Oxford Cambridge and RSA

Friday 09 October 2020 – 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 **28** 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.

Answer **all** the questions.

Write your answer to each question in the box provided.

1 One of Kirchhoff's laws is stated below.

The sum of the currents entering a point in a circuit is equal to the sum of the currents leaving the same point.

Which quantity is conserved according to this law?

A charge

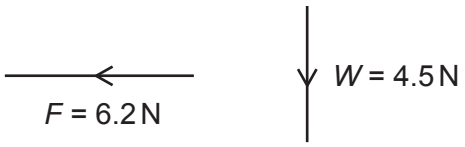
B energy

C mass

D potential difference

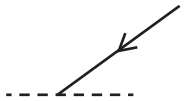
Your answer A **[1]**

2 An object is in equilibrium under the action of three coplanar forces *F*, *R* and *W*.
The diagram below shows the forces *F* and *W*.



The angle between *F* and *W* is 90°.

Which row shows the correct magnitude of *R* and the approximate direction of *R*?

	Magnitude of *R* / N	Direction of *R*
A	7.7	
B	7.7	
C	10.7	
D	10.7	

Your answer A **[1]**

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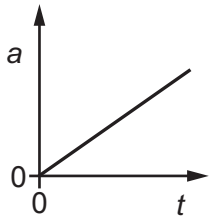
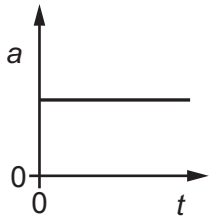
3 A ball, made from scrunched-up paper, is dropped from rest at time $t = 0$.
It reaches terminal velocity before it hits the ground.

Which acceleration a against time t graph is correct for the ball in flight?

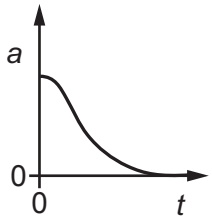
A



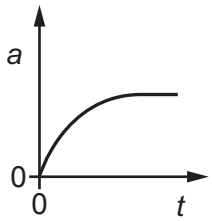
B



C



D



Your answer C **[1]**

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4 An electron with initial kinetic energy of 100 eV and initial speed of $5.9 \times 10^6\,m\,s^{-1}$ is **accelerated** through a potential difference of 250 V.

What is the final speed of this electron?

A $5.9 \times 10^6\,m\,s^{-1}$

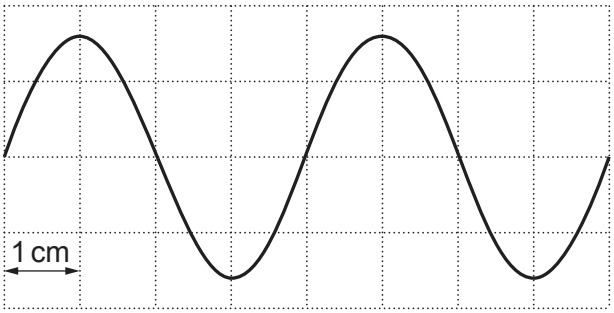
B $7.3 \times 10^6\,m\,s^{-1}$

C $9.4 \times 10^6\,m\,s^{-1}$

D $1.1 \times 10^7\,m\,s^{-1}$

Your answer D **[1]**

5 The diagram below shows the oscilloscope trace for an electrical signal.



The frequency of the signal is 250 Hz.

What is the time-base setting of the oscilloscope?

A $1\,ms\,cm^{-1}$

B $2\,ms\,cm^{-1}$

C $4\,ms\,cm^{-1}$

D $8\,ms\,cm^{-1}$

Your answer A **[1]**

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6 This question is about progressive waves and stationary waves.

Which statement is **not** correct?

A A progressive wave transports energy through space.

B A stationary wave must have at least one node.

C For both waves, the amplitude of the oscillation is the same everywhere along the wave.

D In the stationary wave, the oscillations of the particles at two adjacent antinodes are out of phase by 180°.

Your answer C **[1]**

7 A proton has kinetic energy 8.00×10^{-17} J.

Which is the correct expression for the de Broglie wavelength λ of the proton?

