Oxford Cambridge and RSA

A Level Physics B (Advancing Physics)

H557/01 Fundamentals of Physics

Thursday 15 June 2017 – Morning

Time allowed: 2 hours 15 minutes

You must have:
- The Data, Formulae and Relationships Booklet (sent with general stationery)

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

First name	
Last name	

Centre number						Candidate number				

INSTRUCTIONS
- Use black ink. You may use an HB pencil for graphs and diagrams.
- Complete the boxes above with your name, centre number and candidate number.
- Answer **all** the questions.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the barcodes.

INFORMATION
- The total mark for this paper is **110**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended responses will be assessed in questions marked with an asterisk (*).
- This document consists of **36** pages.

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SECTION A

You should spend a maximum of 40 minutes on this section.

Write your answer for each question in the box provided.

Answer **all** the questions.

1 Which pair contains one vector and one scalar quantity?

A velocity acceleration

B displacement force

C kinetic energy work done

D momentum distance

Your answer ☐ **[1]**

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

A $1\ C\ V^{-1}$

B $1\ S^{-1}$

C $1\ C^2\ J^{-1}\ s^{-1}$

D $1\ A\ V^{-1}$

Your answer ☐ **[1]**

3 Which quantity is followed by a reasonable estimate of its order of magnitude?

A weight of an apple 10^0 N

B volume of a table tennis ball 10^3 cm^3

C wavelength of infra-red radiation 10^4 m

D temperature of Sun's surface 10^5 K

Your answer ☐ **[1]**

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4 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 $\frac{V_{total}}{V_{noise}} \approx 10^3$

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]**

Turn over for the next question

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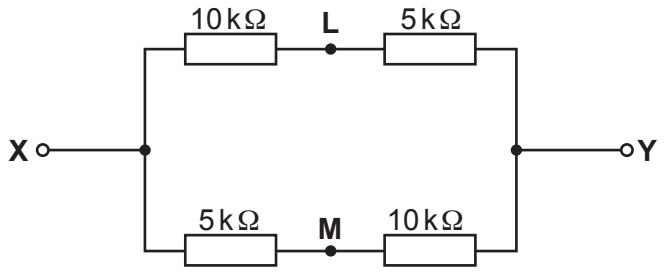
The following information is for use in questions **5** and **6**.

The diagram shows a combination of four resistors.



5 What is the resistance between **X** and **Y**?

A 5 kΩ

B 7.5 kΩ

C 15 kΩ

D 30 kΩ

Your answer ☐ **[1]**

6 A battery of e.m.f. 12 V and negligible internal resistance is connected across **X Y**.

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]**

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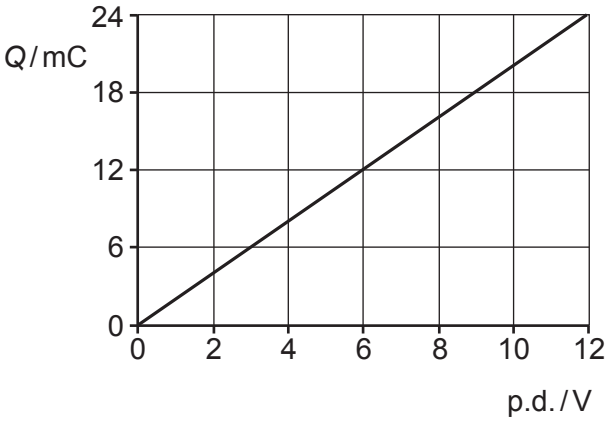
The following information is for use in questions **7** and **8**.

The diagram shows the $Q - V$ graph for a capacitor charged to 12 V.



7 What is the capacitance?

A 2×10^{-3} F

B 144×10^{-3} F

C 288×10^{-3} F

D 500 F

Your answer ☐ **[1]**

8 Which of the following is the energy stored?

A 2×10^{-3} J

B 144×10^{-3} J

C 288×10^{-3} J

D 500 J

Your answer ☐ **[1]**

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9 Electrons accelerated through a potential difference *V* pass through a thin layer of graphite. The beam forms a diffraction pattern of rings on a fluorescent screen.
When *V* is made larger the diameter of the rings get smaller and they also become brighter.

Which **one** of the following statements about this experiment is correct?

A The power delivered to the fluorescent screen decreases as *V* increases.

