Oxford Cambridge and RSA

Wednesday 17 May 2023 – Morning

AS Level Physics A

H156/01 Breadth in physics

Time allowed: 1 hour 30 minutes

You must have:
- the Data, Formulae and Relationships Booklet

You can use:
- a scientific or graphical calculator
- a ruler (cm/mm)

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name StemUp Model Solution

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION
- The total mark for this paper is **70**.
- The marks for each question are shown in brackets **[ ]**.
- This document has **24** pages.

ADVICE
- Read each question carefully before you start your answer.

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Section A

You should spend a maximum of **25 minutes** on this section.

Write your answer to each question in the box provided.

1 What is a typical value, in cm, for the wavelength of microwave radiation?

A 0.0003

B 0.03

C 3

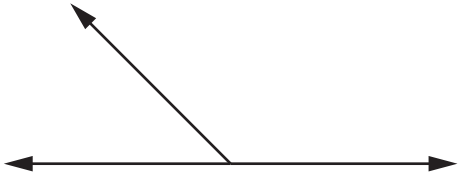
D 300

Your answer C **[1]**

2 The diagrams show four systems of forces with three forces acting at a single point. The forces are in the same plane. The diagrams are drawn to scale.

Which system could be in equilibrium?

A



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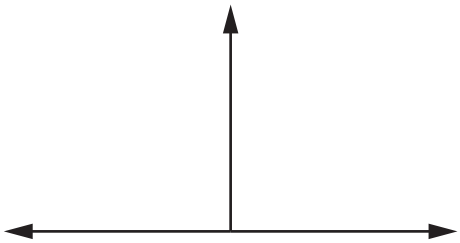

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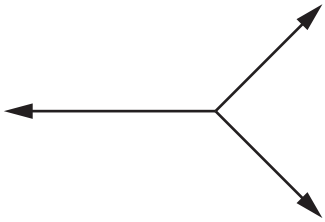

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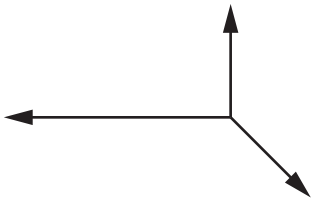

Your answer C **[1]**

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3 An electron beam is passed through a thin slice of graphite and a diffraction pattern is produced.

The approximate spacing between the carbon atoms in the graphite is d.
The approximate de Brogie wavelength of an electron in the beam is λ.

Which statement is correct?

A $\lambda \approx d$

B $\lambda \approx \frac{1}{d}$

C $\lambda \gg d$

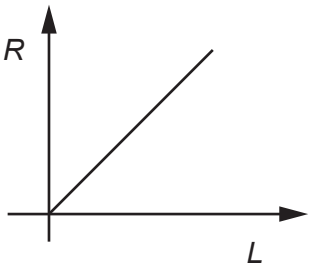
D $\lambda \ll d$

Your answer A **[1]**

4 A student investigates a conducting wire of constant cross-sectional area, at constant temperature.

The resistance R is measured for a range of lengths L.

The following graph is plotted:



Which expression is equal to the gradient of the graph?

A resistivity

B resistivity × cross-sectional area

C $\frac{\text{resistivity}}{\text{cross-sectional area}}$

D $\frac{\text{cross-sectional area}}{\text{resistivity}}$

Your answer C **[1]**

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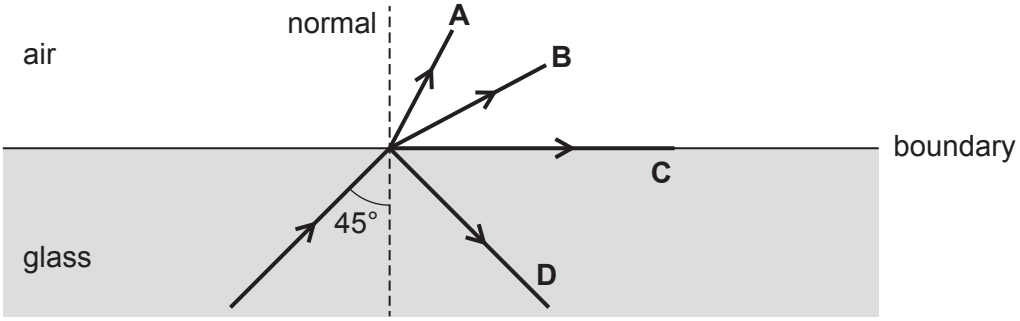
5 A ray of monochromatic light is travelling through glass.