A $\lambda = \dfrac{6.63 \times 10^{-34}}{2 \times 1.67 \times 10^{-27} \times 8.00 \times 10^{-17}}$

B $\lambda = \dfrac{6.63 \times 10^{-34}}{2 \times 9.11 \times 10^{-31} \times 8.00 \times 10^{-17}}$

C $\lambda = \dfrac{6.63 \times 10^{-34}}{\sqrt{2 \times 1.67 \times 10^{-27} \times 8.00 \times 10^{-17}}}$

D $\lambda = \dfrac{6.63 \times 10^{-34}}{\sqrt{2 \times 9.11 \times 10^{-31} \times 8.00 \times 10^{-17}}}$

Your answer C **[1]**

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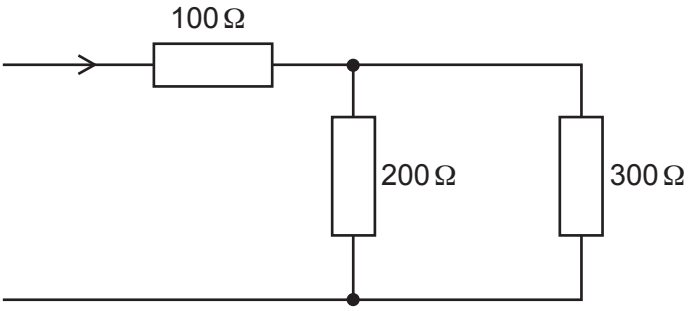
8 The diagram below shows an electrical circuit.



The resistance of each resistor is shown.
All resistors are made from the same material and have the same diameter.
The mean drift velocity of the charge carriers in the 100 Ω resistor is v.

What is the mean drift velocity of the charge carriers in the 300 Ω resistor?

A 0.40v

B 0.50v

C 0.60v

D 1.00v

Your answer A **[1]**

9 A 0.30 kg mass is hung from a spring. The length of the spring is now 16.0 cm.
The length of the spring becomes 17.5 cm when an **additional** 0.20 kg mass is hung from the spring. The spring obeys Hooke's law.

What is the force constant of the spring?

A 11 N m^{-1}

B 12 N m^{-1}

C 130 N m^{-1}

D 330 N m^{-1}

Your answer C **[1]**

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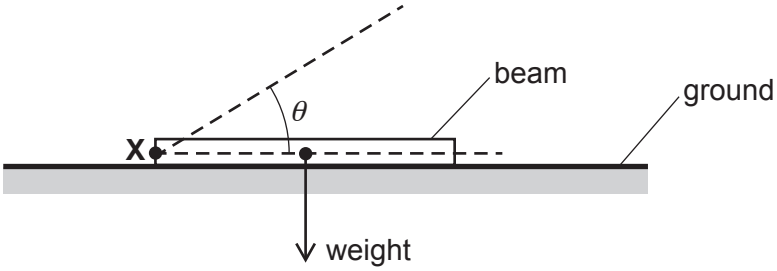
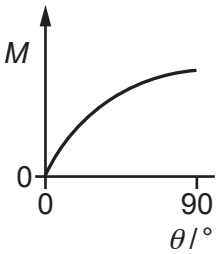
10 A uniform beam is initially lying on horizontal ground, as shown below.



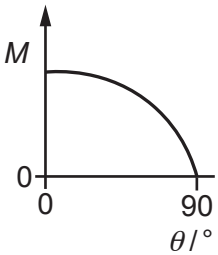
The end **X** of the beam is hinged.
The beam is tilted from angle $\theta = 0$ to $\theta = 90°$.
The moment of the weight of the beam about point **X** is M.

Which M against θ graph is correct?

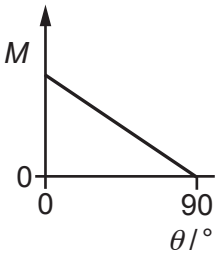
A



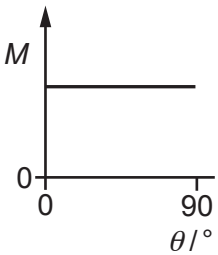
B



C



D



Your answer B **[1]**

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11 A small block of wood is placed in deep water.
The block is at rest with 80% of its volume under the surface of water.
The weight of the block is 6.0 N.

What is the upthrust acting on the block?

A 0

B 1.2 N

C 4.8 N

D 6.0 N

Your answer D **[1]**

12 The momentum of an object moving to the left is 28 kg m s^{-1}.
A force of magnitude 3.5 N acts on the object to the right for a time of 2.0 s.

What is the **change** in the momentum of the object?

