect A in part (a)(ii). [If $A = 1.96 \times 10^{-7} m^2$ then E will be a quarter the value above – approx 3×10^{10} Pa.] <u>Examiner's Comments</u> In order to gain full marks in the question candidates need to use the gradient of the line rather than a single data point. Most candidates gave the correct unit and used the correct relationship to find Young Modulus. A few candidates mis-read the data from the graph or used two points on the line which were too close together.

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
	c	Level 3 (5–6 marks) ✓✓ - Combines their %uncertainties correctly to find overall %uncertainty in E. - Identifies (with reason) that extension provides the greatest source of uncertainty - Justifies improvement for any two sources of uncertainty. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) ✓✓ Minimum 2 of: - Calculation of reasonable %uncertainty in variable(s) (not area) or E. - Comparison of two or more %uncertainties or complete set of uncertainties listed (A, l, F and x OR A, l and gradient). - Identifies reasons for at least two sources of uncertainty. - Suggest improvements to mitigate at least two sources of uncertainty. <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1–2 marks) ✓✓ Minimum 2 of: - Identifies reason for source of uncertainty; - Suggests improvement for at least one source of uncertainty - Attempts to calculate % uncertainty for at least one variable other than area.	6	Indicative scientific points may include: Determining the uncertainty in E: 'worst fit' line drawn using error bars. - Gradient of worst fit line calculated correctly. % uncertainty in gradient worked out. - Addition of % uncertainties in gradient, area and length for overall % uncertainty in E. - Max value for E calculated using max gradient, max length and min area AND/OR min value for E from min gradient, min length and max area. % uncertainty in E worked out. - Expect % uncertainties as follows: E in region of 30% - Gradient in region of 20 to 25% - Area 2.4% (ecf from (a)(ii)) - Length 0.5% - Force up to 20% (depending on value) - Extension up to 100% (depending on value) - Use data point value to estimate % uncertainty in F (using smallest value of F to give largest uncertainty) - Use data point value to estimate % uncertainty in F (using smallest value of x to give largest uncertainty). - Finding max and min values of E from equation $E = F l \div A x$ and appropriate substitution. Identifying sources of uncertainty and improvements: - Uncertainties in load: - variation in 100g masses - weigh masses individually on scales/balance - Uncertainty in area/diameter. - variation in thickness of wire - not cylindrical/ not circular cross section. - uncertainty in diameter give larger uncertainty in area as it is squared. - Diameter measured in different

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			<i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.		<u>planes/directions</u> (NOT different places along wire). ◦ Use of thicker wire will reduce % uncertainty in diameter • Uncertainty in length ◦ kinked wire ◦ not initially straight/taut ◦ use fresh wire ◦ pre-load wire (to remove kinks) • Uncertainty in extension ◦ small measurement so large % uncertainty ◦ Explanation of zero errors ◦ Extension provides the largest source of error. ◦ longer wire so larger extensions ◦ use of travelling microscope/Vernier scale. • if thicker wire used then extension will be smaller so % uncertainty increases in extension. • Measure extension loading and unloading (for elastic deformation only). Examiner's Comments Several approaches to finding the percentage uncertainty in the value for Young Modulus were used, but a number were not well set out and identified. Many candidates added the individual percentage uncertainty in the four variables – force, area, extension and length, whilst others found the gradient of a steep and/or shallow worst fit line, and then used that to find a maximum and/or minimum value for E. Whilst many candidates did realise that the variable with by far the greatest uncertainty was the extension, not all of them were able to describe appropriate mitigation in sufficient detail to gain Level 3. Many candidates' explanations made vague suggestions about using more precise measuring instruments without naming suitable ones. Candidates need to realise that rulers with smaller divisions would be unusable, and that using larger