B The diameter of the diffraction rings is independent of the interatomic spacings in graphite.

C The wavelength of the electrons decreases as their kinetic energy increases.

D The momentum of the electrons decreases as *V* increases.

Your answer ☐ **[1]**

10 Which **one** of the following statements about photons is correct?

The probability of arrival of a photon at a position

A is proportional to the amplitude of the waves arriving at that position.

B is greater if the phasor amplitudes for paths from the source to that position "curl up" when they are added.

C is proportional to the (resultant phasor amplitude)^2 for all photon paths from the source to that position.

D is proportional to the phasor amplitude for the photon path straight from the source to that position.

Your answer ☐ **[1]**

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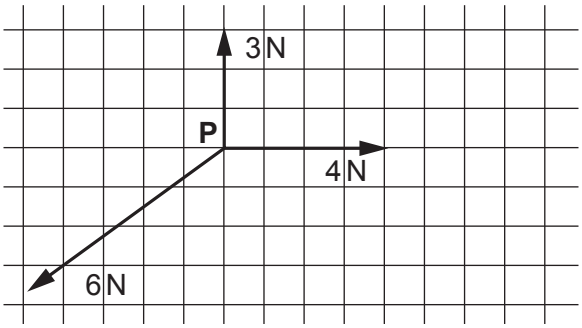
11 The three forces in this vector diagram act in one plane on an object **P**.



What is the magnitude and direction of the resultant?

A 1 N ↙

B 1 N ↗

C 1 N →

D 11 N ↙

Your answer ☐ **[1]**

12 A car travelling at $10\,\mathrm{m\,s^{-1}}$ is brought to rest in a braking distance of 10 m.

Using the same average braking force, in what distance can the car be brought to rest from a speed of $40\,\mathrm{m\,s^{-1}}$?

A 20 m

B 40 m

C 80 m

D 160 m

Your answer ☐ **[1]**

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13 The drag force F of the air on a train is

$$F \approx 10v^2$$

where F is in newtons and the speed v is in $\mathrm{m\,s^{-1}}$.

What **power** must be delivered by the engine to keep the train travelling at a constant $50\,\mathrm{m\,s^{-1}}$?

A 25 kW

B 125 kW

C 1.25 MW

D 2.5 MW

Your answer ☐ **[1]**

14 Suppose that a particular radioactive nucleus is observed for a period of time to find when it decays.
The isotope's half-life is 1 hour, and after 1 hour the particular nucleus has **not** decayed.

The chance that it will decay in the next second

A cannot be stated because the chance varies randomly from second to second.

B is now half the chance that it had to decay in the first second.

C is just the same as the chance that it would have decayed in the first second or any other second.

D is the same as the chance that it will not decay in the next second.

Your answer ☐ **[1]**

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The following information is for use in questions **15** and **16**.

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.

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

A $\frac{1}{4}$

B $\frac{1}{2}$

C 2

D 4

Your answer ☐ **[1]**

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

A $\frac{1}{4}$

B $\frac{1}{2}$

C 2

D 4

Your answer ☐ **[1]**

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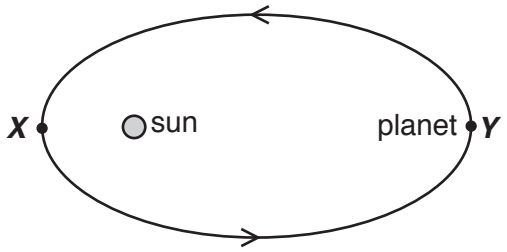
The following information is for use in questions **17** and **18**.

A planet is in elliptical orbit around the Sun as shown.



17 Which of the following is correct?

A As the planet leaves ***X*** it is speeding up.

B As the planet approaches ***X*** it is slowing down.

C As the planet approaches ***Y*** it is speeding up.

D As the planet leaves ***Y*** it is speeding up.

Your answer ☐ **[1]**

18 Which of the following quantities is **greater** at ***Y*** than at ***X***?

A the gravitational force on the planet from the sun

B the gravitational potential energy of the planet-sun system

C the kinetic energy of the planet in its orbit

D the total energy of the planet-sun system

Your answer ☐ **[1]**

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19 Two samples **L** and **M** contain the same mass of an ideal gas.

In which of the following cases will it always be true that the molecules in **L** have a larger root mean square speed than those in **M**?