A 7.0 kg m s^{-1}

B 21 kg m s^{-1}

C 28 kg m s^{-1}

D 35 kg m s^{-1}

Your answer A **[1]**

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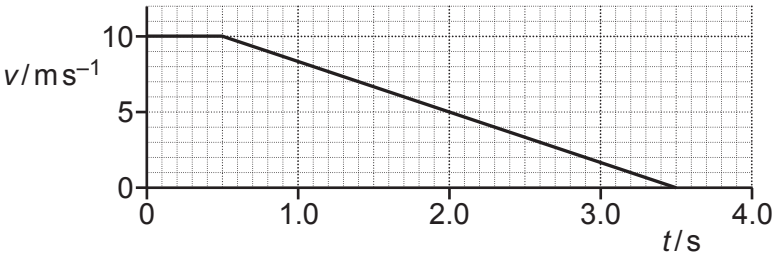
13 A driver sees an obstacle ahead in the road at time $t = 0$ and then applies the brakes.
The velocity v against time t graph for the car is shown below.



Which row is correct?

	Reaction time of driver / s	Braking distance of car / m
A	0.5	15.0
B	0.5	17.5
C	3.5	15.0
D	3.5	17.5

Your answer A **[1]**

14 A seabird dives vertically into water.
The seabird is briefly stationary at its **greatest** depth.
In water, the upthrust on this seabird is always greater than the weight of the seabird.

Which statement is correct at the instant of greatest depth?

A The seabird experiences greatest drag.

B The seabird has an upward acceleration.

C The upthrust on the seabird is equal to drag.

D The weight of the seabird is equal to drag.

Your answer B **[1]**

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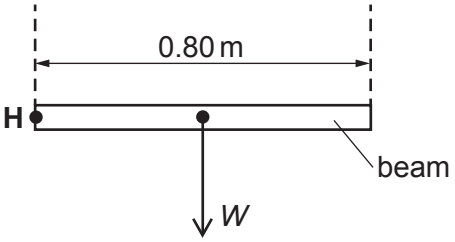
15 A uniform beam has length 0.80 m and weight W.
The beam is hinged at point **H**.
A cable is attached to the beam at a distance x from **H**. The vertical upwards force in the cable is $0.75\,W$. **The cable is not shown in the diagram.**
The beam is at rest in the horizontal position.



Which condition is correct?

A $x < 0.40$ m

B $x = 0.40$ m

C $0.40\text{ m} < x < 0.80$ m

D $x = 0.80$ m

Your answer C **[1]**

16 What is the S.I. unit for electrical charge?

A ampere

B coulomb

C ohm

D volt

Your answer B **[1]**

17 Which pair of quantities have the same S.I. base units?

A force, energy

B moment, momentum

C power, work done

D work done, moment

Your answer D **[1]**

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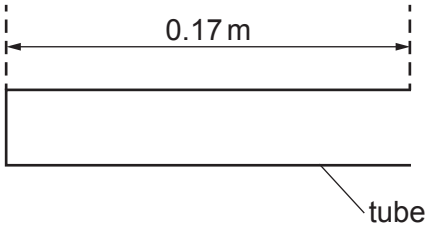
18 A stationary sound wave, of fundamental mode of vibration, is formed in a tube closed at one end.



The length of the tube is 0.17 m. The speed of sound in air is 340 m s^{-1}.

What is the fundamental frequency of the stationary wave?

A 500 Hz

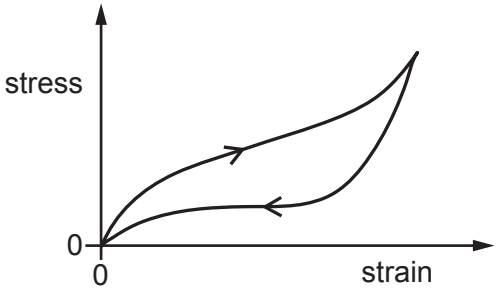
B 1000 Hz

C 2000 Hz

D 4000 Hz

Your answer A **[1]**

19 The stress against strain graph for a particular material is shown below.



Which term is correct for a property of this material?