The refractive index of the glass is 1.5.

The ray is incident on a glass-air boundary with angle of incidence of 45°.



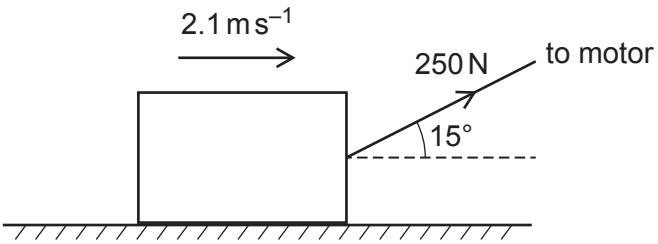
Which is the correct path of the ray after it reaches the boundary?

Your answer D **[1]**

6 The diagram shows a motor pulling a load along a flat, horizontal surface.

The load is connected to the motor by a string at an angle of 15° to the surface. The tension in the string is 250 N. The load reaches a constant speed of 2.1 m s^{-1}.

The diagram does not show the other forces acting on the load.



What is the output power of the motor?

A 120 W

B 140 W

C 460 W

D 510 W

Your answer D **[1]**

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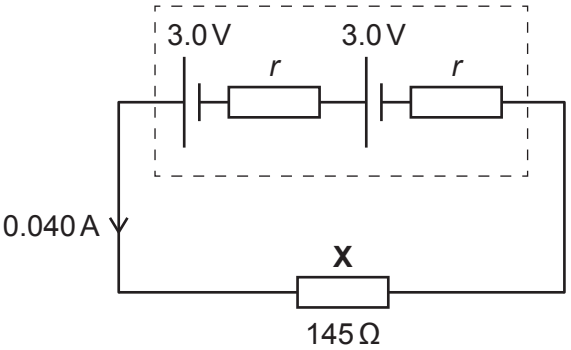
7 Two identical cells are connected in series in a circuit with a resistor **X** of resistance 145 Ω. The e.m.f. of each cell is 3.0 V. The current in **X** is 0.040 A.



What is the internal resistance *r* of one of the cells?

A 0.10 Ω

B 0.20 Ω

C 2.5 Ω

D 5.0 Ω

Your answer C **[1]**

8 Electromagnetic radiation is incident on a clean metal plate. Electrons are released from the surface of the plate.

Which statement is correct?

A The energy of a photon is directly proportional to its frequency.

B The kinetic energy of the released electrons depends on the rate of incidence of photons.

C The photoelectric effect demonstrates the wave-like nature of electromagnetic radiation.

D The rate at which electrons are released depends on the frequency of the radiation.

Your answer A **[1]**

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9 Two copper wires, **X** and **Y**, are connected in series to a source of e.m.f.

The length of **X** is equal to the length of **Y**.
The cross-sectional area of **X** is greater than the cross-sectional area of **Y**.

Which **two** quantities are equal in value for both **X** and **Y**?

A charge carrier density, current

B charge carrier density, electron drift velocity

C current, resistance

D electron drift velocity, resistance

Your answer A **[1]**

10 Resistance and resistivity are two quantities used to describe the behaviour of a conductor.

How do these quantities change, if at all, when the length of a conductor is increased?

	resistance	**resistivity**
A	constant	constant
B	constant	increase
C	increase	constant
D	increase	increase

Your answer C **[1]**

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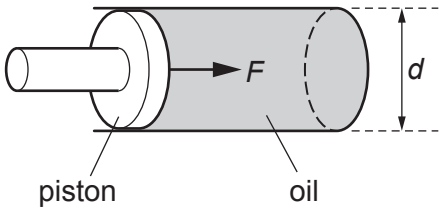
11 The diagram shows a closed cylinder with internal diameter d.