1 **L** is at a greater temperature than **M**

2 **L** has a greater volume than **M**

3 **L** is at a greater pressure than **M**

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]**

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20 At 300 K a process has an activation energy $E = 10kT$.

The temperature is raised to 330 K.

Which statement about the rate of the process is correct?

It will increase by

A 10% because temperature has increased by 10%.

B 10% because the mean square speed of the particles has increased by 10%.

C 9.1 times because $\frac{E}{kT} = \frac{3000k}{330k} = 9.1$.

D 2.5 times because $e^{\frac{-E}{kT}}$ has increased by $\frac{e^{-9.1}}{e^{-10}} = 2.5$ times.

Your answer ☐ **[1]**

21 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]**

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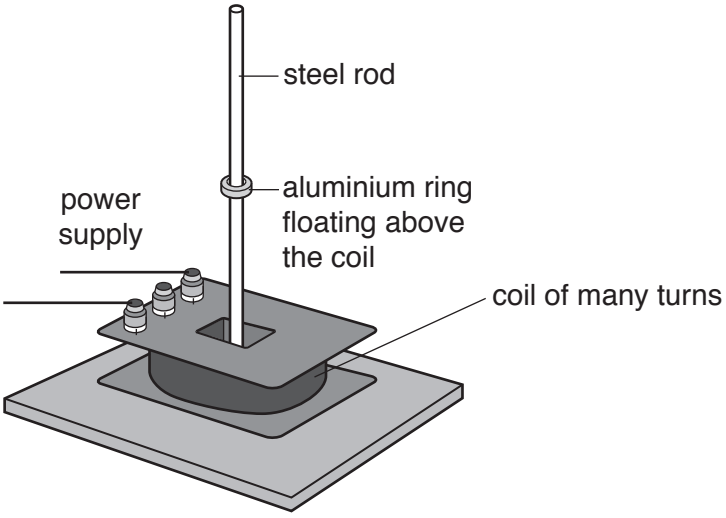
22 An aluminium ring is free to move on a steel rod.
When the power supply is on, the ring floats.



Which of the following is correct?

A An a.c. or d.c. power supply can be used.

B The induced current in the ring is in the same direction as the current in the coil.

C The only purpose of the steel rod is to support the ring.

D When the ring is pushed down towards the coil more flux links it and the induced current increases.

Your answer ☐ **[1]**

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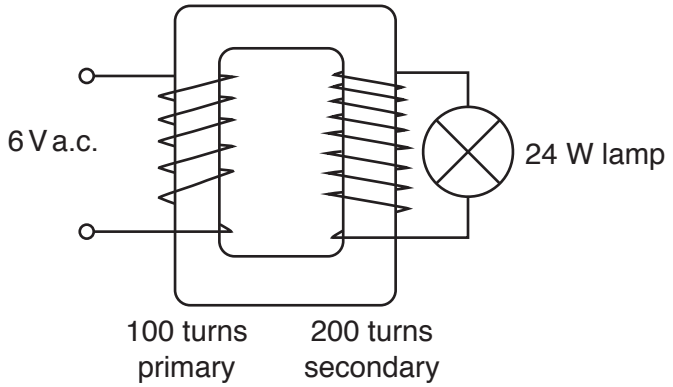
The following information is for use in questions **23** and **24**.

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.



23 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]**

24 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]**

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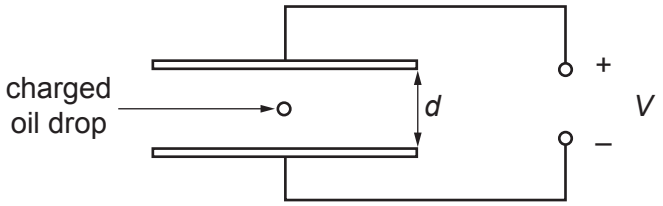
25 An oil drop of mass m charged by one electron is balanced between two parallel horizontal metal plates. A potential difference V is applied between the plates as shown.



Which expression shows the balanced electrical and gravitational forces acting?