A brittle

B ductile

C elastic

D plastic

Your answer C **[1]**

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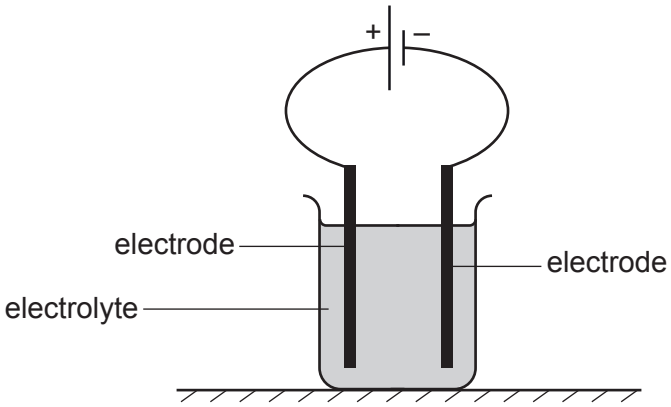
20 Two electrodes are placed into a liquid (electrolyte).
The electrodes are connected to a cell.



Which row is correct?

	Direction of conventional current in the electrolyte	Particles responsible for the current in the electrolyte
A	To the left	Electrons
B	To the left	Ions
C	To the right	Electrons
D	To the right	Ions

Your answer D **[1]**

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Question 21 starts on page 14

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SECTION B

Answer **all** the questions.

21 **(a)** Two objects collide. The collision is perfectly elastic.

State **two** quantities that are conserved in this type of collision.

1 momentum

2 kinetic energy (and total energy)

[2]

(b) The diagram below shows a person on a horizontal skateboard holding a heavy ball.

The person is initially stationary.
The person throws the ball horizontally to the right.

Describe and explain the motion of the person on the skateboard **immediately** after the ball is thrown.

The person moves to the left (opposite direction to the ball). Momentum is conserved; total momentum is zero at the start, so the momentum of the person is equal and opposite to that of the ball. The person has a greater mass, so the speed of the person is less than the speed of the ball.

[3]

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22 A toy parachute is falling through air.
The air resistance F acting on the parachute is given by the expression

$F = kv^2$

where v is the speed of the parachute and k is a constant.

(a) The S.I. base units for F are $kg\,m\,s^{-2}$.

Show that the S.I. base units for k are $kg\,m^{-1}$.

$k = F / v^2$

units of $v = m\ s^{-1}$, so units of $v^2 = m^2\ s^{-2}$

units of $k = kg\ m\ s^{-2} / (m^2\ s^{-2})$

$= kg\ m^{1-2}\ s^{-2+2} = kg\ m^{-1}$

[2]

(b) The following items of data are collected for the parachute.

- $v = 1.20 \pm 0.12\,m\,s^{-1}$
- $F = 4.00 \pm 0.24\,N$

Calculate the absolute uncertainty in k. Write your answer to 2 significant figures.

$k = F / v^2 = 4.00 / 1.20^2 = 2.78\ kg\ m^{-1}$

% uncertainty in $v = (0.12 / 1.20) \times 100 = 10\%$

% uncertainty in $F = (0.24 / 4.00) \times 100 = 6\%$

% uncertainty in $k = 2 \times 10\% + 6\% = 26\%$

absolute uncertainty $= 0.26 \times 2.78 = 0.72\ kg\ m^{-1}$

absolute uncertainty in k = ...0.72..... $kg\,m^{-1}$ **[3]**

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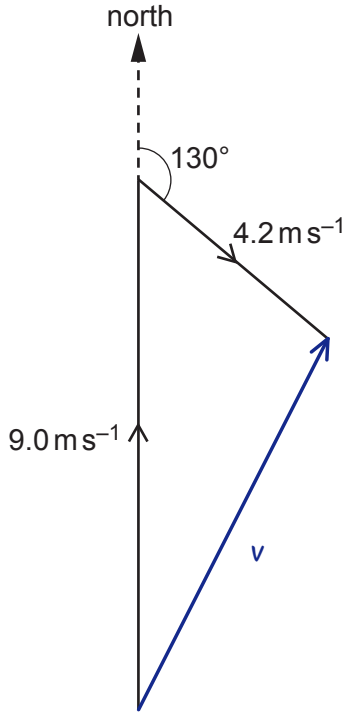
23 A drone is a small remotely-controlled aircraft.

(a) A drone is travelling horizontally in a cross-wind.
The drone is travelling due north at a constant speed $9.0\,m\,s^{-1}$ relative to the air.
The speed of the wind is $4.2\,m\,s^{-1}$. The direction of the wind is 130° from the north.

An incomplete vector diagram for determining the resultant velocity of the drone is shown below.



The vector diagram is drawn to scale.