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					forces would result in plastic deformation, so this type of suggestions were not credited. The most obvious solution of increasing the length of the wire causes practical problems to do with space in the laboratory, which needed to be mentioned to gain higher level marks. Other valid suggested improvements included increasing the area of the wire, but again candidates needed to mention that this would actually cause less extension so probably not worth doing in practice. Weighing any masses used with digital balance or using a digital Newton-meter were acceptable suggestions. Some candidates suggested using a different material wire, but this would defeat the object if they needed to find the properties of a particular material. As it was clear from part (a), that a micrometer screw gauge was used to find several readings of the diameter of the wire, this was not credited in this question. If further details such as measuring diameter in different planes or directions to check that the wire was cylindrical, then credit could be given. Suggesting repeat readings also needed clear description to gain credit here. Candidates could suggest recording values of extension whilst loading and unloading the wire, or repeat the whole experiment on a new piece of the same wire and finding an average value for E, but not repeating readings of extension and finding the average as each wire will behave in a slightly different manner.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			Exemplar 5 improve on this, be used. This is ~~percentage~~ uncertainty was overall uncertainty the force, weigh adding onto the would decrease on the digital balance. To improve ext can be measured and a vernier to ± 0.01 mm, technique. Along ~~a~~ thinner wire extension - this is from x, but not. To reduce the x could be calculated mass - density, we have smaller force highest uncertainty length ($x \pm$ This candidate has used the graph to find a lowest possible gradient and thence to a percentage uncertainty for the gradient. This is then combined with the percentage uncertainties of the length and the area. The list of uncertainties at the end of the text clearly identifies extension as having the largest uncertainty. In order to mitigate the uncertainties several suggestions are made; using a longer length of wire, weighing the individual masses on a digital balance and using a thinner wire. The latter suggestion is analysed in terms of increasing the uncertainty of the area, but as this is lower than the uncertainty in the extension it is still beneficial. This gains Level 3.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			Exemplar 6  $\% \text{ uncertainty (x)} = \frac{1}{x} \text{ worst gradient} = 0.2/5.0 = 4\%$ $\therefore \% \text{ uncertainty in force} = 2\%$ $\% \text{ uncertainty in area} = 2\%$ $\% \text{ uncertainty in A} = 2\%$ The largest uncertainty comes from the gradient which is made from the extension and the force so these are the areas that we aim to improve. For the extension, we can improve reduce the uncertainty by either using a more precise measuring device like a digital vernier calliper or by increasing the values for x for a certain force and so reduce the $\% \text{ uncertainty}$. In relation to the force, we can increase the $\% \text{ uncertainty}$ by using a more precise digital top pan balance. The worst $\% \text{ uncertainty in the extension is } 0.2/5.0 \times 100 = 4\%$ in comparison to that of the force: $0.2/5.0 \times 100 = 4\%$. The main source of uncertainty that is needed to be improved upon is the extension. This response is Level 3. The percentage uncertainty in the gradient is calculated from an acceptable line of worst fit drawn on the graph in Fig 4.2. The percentage uncertainty for length is correctly determined, but the candidate has used the percentage uncertainty in diameter instead of the percentage uncertainty in area. Nevertheless, all the percentage uncertainties are correctly combined and

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					the largest ones clearly identified. Appropriate suggestions for mitigating the uncertainty in both extension and force are explained.
			Total	21	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
80	a		Transmitted intensity falls to minimum (after second filter is turned through 90°) and then rises to maximum at 180°/after half a rotation/when planes of polarisation are parallel ✓ AW Filters only transmit light oscillating in one plane/plane of polarisation of filter 2 must match that of filter 1 AW ✓	2	For m.p. 2 candidate must be clear that filters only pass light in one plane (of oscillation) Examiner's Comments Nearly all responses showed a familiarity with the set up described in the question and gained the first mark for correctly describing the variation in intensity of transmitted light. The second marking point was more discriminating. Lower level responses did not clearly explain that the filters pass light in one plane of polarisation and so missed out on the second mark. Exemplar 1 Intensity will fluctuate between 0 and its max intensity value with a sin wave graph shape when plotted against time. The period would be the time for the second filter to rotate through an entire 360° rotation. When filter 2 is at 90° filter 1, no light gets through as 0 intensity as both horizontal and vertical components are stopped.  This explanation did not clearly explain the action of the filters, the candidate does not explain why 'horizontal and vertical components are stopped'.
	b	i	p.d. across LDR minimum at 0° and 180°/when planes of polarisation are parallel ✓ p.d. across LDR maximum at 90° and 270°/when planes of polarisation are crossed ✓		Or 180° and 360°