A $eVd = mg$

B $\frac{eV}{d} = mg$

C $\frac{V}{ed} = mg$

D $\frac{dV}{e} = mg$

Your answer ☐ **[1]**

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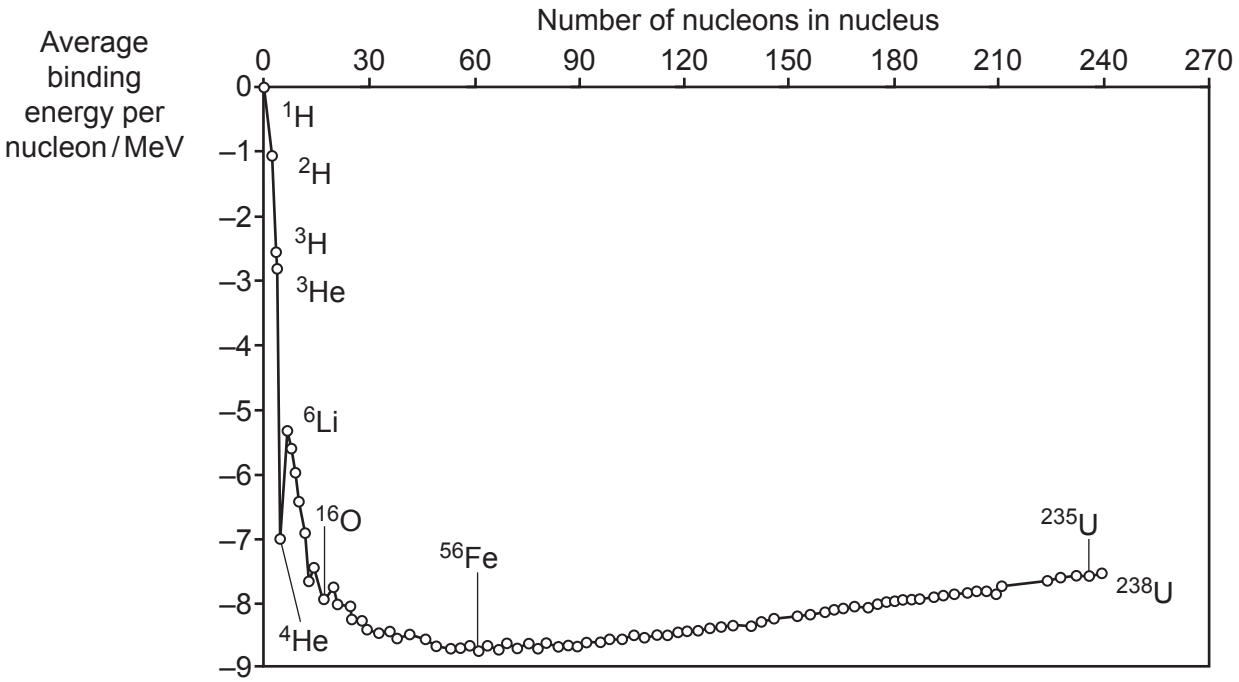
The following information is for use in questions **26** and **27**.

The graph shows how the binding energy per nucleon varies with the nucleon number for stable nuclei.



26 Which **one** of the following statements is correct?

A All unstable nuclei have less binding energy than stable nuclei.

B ^{56}Fe requires less energy per nucleon than other stable nuclei to pull it apart into individual nucleons.

C Binding energy can be released in the fission of some heavy elements

D Binding energy is the energy released when a nucleus breaks down into individual nucleons.

Your answer ☐ **[1]**

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27 Which is the best estimate for the total binding energy for a nucleus of $^{16}_{8}O$ (Oxygen)?

A – 10 pJ

B – 20 pJ

C – 64 pJ

D – 128 pJ

Your answer ☐ **[1]**

28 Isotopes of a given element all have the same

A proton number.

B charge / mass ratio.

C neutron number.

D nucleon number.

Your answer ☐ **[1]**

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29 Which of the following statements about the α-particle and the β-particle is correct?

A If both have the same kinetic energy, the speed of the β-particle is less than that of the α-particle.

B If both have the same momentum, the de Broglie wavelength of the α-particle must be the same as that of the β-particle.

C If both have the same momentum, the kinetic energy of the α-particle is greater than that of the β-particle.

D The rest energies of both the α-particle and the β-particle are the same.

Your answer ☐ **[1]**

30 $^{214}_{82}Pb$ decays by a series of transformations to a final stable product.

The particles emitted are: β, β, α, β, β, α.

Which one of the isotopes below is the final product?

A $^{206}_{82}Pb$

B $^{210}_{82}Pb$

C $^{208}_{83}Bi$

D $^{214}_{83}Bi$

Your answer ☐ **[1]**

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SECTION B

Answer **all** the questions.