The cylinder is filled with oil. A piston applies a force F to the oil.

Which is the correct expression for the pressure in the oil?

A $\frac{2F}{\pi d^2}$

B $\frac{\pi d^2}{2F}$

C $\frac{4F}{\pi d^2}$

D $\frac{\pi d^2}{4F}$

Your answer C **[1]**

12 An LED is designed to emit red light. In an experiment, the potential difference across the LED is gradually increased. It begins to emit light when the potential difference reaches a value V_0.

The experiment is repeated for an LED designed to emit green light. A different value of V_0 is observed.

Which row of the table describes the values in the second experiment?

	change to V_0	**change to wavelength of emitted light**
A	decrease	increase
B	decrease	decrease
C	increase	increase
D	increase	decrease

Your answer D **[1]**

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13 Unpolarised light is observed through a single polarising filter.

The intensity of the light transmitted by the filter is half the intensity of the incident light.

What happens to the intensity of the transmitted light when the filter is rotated through 90°?

A decreases

B decreases and then increases

C increases

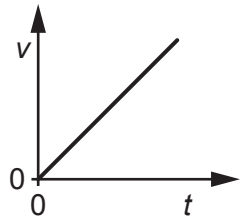
D does not change

Your answer D **[1]**

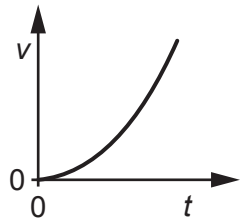
14 An object is released from rest and then falls freely under gravity. Air resistance is negligible.

Which graph shows how the velocity *v* of the object varies with time *t*?

A



B



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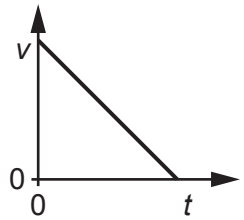
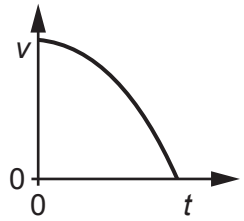


D



Your answer A **[1]**

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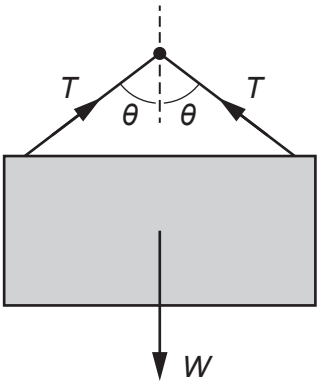
15 A cable is used to hang a picture from a nail. The diagram shows all the forces acting on the picture. T is the tension in the cable and W is the weight of the picture.



Which is the correct expression for W?

A $W = T \cos \theta$

B $W = 2T \cos \theta$

C $W = T \sin \theta$

D $W = 2T \sin \theta$

Your answer B **[1]**

16 An object is in equilibrium.

Only two forces, **X** and **Y**, act on the object.

Which of the following statements must be correct?

1 **X** and **Y** are equal and opposite.
2 **X** and **Y** are a Newton's 3rd law force pair.
3 The object is at rest.

A Only 1

B 1 and 2

C 1 and 3

D 1, 2 and 3

Your answer A **[1]**

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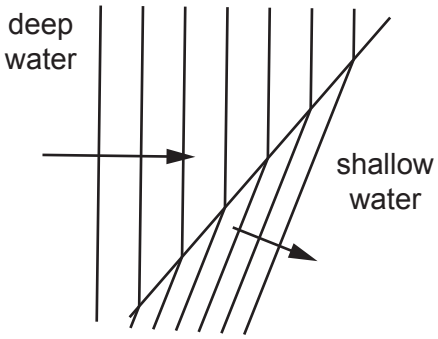
17 A ripple tank can be used to demonstrate wave effects. When water waves in a ripple tank travel from deep to shallow water the wavelength decreases.