(i) Complete the vector diagram to show the resultant velocity of the drone. **[1]**

(ii) Determine the magnitude of the resultant velocity v of the drone.

cosine rule (angle between vectors = 180° − 130° = 50°):

$v^2 = 9.0^2 + 4.2^2 - 2 \times 9.0 \times 4.2 \times \cos 50°$

$v^2 = 81 + 17.64 - 48.6 = 50.0$

$v = 7.07\ m\ s^{-1}$

(check: resultant line on diagram = 5.5 cm, so 7.1 $m\ s^{-1}$)

v = ...7.1..... $m\,s^{-1}$ **[2]**

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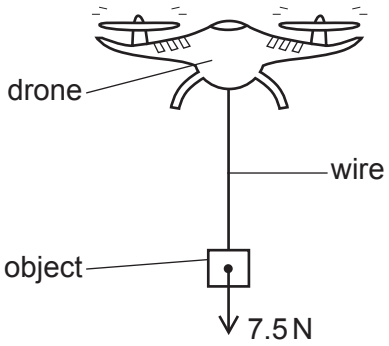
(b) The diagram below shows an object of weight 7.5 N hung from the drone using a steel wire.



The drone is now hovering at a fixed position above the ground.

(i) The wire has cross-sectional area $8.2 \times 10^{-7}\,m^2$ and original length 62 cm.
The Young modulus of steel is 2.0×10^{11} Pa. The wire obeys Hooke's law.

Calculate the extension x of the wire.

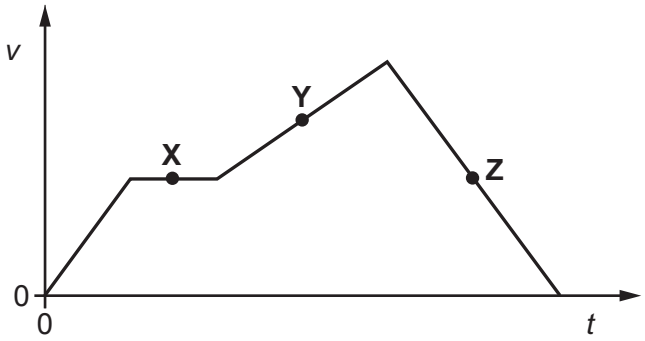
$E = FL / Ax$, so $x = FL / AE$

$x = (7.5 \times 0.62) / (8.2 \times 10^{-7} \times 2.0 \times 10^{11})$

$x = 2.84 \times 10^{-5}$ m

x = 2.8×10^{-5} m **[3]**

(ii) The drone now moves vertically upwards.
The velocity v against time t graph for the drone is shown below.



The tension in the wire at **X** is 7.5 N.

Describe and explain how the tension in the wire at **Y** and **Z** compares with 7.5 N.

At Y the gradient of the graph is positive; the drone and object accelerate upwards, so the resultant force is upwards and the tension is greater than 7.5 N.

At Z the gradient is negative; they decelerate (slow down), so the resultant force is downwards and the tension is less than 7.5 N. **[3]**

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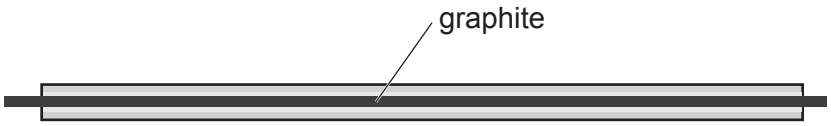
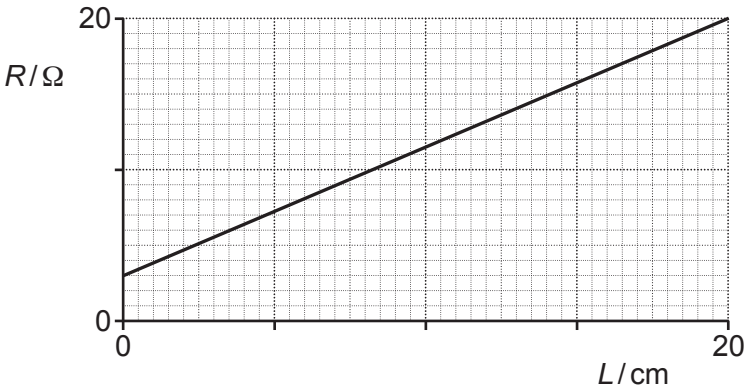
24 **(a)** The diagram below shows a pencil cut along its length exposing the graphite.