31 The main bolt of a lightning strike flows through air already ionised by a “leader” strike.

(a) 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]

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32 This question is about refractive index.

For light passing from a vacuum into a medium, the refractive index is $n_{medium} = \frac{c}{c_{medium}}$

(a) Complete this line of algebraic reasoning.

$$n_{glass} = \frac{c}{c_{glass}}, \quad n_{water} = \frac{c}{c_{water}} \quad \rightarrow \quad \frac{n_{glass}}{n_{water}} = \frac{_____}{_____} = \frac{c_{water}}{c_{glass}}$$ **[1]**

(b) **Fig. 32.1** shows a ray of light going from glass into water at an angle of incidence $i = 30°$.

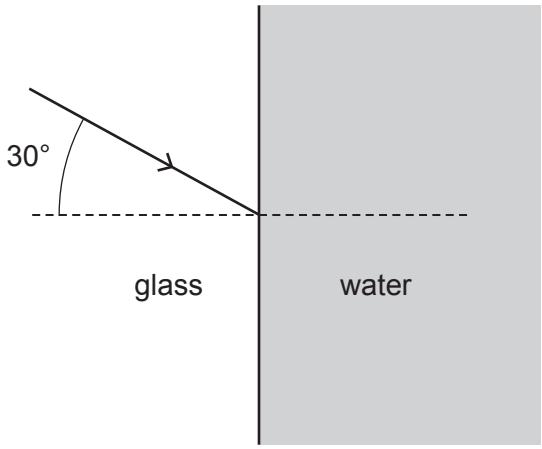

Fig. 32.1

Calculate the angle of refraction r in the water.

$n_{glass} = 1.6$ $\quad$ $n_{water} = 1.3$

$r =$ ..... ° **[2]**

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

(a) **(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]**

(ii) 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]**

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34 A student makes an iterative model for the decay of charge on a capacitor. The time constant of the circuit is $RC = 10\,\text{s}$.

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

(a) Complete the numerical values in the two blank cells in the table. **[2]**

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

.....

.....

.....

..... **[2]**

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

.....

.....

.....

..... **[2]**

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35 An asteroid is tracked from the Earth by radar pulses.
A pulse places it at a distance of 44.444 light-minutes from Earth.
After 24 hours a second pulse places it 44.204 light-minutes from Earth.

(a) Use this data to calculate the average velocity of approach of the asteroid relative to Earth.

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

(b) The path of the asteroid is shown in **Fig. 36.1**. After 24 hours the angular shift in position of the asteroid relative to Earth is 1.8 mrad.

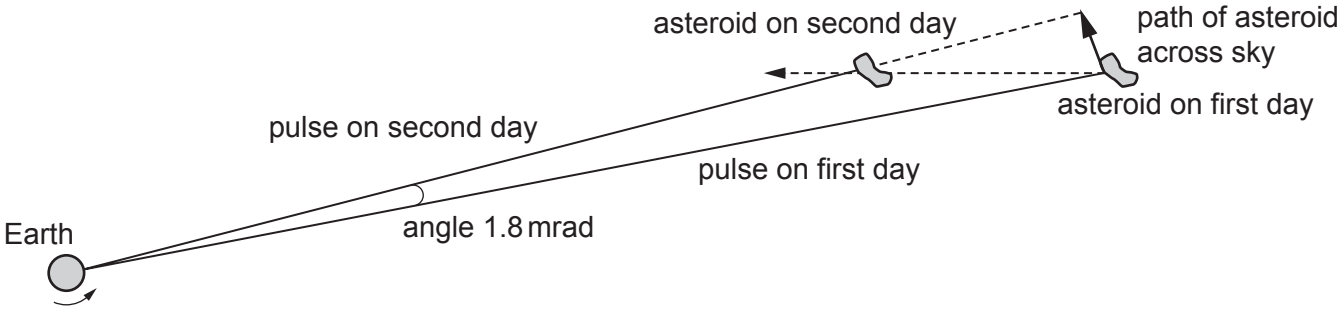

Fig. 36.1 (not to scale)

Estimate the velocity component of the asteroid perpendicular to its direction from Earth.
Make your method clear.

perpendicular velocity = ... $m\,s^{-1}$ **[3]**

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SECTION C

Answer **all** the questions.