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
	Resistance of LDR falls as light intensity rises ✓ Low(er) proportion of total resistance when light intensity high(er) ✓	4	ORA. Look for clear link between light level and resistance ORA Fourth marking point can be given for correct and clear use of potential divider equation Examiner's Comments This question proved challenging for some. A good answer linked the correct variation of resistance with intensity and the effect of this on the potential difference across the LDR in series with a fixed resistor. Lower ability candidates did not describe the variation of p.d. for a complete rotation, even though the question specified this. Many responses incorrectly suggested that the resistance of an LDR increases with light intensity. Although most responses made the link between maximum resistance and maximum p.d., only the best responses explained this using understanding of potential dividers. Exemplar 2 filters which produce maximum and minimum p.d.s. As the light intensity increases, the resistance decreases and as a result the voltage over the LDR would also decrease as it would have a smaller resistance in proportion to the total resistance. Therefore the maximum p.d. across the LDR would be produced when the light intensity is at a minimum (90°/270°) as at this point the resistance would be greatest and the minimum p.d. when the light intensity is at a maximum (0°/360°). This response gives a clear description of the variation in potential difference, links resistance to light intensity and links potential difference across the LDR to the proportion it contributes to the total resistance the circuit.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	$\frac{3.01}{6.00} = \frac{R}{403}$ Calculation to $R_{\text{LDR}} = 4.03 \times 10^5 \Omega / 403 \text{ k}\Omega$ ✓	2	Correct bald answer merits both marks. Must use max p.d. value Unrounded $R_{\text{LDR}} = 402.6755853 \dots \text{k}\Omega$ <u>Examiner's Comments</u> Most candidates recognised this as a potential divider calculation. Those candidates who realised that the greatest p.d. is 3.01 V and that there is no uncertainty in the p.d. of the cell gained both marks. The most common error was to take the maximum p.d. as 3.00 V.
			Total	8	

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Question			Answer/Indicative content	Marks	Guidance
81	a		Conductance $G = 1/R = 1/0.13 \Omega \checkmark$ (= 7.69 S) conductivity = $7.69 \text{ S} \times 1.5 \text{ m}/(\pi \times (2.5 \times 10^{-4} \text{ m})^2) \checkmark$ $= 5.9 \times 10^7 \text{ S m}^{-1}$ (2 s.f.) $\checkmark$	3	Correct bald answer gains all 3 marks allow calculation of resistivity followed by $\sigma = 1/\rho$ for three marks. If resistivity (= $1.7 \times 10^{-8} \Omega \text{ m}$) given on answer line, one mark only. Examiner's Comments This standard calculation was accurately performed by most candidates.
	b		$v = I/nae$ $= 2.3 \text{ A}/(8.5 \times 10^{28} \text{ m}^{-3} \times \pi \times (2.5 \times 10^{-4} \text{ m})^2 \times 1.6 \times 10^{-19} \text{ C}) \checkmark$ $= 8.6 \times 10^{-4} \text{ m s}^{-1} \checkmark$	2	m.p.1. is for correct rearrangements and substitution m.p.2 is correct evaluation. Correct bald answer gets both marks. Examiner's Comments This standard calculation was accurately performed by most candidates. Less able candidates incorrectly rearrange the equation given in the stem of the question.
	c		Level 3 (5–6 marks) Marshals argument in a clear manner. All technical vocabulary is used with accuracy and clarity. Explains basic model of conduction in both metals and semiconductors and clearly explains how this results in different variations of conductivity. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Describes the two different mechanisms of conduction but the description lacks detail and precision. Technical vocabulary used correctly but not always with complete clarity. <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i>	6	Indicative scientific points may include: Semiconductors • Far fewer 'free' electrons m^{-3} than in conductors • Increased temperature increases energy of atoms in the semiconductor • Increased temperature reduces fraction E/kT • Definition/explanation of Boltzmann factor in relation to this context • smaller fraction E/kT increases magnitude of $e^{-E/kT}$ • Linking higher Boltzmann factor to increased number density of charge carriers Conductors: • Conductivity decreases with increasing temperature • Cloud of free electrons AW