The resistance of a length L of the graphite is R. A student directly measures R using a multimeter (ohmmeter).

The following graph is plotted by the student.



(i) Suggest why the graph does not pass through the origin.

Systematic (zero) error: the ohmmeter was not zeroed / the connecting leads and crocodile clips have resistance. **[1]**

(ii) The resistivity of graphite is ρ.

Describe how the student can use the graph above, and an additional measuring instrument, to accurately determine ρ.
No calculations are required.

Use a micrometer (or vernier calliper) to measure the diameter d of the pencil lead in several positions and take the average. Then $A = \pi d^2/4$.
Find the gradient of the R against L graph using a large triangle.
$R = \rho L / A$, so gradient $= \rho / A$ and $\rho =$ gradient $\times A$.

[3]

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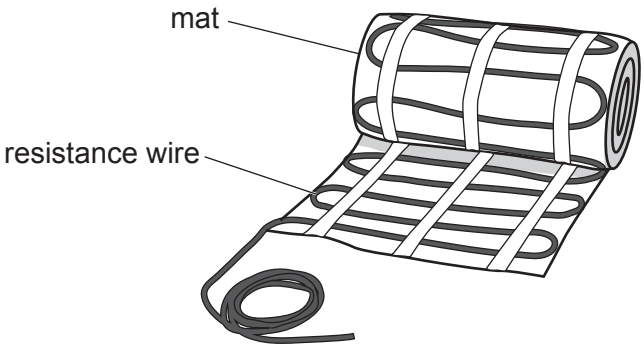
(b) The diagram below shows a mat used for underfloor heating.



Each mat has resistance wire. The wire has cross-sectional area $6.7 \times 10^{-8}\,m^2$, total length 25 m and resistance 180 Ω. Each mat dissipates 300 W when connected to the mains supply.

(i) A total output power 1.2 kW is required for a room.

Calculate the number of mats required.

number of mats = 1200 / 300

number of mats = ...4.... **[1]**

(ii) Calculate the resistivity ρ of the material of the wire.

$R = \rho L / A$, so $\rho = RA / L$

$\rho = (180 \times 6.7 \times 10^{-8}) / 25$

$\rho = 4.82 \times 10^{-7}\ \Omega\ m$

ρ = ...4.8×10^{-7}.... Ω m **[2]**

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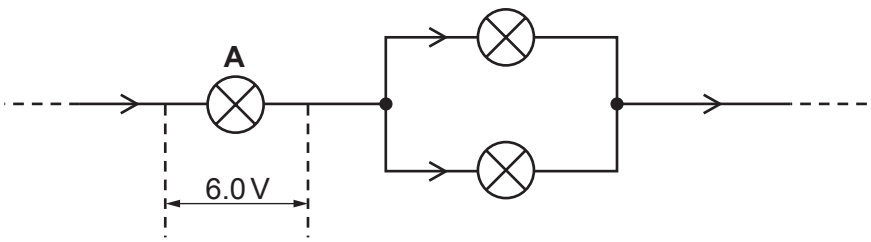
25 **(a)** A student connects a calibrated 10.0 Ω resistor across a chemical cell of electromotive force (e.m.f.) 1.50 V.
The student expects the current in the resistor to be 0.150 A.

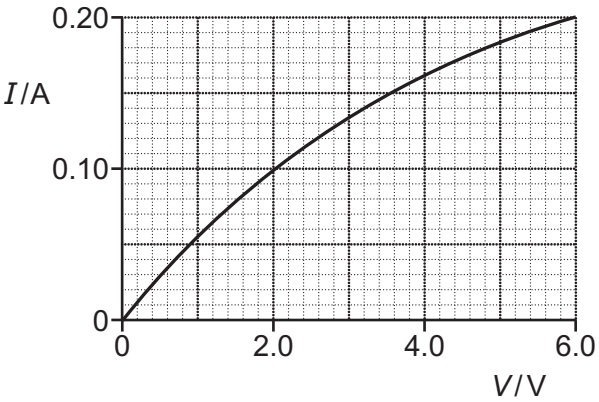
Explain why the actual current will not be 0.150 A.

The actual current is less than 0.150 A. The cell has internal resistance, so the total resistance is greater than 10.0 Ω (some p.d., lost volts, is across the internal resistance). **[2]**

(b) The diagram below shows part of an electrical circuit connected by the student.