What happens to the speed and frequency of the waves as they move from deep to shallow water?

	speed	**frequency**
A	decrease	increase
B	decrease	constant
C	increase	increase
D	increase	constant

Your answer B **[1]**

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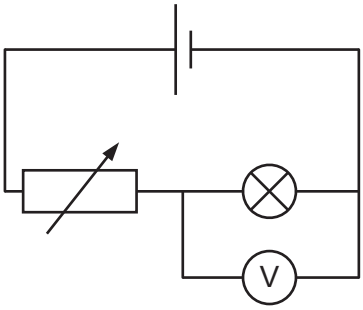
18 A tungsten filament lamp is connected in a circuit as shown.



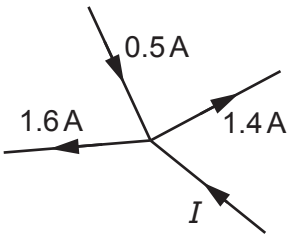
The variable resistor is adjusted so that the temperature of the filament lamp increases.

What happens to the resistance of the lamp and the reading on the voltmeter?

	resistance of the lamp	**voltmeter reading**
A	decreases	decreases
B	decreases	increases
C	increases	decreases
D	increases	increases

Your answer D **[1]**

19 The diagram shows the currents passing in and out of a point in a circuit.



What is the value of the current I?

A 0.3A

B 0.5A

C 2.5A

D 3.0A

Your answer C **[1]**

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20 An uncharged oil drop gains a charge of $+4.0 \times 10^{-18}$ C.

What is the change in the number of electrons on the oil drop?

A Gained 25 electrons

B Gained 64 electrons

C Lost 25 electrons

D Lost 64 electrons

Your answer C **[1]**

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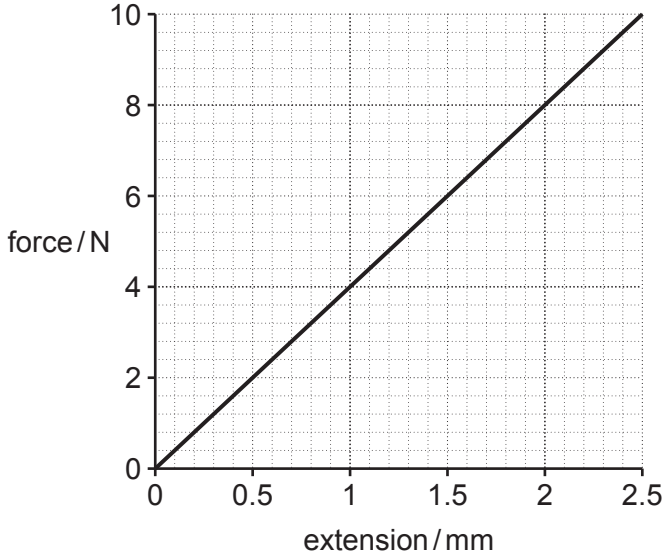
Section B

21 A student investigates the properties of a spring. They hang masses from the spring and measure the extension of the spring for every 100 g mass added. They plot their results on a graph of force against extension.



(a) Calculate the force constant of the spring.

$k = F/x$ = gradient = $10.0 \div (2.5 \times 10^{-3})$

$k = 4000\ N\ m^{-1}$

force constant = 4000 $N\,m^{-1}$ **[2]**

(b) The student extends their investigation to determine the Young modulus of copper. They make measurements to determine the length and the cross-sectional area of a copper wire.

Describe how they should determine the cross-sectional area of the wire.

Use a micrometer to measure the diameter d of the wire.

Measure the diameter at several different places along the wire (and in different orientations) and calculate a mean diameter.

Calculate the cross-sectional area using $A = \pi d^2/4$ (or $A = \pi r^2$ with $r = d/2$).