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Question			Answer/Indicative content	Marks	Guidance
			Level 1 (1–2 marks) Attempts description of at least one type of behaviour and makes relevant points but the answer is limited and superficial. <i>There is an attempt at a logical structure with a line of reasoning.</i> <i>The information is in the most part relevant</i> 0 marks No response or no response worthy of credit.		• Interact with positive ions in lattice • Electrons accelerate between interactions with lattice due to electric field • Increase temperature increases lattice vibration • Reduces mean free path (AW) of free electrons • Increase in drift velocity lower than increase field strength would suggest Examiner's Comments This is the second Level of Response question on the paper. Candidates were required to explain the effect of increasing temperature on the conductivity of semiconductors and metals. A description of the microscopic structure of the materials was also required. Candidates could make use of the information in the stem of part (b) to help in this question. The best responses clearly separated the conduction process in metals (free electrons travelling through the lattice of positive ions) from that in semiconductors (far fewer free electrons) and then described the effect of increasing temperature, bringing in the relationship given in the stem. A significant proportion of responses considered the activation process as the most important factor in the conductivity of both semiconductors and metals. Other responses did not state which material was being discussed. The best responses showed a greater knowledge of semiconductors than is required by the specification as well as a firm grasp of the mechanism of metallic conduction.

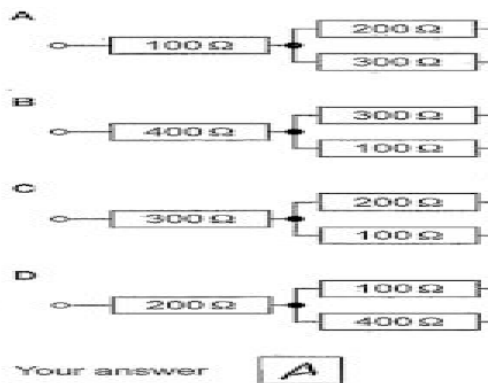
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					Exemplar 10 <u>Semiconductors:</u> • $e^{-\frac{E}{kT}}$ is the Boltzmann factor - it gives the fraction of particles with the extra energy E compared to those without. As temperature increases, $\frac{E}{kT}$ decreases and so $e^{-\frac{E}{kT}}$ increases - this means more electrons have the energy required to be liberated. • In semiconductors, charge is carried by liberated electrons. The more electrons there are, the more charge carriers there are, and so the higher the conductivity. This shows that as temperature increases in a semi-conductor, its conductivity increases. The Boltzmann factor shows that as temperature increases further, the conductivity increases. This is because all atoms become ionised. <u>Metals</u> • As the temperature of a metal increases, its atoms gain more kinetic energy, causing them to vibrate more. This reduces the drift velocity, v, as electrons' path is obstructed more and their movements are more random. As $I = nAev$, a decrease in v causes a decrease in current, which leads to a decrease in conductance. As $G = \frac{IA}{V}$, and V and A are constant, a decrease in conductance means a decrease in conductivity has occurred. This response gained 6 marks. Note that it is not perfect and could be bettered but it answered the question posed to a level meriting the highest grade. Labelling sections of the answer 'semiconductors' and 'metals' immediately shows clarity. The discussion of conduction in semiconductors makes a clear connection to the equation given in the stem and shows a good application of the Boltzmann factor. The discussion of conduction in metals is secure although it does not consider the average distance travelled by electrons between collisions. Taken as a whole this represents a good response to an open-ended question and combines analysis, knowledge and understanding.
			Total	11	

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Question			Answer/Indicative content	Marks	Guidance
82			D	1	
			Total	1	
83			D	1	
			Total	1	
84			C	1	
			Total	1	
85			B	1	<u>Examiner's Comments</u> A common feature of responses from less able candidates was to make “power of ten” errors in the calculation and select response D (0.034m) rather than the correct answer B (0.0034m)
			Total	1	
86			A	1	<u>Examiner's Comments</u> This question was based on the ratio of electrical powers in two circuits – one parallel, one series – containing identical resistors. A common incorrect response was to give the inverse of the correct ratio.
			Total	1	