The lamps are identical.
The graph below shows the I-V characteristic of one of the lamps.



The potential difference (p.d.) across lamp **A** is 6.0 V.

Use the graph to determine the total resistance of the lamps.

lamp A: V = 6.0 V, so from the graph I = 0.20 A

each parallel lamp: I = 0.20 / 2 = 0.10 A, so from the graph V = 2.0 V

total p.d. = 6.0 + 2.0 = 8.0 V

R = V / I = 8.0 / 0.20 = 40 Ω (R_A = 30 Ω, $R_{parallel}$ = 10 Ω)

resistance = 40 Ω **[3]**

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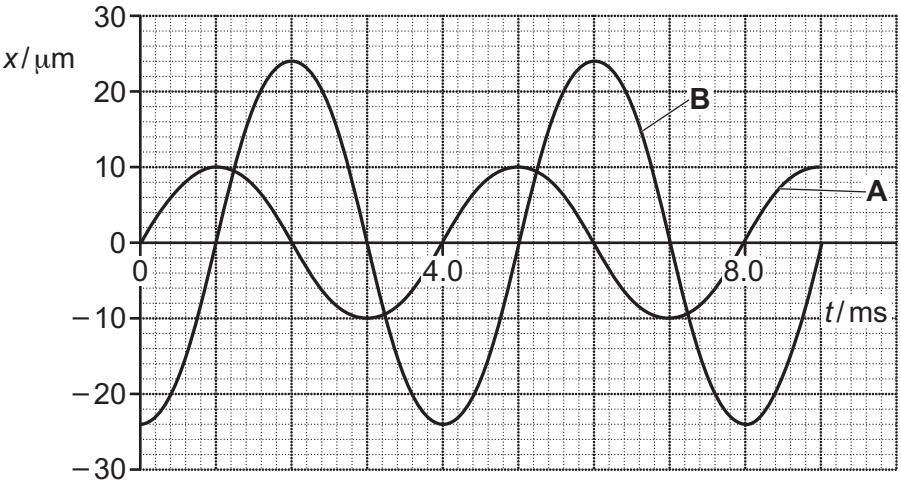
26 Two progressive waves **A** and **B** meet at a point **P**.
The displacement x against time t graphs for **A** and **B** at the point **P** are shown below.



(a) Explain how the graphs show that the waves are coherent.

There is a constant phase difference between A and B (90°).

..... **[1]**

(b) Determine the frequency f of the wave **A**.

period of A, T = 4.0 ms = 4.0 × 10^{-3} s

f = 1 / T = 1 / 4.0 × 10^{-3}

f = ...250... Hz **[2]**

(c) The intensity of wave **A** is I_0.

Determine the intensity of wave **B** in terms of I_0.

intensity ∝ amplitude^2; amplitude A = 10 μm, B = 24 μm

intensity of B = (24 / 10)^2 I_0 = 5.76 I_0

intensity = ...5.8... I_0 **[2]**

(d) Determine the resultant displacement at the point **P** at time t = 2.5 ms.

at 2.5 ms: x_A = +10 μm and x_B = 0, sum = 10 μm

resultant displacement = ...10... μm **[1]**

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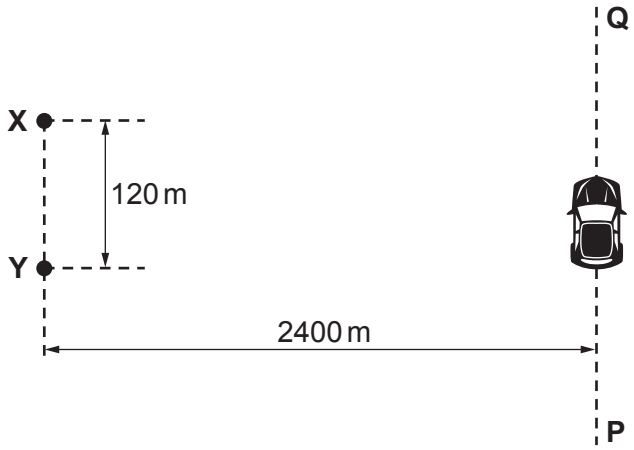
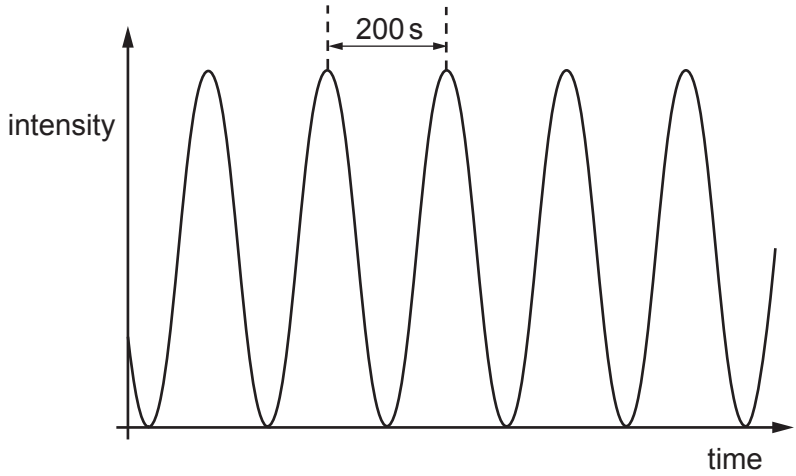
27 The diagram below shows two coherent sources of radio waves **X** and **Y**.