[3]

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(c) **(i)** Show that an expression for the Young modulus E is

$$E = \frac{kL}{A}$$

L = length of wire
A = cross-sectional area of wire
k = force constant of wire

$E = \sigma/\varepsilon$, where stress $\sigma = F/A$ and strain $\varepsilon = x/L$

Hooke's law: $F = kx$

$E = (F/A) \div (x/L) = FL/(Ax)$

$E = (kx \times L)/(A \times x)$

so $E = kL/A$

[2]

(ii) The student records the following results for a copper wire.

$L = 2.0\,\text{m} \pm 0.05\ \%$
$A = 2.9 \times 10^{-8}\,\text{m}^2 \pm 2\ \%$
$k = 1670\,\text{N m}^{-1} \pm 1.25\ \%$

Calculate the value of the Young modulus of the wire and its percentage uncertainty.

$E = kL/A = (1670 \times 2.0) \div (2.9 \times 10^{-8}) = 1.15 \times 10^{11}\ \text{N m}^{-2}$

% uncertainty = 0.05 + 2 + 1.25 = 3.3 %

Young modulus = ...1.2×10^{11}..... N m^{-2} ± .....3.3..... % **[3]**

(iii) The student researches the Young modulus of copper.

They find a value of $1.17 \times 10^{11}\,\text{N m}^{-2}$.

Determine whether this value is consistent with your answer to **(c)(ii)**.

% difference = $(1.20 - 1.17) \times 10^{11} \div 1.17 \times 10^{11} \times 100 = 2.6$ %

Range of my value: $1.2 \times 10^{11} \pm 3.3\ \% = 1.16$ to $1.24 \times 10^{11}\ \text{N m}^{-2}$

2.6 % difference < 3.3 % uncertainty (1.17×10^{11} lies within the range), so the value is consistent with my answer.

[2]

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22 Sound waves in air are longitudinal waves consisting of compressions and rarefactions.

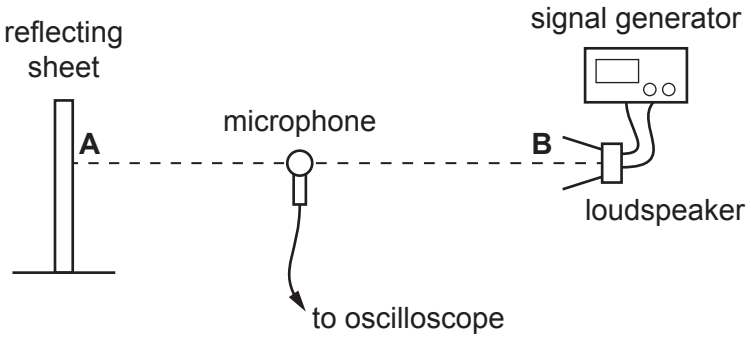
(a) Explain how the movement of air molecules creates compressions and rarefactions.

The air molecules vibrate (oscillate back and forth) about their mean positions.

The oscillations are parallel to the direction of energy transfer (the direction of propagation of the wave).

This creates regions where the molecules are closer together (compressions, high pressure) and regions where they are further apart (rarefactions, low pressure). **[3]**

(b) A student investigates sound waves. They set up the following apparatus.



The sound wave emitted from the loudspeaker at **B** travels to the reflecting sheet at **A** and is reflected. A stationary wave is formed between the loudspeaker and the sheet.

The student moves a microphone along the line **AB**. The microphone is connected to an oscilloscope. The oscilloscope shows the relative amplitude of the stationary wave at each point along the line. The student observes a series of nodes and antinodes.

(i) Explain how a stationary wave with nodes and antinodes is formed.

The incident wave from the loudspeaker and the wave reflected from the sheet travel in opposite directions and superpose (interfere).

Where the waves meet in phase there is constructive interference giving maximum amplitude: antinodes.