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Question			Answer/Indicative content	Marks	Guidance
87			A	1	<u>Examiner's Comments</u> Exemplar 1  Whilst working is not required or credited, successful candidates, as in this exemplar, often showed their working against each of the networks.
			Total	1	
88			A	1	<u>Examiner's Comments</u> Higher ability candidates realised that they had to apply an energy equation to a mass on a spring problem, kinetic energy gained = potential energy lost ($\frac{1}{2} m v^2 = \frac{1}{2} k x^2$) to find the maximum velocity reached.
			Total	1	
89			D	1	
			Total	1	

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Question			Answer/Indicative content	Marks	Guidance
90			A	1	<u>Examiner's Comments</u> This pair of questions concerned a capacitor charging from a supply through a fixed resistance. Candidates were offered a variety of currents and voltage distributions and had to select the correct combinations for when the switch was just closed (Qu 13) and after 3 seconds when they could deduce the capacitor would be fully charged due to a low RC value $\ll$ 3 seconds (Qu14). Most candidates selected the correct response (D) for Qu 13 fewer than half of candidates identifying A as the correct response for Qu14 where many thought the capacitor would be half charged rather than fully charged after the 3 seconds.
			Total	1	
91			C	1	
			Total	1	
92			B	1	<u>Examiner's Comments</u> A majority of candidates were able to read the thermistor resistance from the graph and apply it within a potential divider equation to find the resistance of the fixed resistor at a given temperature.
			Total	1	

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Question			Answer/Indicative content	Marks	Guidance
93	a		(power = $1/f$) = $1/v - 1/u$ ✓	L	rearrangement accept real is + sign convention i.e. all signs positive
			= $1/1.5 - 1/-0.03$ ✓	M	substitution with correct sign / all + ve signs
			= 34 (D) ✓	M	evaluation not -32.7 (D) / 32.7 (D) / -34 (D)
	b		($M = v/u = 1.5 / 0.03$) = 50 ✓	L	accept - 50 <u>Examiner's Comments</u> Exemplar 3 $\frac{1}{v} = \frac{1}{u} + \frac{1}{f}$ $\frac{1}{1.5} - \frac{1}{-0.03} = \frac{1}{f} \Rightarrow f = 34$ power of the lens = ... 34 D Successful candidates could calculate the power of the projector lens in part (a) for the digital clock as 34 D. The course encourages the use of Cartesian sign convention, as per exemplar 3, but methods assuming the “real is positive” sign convention were given full credit. Most candidates then were successful in correctly calculating the magnification as x50 for part (b).
Total				4	

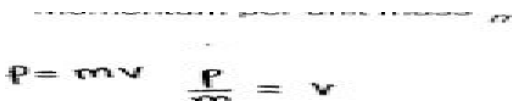
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
94	a		time = file size / rate OR = $1.2 \times 10^9 \times 8 / 24 \times 10^6$ ✓	L	method in words / numbers accept 8 bits per byte missed accept calculation in bytes and bytes/s
			= 400 s > 360 s OR 400 s > 6 min OR 6.7 min OR 6 min 40 s ✓	L	evaluation must compare answers in secs to 6 minutes accept 6.6 s with / without recurring sign accept 6.8 s from using computer k = 1024 <u>Examiner's Comments</u> Exemplar 4 $\frac{1.2 \times 10^9 \times 8}{24 \times 10^6} = 400$ $\frac{400}{60} = 6.67 \text{ minutes}$ Successful candidates, as in exemplar 4, calculated the download time as 6.7 minutes for full credit.
	b		8 (kHz) ✓	M	accept labelled diagrams showing waveform being sampled twice per wave / to avoid aliasing
			because there must be at least 2 samples per cycle (to pick up any variation) ✓	M	not because of Nyquist theorem / sampling f must be twice highest signal f / due to information loss <u>Examiner's Comments</u> Successful candidates correctly calculated that the highest frequency of sound recorded was 8 kHz (half the sampling frequency) but less able candidates could not give an explanation that identified the need for two samples per cycle to pick up the variation, or the need to avoid aliasing. Some candidates stated or referred to the Nyquist theorem but this was not considered worthy of credit.
			Total	4	