The diagram is **not** drawn to scale.

The radio waves are in phase at **X** and **Y**.
A car moves at a constant speed along the line **PQ**. The line **PQ** is parallel to line **XY**.
The separation between **X** and **Y** is 120 m.
The perpendicular distance between lines **PQ** and **XY** is 2400 m.

The intensity against time graph below shows the variation of the intensity of the radio waves at the position of the moving car.



(a) State the **principle of superposition of waves**.

Where two or more waves meet, the resultant displacement is equal to the sum of the individual displacements of the waves. **[1]**

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(b) Explain the maxima and minima in the variation of the intensity.

Maxima: constructive interference, the waves arrive in phase,

phase difference zero, path difference = nλ.

Minima: destructive interference, phase difference 180°,

path difference = (n + ½)λ. **[2]**

(c) The time between adjacent maxima is 200 s.
The speed of the car is 18 m s^{-1}.

Calculate the wavelength λ of the radio waves.

distance between adjacent maxima x = vt

x = 18 × 200 = 3600 m

λ = ax / D

λ = (120 × 3600) / 2400

λ = 180 m **[3]**

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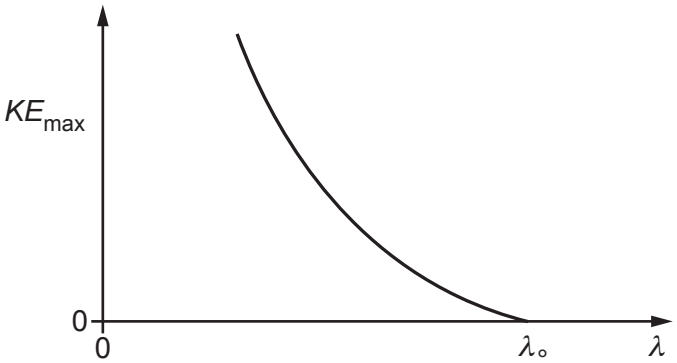
28 **(a)** Electromagnetic radiation, with a range of wavelengths, is incident on a metal.
Electrons are removed from the metal due to the photoelectric effect.

The maximum kinetic energy KE_{max} of the emitted electrons against wavelength λ graph is shown below.



Explain the shape of the graph in terms of quantum physics.

Radiation is photons; one photon interacts with one electron. Energy of photon = work function + KE_{max}, so $KE_{max} = hc/\lambda - \varphi$; as λ increases the photon energy decreases, so KE_{max} decreases.

At λ_0 the photon energy equals the work function, so $KE_{max} = 0$. For $\lambda > \lambda_0$ photon energy < work function, so no electrons are emitted.

..... **[3]**

(b) Some lasers are used in eye surgery.
One such laser emits a beam of light of wavelength 490 nm and power 230 mW.

Calculate

(i) the energy of each photon of light from the laser.

$E = hc / \lambda$

$E = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / 490 \times 10^{-9}$

$E = 4.06 \times 10^{-19}$ J

energy = 4.1×10^{-19} J **[2]**

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(ii) the number of photons of light emitted in each second.

number per second = power / energy of each photon

$= 0.230 / 4.06 \times 10^{-19}$

$= 5.67 \times 10^{17}$

number of photons = 5.7×10^{17} **[2]**

END OF QUESTION PAPER

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ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

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