Where the waves meet in antiphase there is destructive interference giving minimum (zero) amplitude: nodes. **[3]**

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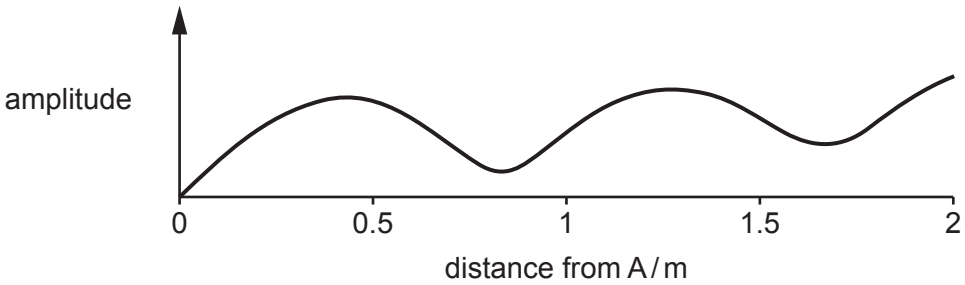
(ii) The student measures the amplitude of the stationary wave at a range of distances from the reflecting sheet **A**. Their results are shown below.



The amplitudes at the nodes are observed to be:
- not exactly equal to zero
- closer to zero at distances closer to the reflecting sheet.

Explain these observations.

The intensity (amplitude/energy) of the wave decreases with distance travelled, and some energy is absorbed when the wave is incident on the sheet.
So the reflected wave has a lower amplitude than the incident wave and destructive interference is incomplete: the node amplitude is not zero.
The difference in amplitudes of the two waves increases with increasing distance from A, so nodes are closer to zero near A. **[3]**

(iii) The student measures the distance between two adjacent nodes as 0.84 m.

The frequency of the sound wave is 200 Hz.

Use these measurements to calculate a value for the speed of sound waves in air.

adjacent nodes are $\lambda/2$ apart: $\lambda = 2 \times 0.84 = 1.68$ m

$v = f\lambda = 200 \times 1.68 = 336$ m s^{-1}

speed of sound waves = 336 m s^{-1} **[2]**

(iv) The student wants to reduce the uncertainty in their calculated value for the speed of sound waves in air.

Suggest a suitable improvement to the student's method.

Measure the distance across several nodes (minima) and divide, and repeat and calculate a mean. **[1]**

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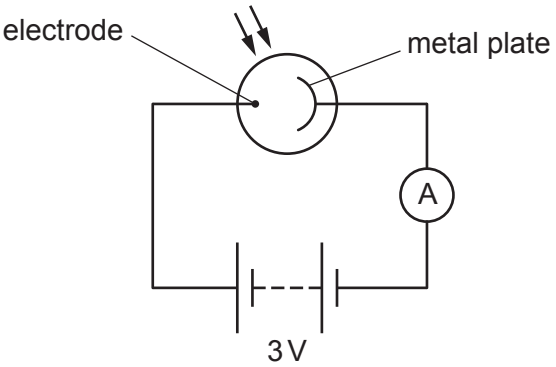
23 A light meter is used to measure the intensity of electromagnetic radiation. The meter consists of a metal plate and an electrode within an evacuated glass tube. It is connected to a circuit with an ammeter, a battery of e.m.f. 3.0 V and negligible internal resistance.



Electromagnetic radiation is incident on the metal plate. Electrons are released due to the photoelectric effect and are attracted to the electrode.

(a) Calculate the work done on an electron as it moves from the metal plate to the electrode.

$W = eV = 1.60 \times 10^{-19} \times 3.0$

$W = 4.8 \times 10^{-19}$ J

work done = 4.8×10^{-19} J **[2]**

(b) Explain why the frequency of the electromagnetic radiation must be above a minimum value for electrons to be released.

Electromagnetic radiation consists of photons; each electron absorbs the energy of one photon.

An electron is only emitted if the energy of the photon is equal to or greater than the work function of the metal.