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Question			Answer/Indicative content	Marks	Guidance
95	a		$I = \sum \varepsilon / \sum R = \{12 - 9.0\} / \{17.7\}$ ✓	L	allow first mark for recognition that 3 V drives the current OR for total resistance = 17.7 Ω
			= 0.17 (A) OR 0.169 (A) ✓	M	
	b		$t = Q / I = 0.50 \times 3600 / 0.12$ ✓	L	beware $500 \times 10^{-3} / 0.12 = 4.17$ is nonsense (ratio of two currents) so 0/2 marks accept 4.17 (hours) from correct method <u>Examiner's Comments</u> Exemplar 5 (a) Show that the initial current ch  (b) When fully charged, the reed current of 500 mA for an hour Estimate the time needed to n $Q = It$ $Q = 500 \times 10^{-3} \times t$ $= 1800 C$ This question on the application of Kirchhoff's law was challenging. Although only a one loop circuit, the opposition of the charging solar cell and the rechargeable battery caused confusion; the most able candidates, as in exemplar 5, could show that the circuit current (0.17 A) was less than 0.2 A in part (a). Less able candidates were given credit for finding the sum of e.m.f.s around the circuit, the sum of the I R products or the total circuit resistance. In part (b) this candidate has successfully gone on to use $Q = I t$ to find the time to recharge the battery as 4.2 hours.
			= 1.5×10^4 s = 4.2 (hours) ✓	L	
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
96		i	k.e. gained = e.p.e. lost OR $\frac{1}{2} m v^2 = Q V$ ✓	L	energy conservation in words / algebra
			$\{mv\}^2 = 2 m Q V \rightarrow mv / m = \sqrt{2 VQ / m}$ OR $mv / m = \sqrt{2 m V Q / m^2} \rightarrow v = \sqrt{2 VQ / m}$ ✓	H	allow momentum per unit mass = velocity and subsequent derivation of v <u>Examiner's Comments</u> Exemplar 8  This part required algebraic reasoning and was often omitted by less able candidates. Those that were successful, as in exemplar 8, started from the equation for accelerated ions $QV = \frac{1}{2} m v^2$ and manipulated it to show that the momentum transfer per unit mass in the ion drive $p / m = \sqrt{2 VQ / m}$. Alternatively, some candidates realised that momentum per unit mass is in fact velocity for the ions and went on to derive v for full credit.
		ii	H^+ has highest Q / m ✓	S&C	ignore Xe^+ is safer / energy to lift mass of H from Earth
			so best momentum transfer / larger p/m ✓	S&C	expect momentum comment <u>Examiner's Comments</u> Candidates were asked to compare the effectiveness of using $^1H^+$ and $^{130}Xe^+$ ions in the ion drive. Many gave trivial answers about availability and scored zero, but more able candidates gained full credit for arguing that $^1H^+$ has the largest charge mass ratio (Q / m) and hence the largest momentum transfer per unit mass.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	$T = \Delta p / \Delta t = \Delta p / \Delta m \times \Delta m / \Delta t$ OR $\Delta m / \Delta t = T / \{\Delta p / \Delta m\} = 0.24 / \sqrt{2 \times 2000 \times 9.6 \times 10^7}$ ✓ $= 3.87 \times 10^{-7} \text{ kg s}^{-1} (< 4 \times 10^{-7} \text{ kg s}^{-1})$ ✓	S&C S&C	No credit for only working out velocity of ions Examiner's Comments Successful candidates were able to recognise that thrust, $T = \Delta p / \Delta t$ and therefore $T = \Delta p / \Delta m \times \Delta m / \Delta t$. They could then re-arrange this and use the equation $p / m = \sqrt{2 V Q / m}$ given in part (i) to show that mass transfer rate was the thrust divided by momentum per unit mass, and hence that a 2000 V accelerator uses propellant at less than $4 \times 10^{-7} \text{ kg s}^{-1}$ to produce 0.24 N thrust.
			Total	6	
97			best fit straight line drawn to intercept the current axis ✓ giving intercept from graph current = 9.7 A ✓ $R_{\text{ARMATURE}} = 12.0 / 9.7 = 1.2(4) (\Omega)$ ✓	L M M	must be sensible l.o.b.f. expect line to miss some uncertainty bars (intercept may be off top of the y-axis) expect in range 9.5 to 9.9 A but allow ecf from their graph FT allow ecf 12 / current value correctly evaluated accept in range 1.2 to 1.3 (Ω) Examiner's Comments Candidates were given data for a motor showing an inverse relationship between the current to the rotor coil and the frequency of rotation. They were asked to draw a straight line of best fit to the data and to extrapolate the current in the coil when the motor has stopped rotating (stalled) under mechanical load ($9.7 \pm 0.3 \text{ A}$). Successful candidates could then go on to use this current to predict the electrical resistance of the rotor coil by evaluating $12 \text{ V} / 9.7 \text{ A}$ to give 1.2Ω.
			Total	3	

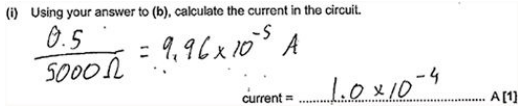
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
98	a		$\text{p.d} = 6.1 \text{ V} \times (4.7 \text{ k}\Omega / 6.9 \text{ k}\Omega) = 4.155 \text{ V} \text{ (} \sim 4.2 \text{ V)}$	1	Must have own value, e.g. 4.16V Penalise rounding error) <u>Examiner's Comments</u> Question 2 is quite challenging for less confident candidates. However, part (a), a standard potential divider question was answered accurately by the majority of the cohort.

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
	b	total resistance of 4.7 kΩ resistor and voltmeter R_T: $3.2 \text{ V} = 6.1 \text{ V} \times (R_T / (R_T + 2.2 \text{ k}\Omega)) \checkmark \Rightarrow R_T = 2.4 \text{ k}\Omega \checkmark$ $2.4^{-1} = 4.7^{-1} + R_{\text{voltmeter}}^{-1}$ $R_{\text{voltmeter}} = 4.9 \text{ k}\Omega \checkmark$	3	Or via: $2.9 \text{ V} = 6.1 \text{ V} (2.2 \text{ k}\Omega / (R_T + 2.2 \text{ k}\Omega))$ Or via: $I = 2.9 \text{ V} / 2.2 \text{ k}\Omega = 1.32 \text{ mA}$ & $R_T = 3.2 \text{ V} / 1.32 \text{ mA} = 2.4 \text{ k}\Omega$ Reverse method ok If $R_v = 5 \text{ k}\Omega$ total parallel resistance = $2.42 \text{ k}\Omega \checkmark$ $V_v = 6.1 \times \frac{(2.42 \times 10^3)}{2.42 \times 10^3 + 2.2 \times 10^3} \checkmark$ $= 3.197 \text{ V} \checkmark (3.2)$ Using different number of sig figs for R_T gives answers in the range 4.9-5.03 kΩ Examiner's Comments Part (b) was one of the most discriminating questions on the paper. Unusually for a 'show that' question, having the value to aim for did not help the candidates. Answering correctly required recognising that the voltmeter and 4.7 kΩ resistor act as a parallel combination of resistors in series with the 2.2 kΩ resistor. This was clearly a novel situation for some candidates who could not reach the first step of finding the total resistance of the parallel combination. This will be a useful question to use in class. Interestingly, very few candidates attempted the reverse method given in the mark scheme. This may have been an easier route for some but it is good to see that the majority of the cohort try to work towards the expected value rather than use the expected value and work backwards.  Not recognising the voltmeter as a resistor Students may have assumed that all meters are perfect, voltmeters with infinite resistance and ammeters with zero resistance. This question requires that they understand the meter making the measurement will have an impact on the circuit.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c	i	From $\varepsilon = V + Ir$	3	Accept: <u>Examiner's Comments</u> In contrast to part (b) this was a very straightforward task and the majority of candidates gained the mark.