Photon energy $E = hf$ ($E \propto f$), so f must be at least the threshold frequency $f_0 = \varphi/h$. **[3]**

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(c) **(i)** The reading on the ammeter is proportional to the intensity of the radiation. Use your knowledge of the photoelectric effect to explain why.

Intensity of radiation is proportional to the rate of photons incident on the plate (above the threshold frequency).

There is a one-to-one interaction between photons and electrons, so the rate of electrons emitted is proportional to the rate of photons.

Current is the rate of flow of charge ($I = \Delta q/\Delta t$), so the current is proportional to the rate of electron release and hence to intensity. **[3]**

(ii) When the light meter is irradiated with monochromatic radiation of frequency 8.2×10^{15} Hz, the number of electrons emitted every second is $3.1 \times 10^{18}\,s^{-1}$.

The surface area of the metal plate normal to the incident radiation is $4.9 \times 10^{-3}\,m^2$.

Determine the intensity of the radiation.

energy of one photon $E = hf = 6.63 \times 10^{-34} \times 8.2 \times 10^{15} = 5.44 \times 10^{-18}$ J

one photon releases one electron, so 3.1×10^{18} photons per second:

power $P = 5.44 \times 10^{-18} \times 3.1 \times 10^{18} = 16.9$ W

intensity $= P/A = 16.9 \div 4.9 \times 10^{-3}$

intensity $= 3440$ W m^{-2}

intensity = 3.4×10^3 W m^{-2} **[4]**

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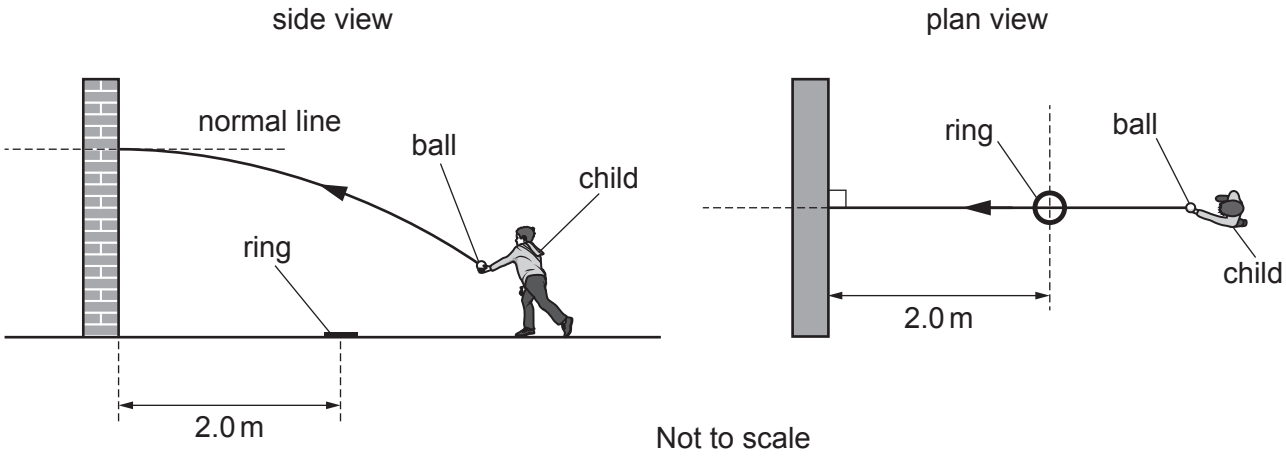
24 In a game, a child throws a ball at a flat, vertical wall. The ball rebounds from the wall. The child wins the game if the ball lands within a circular ring placed on the ground.



The ring has a radius of 15 cm. The centre of the ring is 2.0 m from the wall. The child throws a ball with a mass of 0.058 kg towards the wall.

(a) The ball is incident normally on the wall with a horizontal velocity of $7.2\,\text{m s}^{-1}$. The ball is in contact with the wall for 52 ms before rebounding normally with a horizontal velocity of $3.6\,\text{m s}^{-1}$.