		ii	$I = 0.5/4.9 \times 10^{-3} = 1.0 \times 10^{-4} \text{ A} \checkmark$ $= 0.93 \text{ V} + (0.93 \text{ V}/1 \times 10^6 \Omega)r = 0.5 \text{ V} + (0.5 \text{ V}/4.9 \times 10^3 \Omega)r \checkmark$ $0.93 \text{ V} + (9.3 \times 10^{-7} \text{ A}) \times r = 0.5 \text{ V} + (1.0 \times 10^{-4} \text{ A}) \times r \checkmark$ $r = (0.93 \text{ V} - 0.5 \text{ V})/(1.0 \times 10^{-4} \text{ A} - 9.3 \times 10^{-7} \text{ A}) = 4.3 \text{ k} \Omega \checkmark$	1	Same answer using 5 kΩ Ecf from (b) Assuming $\varepsilon = 0.93 \text{ V} \checkmark$ (explicit) $0.50 \text{ V} = 0.93 \text{ V} - 1 \times 10^{-4} \text{ A} \times r \checkmark$ $r = 4.3 \text{ k} \Omega \checkmark$ Correct bald answer gains two marks Expect values around 4300Ω – sensitive to sfs in values <u>Examiner's Comments</u> Another challenging calculation. The best responses laid out the simultaneous equations clearly and worked through to the correct value. This was very encouraging. Candidates scoring two out of the possible three marks tended to assume that the emf of the potato cell is 0.93 V but did not clearly state their assumption. Exemplar 2 (i) Using your answer to (b), calculate the current in the circuit.  This exemplar has been included to show a clear and unambiguous response. The examiners did not see many with the reasoning laid out so clearly.
			Total	8	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
99		i	$E_k = eV = 1.60 \times 10^{-19} \text{ C} \times 4.3 \times 10^3 \text{ V} (= 6.88 \times 10^{-16} \text{ J}) \checkmark$ $v = \sqrt{2 E_k / m}$ $= \sqrt{(2 \times 6.88 \times 10^{-16} \text{ J} / 9.11 \times 10^{-31} \text{ kg})} = 3.9 \times 10^7 \text{ m s}^{-1} \checkmark$	2	Correct bald answer gains both marks Examiner's Comments This standard calculation was accessible to most candidates. The main source of error was in rearranging the kinetic energy equation. Some candidates gave velocity values far greater than c – perhaps showing a lack of thought about what their calculators showed them.
		ii	rest mass of electron = 512 keV / $8.20 \times 10^{-14} \text{ J} \checkmark$ Gamma factor = $(4.3 \text{ keV} + 512 \text{ keV}) / 512 \text{ keV} = 1.008(4) \checkmark$ Not much bigger than 1, therefore reasonable to ignore. $\checkmark$	3	Accept calculation of gamma from $\frac{1}{\sqrt{1 - \frac{(3.9 \times 10^7)^2}{(3 \times 10^8)^2}}} \checkmark (= 1.0086) = 1.009 \checkmark$ Allow ecf of speed from (a)i If simply stated that relativistic effects can be ignored because velocity is about 0.1 c, one mark. Examiner's Comments Another accessible, familiar calculation. Some candidates did not perform a calculation but gained a mark for stating that the velocity of the electron is about 0.1 c and linking this to the statement that it is reasonable to ignore relativistic effects at this speed. The majority of correct answers were based on calculating the gamma factor through the Lorentz equation rather than using the rest energy and k.e. of the particle.
		iii	$\lambda = 6.63 \times 10^{-34} \text{ J s} / (9.11 \times 10^{-31} \text{ kg} \times 3.9 \times 10^7 \text{ m s}^{-1})$ $= 1.87 \times 10^{-11} \text{ m} \checkmark$	1	Allow ecf from a)i Examiner's Comments A third standard calculation which only caused difficulties to the weakest candidates.
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
100			$\text{resolution} = 70 \text{ km} / (832 \text{ pixels} \times 5/7) \checkmark$ $= 0.12 \checkmark$	2	range 0.10 to 0.13 km pixel⁻¹ <u>Examiner's Comments</u> This is a straightforward question based on work covered early in the course. A large majority of the candidates gained both marks.
			Total	2	