Calculate the average magnitude of the force that the wall exerts on the ball.

$\Delta p = (0.058 \times 7.2) - (0.058 \times -3.6) = 0.626\ \text{kg m s}^{-1}$

$F = \Delta p/\Delta t = 0.626 \div 0.052$

$F = 12.0\ \text{N}$

force = ...12..... N **[3]**

(b) The ball lands on the ground a time of 0.58 s after hitting the wall.

Show that the child wins the game. Air resistance can be assumed to be negligible.

horizontal velocity after rebound is constant (no air resistance):

horizontal distance = 3.6 × 0.58 = 2.09 m from the wall

ring covers 2.0 − 0.15 = 1.85 m to 2.0 + 0.15 = 2.15 m

(or 2.09 − 2.0 = 0.09 m = 9 cm from the centre)

1.85 m < 2.09 m < 2.15 m (9 cm < 15 cm)

so the ball lands inside the ring and the child wins.

[3]

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25 A soil scientist investigates how different types of soil particles fall through water.

A soil scientist measures the terminal velocity of soil particles in water. He fills a tall glass cylinder with water and places a small sample of soil into the water. He uses a video camera, with a known frame rate, to measure the time taken for a particle in the soil to fall a measured distance.

The scientist records the total distance that the particle falls every 0.1 s.

Time / s	Total distance / cm
0.0	0.0
0.1	1.2
0.2	3.5
0.3	6.2
0.4	8.9
0.5	11.6

(a) Use the information in the table to explain why using a video camera to measure the time is more appropriate than a stopwatch in this investigation.

The time intervals are short (0.1 s) and the soil moves fast, so reaction time (about 0.2 s) would be large compared with the time measured. The video can be replayed frame by frame, so the time has a smaller uncertainty. **[2]**

(b) Suggest one other precaution that the scientist should take to ensure that the terminal velocity is determined as accurately as possible.

View the scale at eye level, perpendicular to the cylinder, to avoid parallax error. **[1]**

(c) Use the scientist's results to show that the terminal velocity is about $0.3\,m\,s^{-1}$.

from 0.2 s to 0.4 s: $v = \Delta s/\Delta t = (8.9 - 3.5) \div 0.2 = 27\ cm\ s^{-1} = 0.27\ m\ s^{-1}$

from 0.3 s to 0.5 s: $v = (11.6 - 6.2) \div 0.2 = 0.27\ m\ s^{-1}$

distance in each 0.1 s from 0.2 s onwards is constant (2.7 cm), so velocity is constant: terminal velocity $\approx 0.27\ m\ s^{-1}$, about $0.3\ m\ s^{-1}$

[2]

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(d) Soil scientists classify soil samples according to the diameter of the particles, as shown in the table below.

Soil sample	Range of diameter / mm
clay	< 0.002
silt	0.002 – 0.05
sand	0.05 – 2.0
gravel	>2.0

The terminal velocity of a spherical particle of radius r, falling in water is given by

$$v = \frac{2r^2 g(\rho_s - \rho_w)}{9\eta}$$

ρ_w = density of water = 1000 kg m^{-3}
ρ_s = density of soil particle = 1500 kg m^{-3}
η = constant for water = 1.0×10^{-3} Pa s
g = acceleration of free fall = 9.81 m s^{-2}

Determine which soil sample was used by the scientist in this investigation.

$r^2 = 9\eta v \div 2g(\rho_s - \rho_w)$

$r = \sqrt{[(9 \times 1.0 \times 10^{-3} \times 0.27) \div (2 \times 9.81 \times (1500 - 1000))]}$

$r = 5.0 \times 10^{-4}$ m

diameter $= 2 \times 5.0 \times 10^{-4} = 1.0 \times 10^{-3}$ m $= 1.0$ mm

0.05 mm < 1.0 mm < 2.0 mm, so sand

soil sample = sand **[3]**

END OF QUESTION PAPER

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ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined pages. The question numbers must be clearly shown in the margins.

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