36 The Moon is in circular orbit around Earth at constant speed.

(a) Explain why we describe the Moon as accelerating towards the Earth.

.....

.....

..... **[2]**

(b) **(i)** Starting from the equation for circular motion show that the acceleration of the Moon towards the Earth is given by $a = \frac{4\pi^2 R}{T^2}$

where the Moon's orbital radius is R and the Moon's orbital time is T.

[1]

(ii) Show that the Moon's acceleration is less than $3\,\text{mm}\,\text{s}^{-2}$.

$R = 3.84 \times 10^8\,\text{m}$ $\quad T = 2.35 \times 10^6\,\text{s}$

[1]

(iii) The Moon's orbital radius $R = 60 \times R_{\text{Earth}}$.
The gravitational acceleration at the Earth's surface $g = 9.8\,\text{m}\,\text{s}^{-2}$.
Calculate the acceleration due to the Earth's gravity at the Moon's orbit.
Compare this value to the value calculated in **(ii)**.

acceleration = ... $\text{m}\,\text{s}^{-2}$

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

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37 A ball bearing of diameter 12 mm was dropped through a tube of glycerol (a viscous liquid). The tube was next to a millimetre scale as shown in **Fig. 37.1**. The ball bearing was dropped from rest at the surface of the liquid. It was filmed using a video camera.

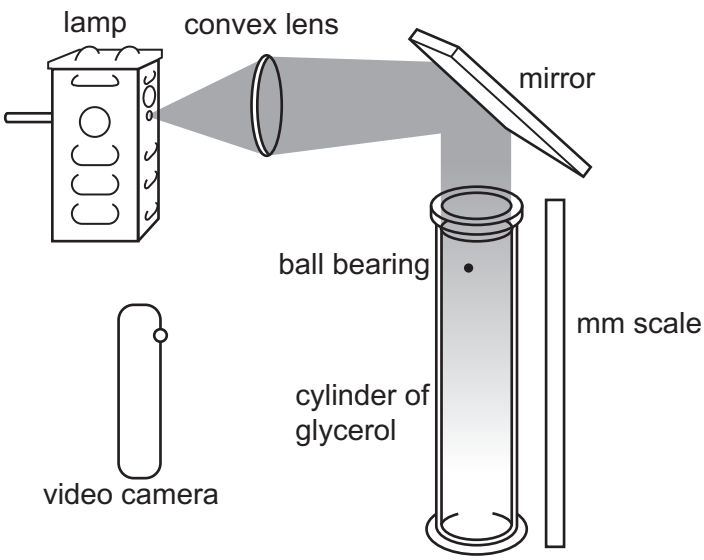

Fig. 37.1

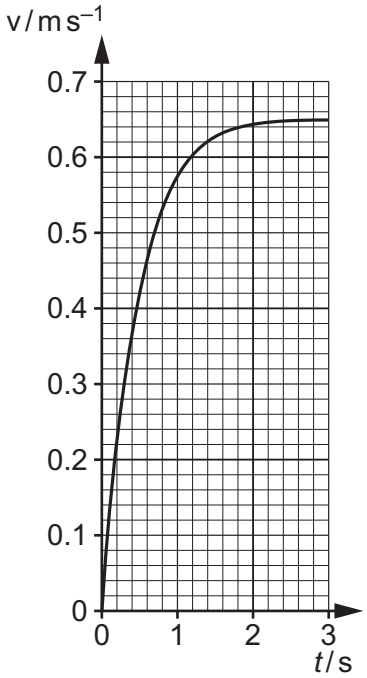

Fig. 37.2

(a) **Fig. 37.2** shows the graph of velocity against time obtained by analysing the video recording. This method has an uncertainty of about ± 3% for velocity measurement.

Use data from **Fig. 37.2** and the measurement precision to calculate the terminal velocity of the ball bearing and its absolute uncertainty.

terminal velocity = ... ± ..... $m\,s^{-1}$ **[2]**

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(b) Describe the motion shown in the graph at time $t = 0.5\,\text{s}$ and explain it by reference to the forces acting on the ball bearing.

.....

.....

.....

.....

..... **[2]**

(c) **(i)** The investigation is extended to see how the terminal velocity v_T varies with ball bearing diameter D.

Identify and justify **one** other variable that you would control during this investigation.

.....

.....

.....

.....

..... **[2]**

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(ii) This table shows the data obtained in the extended investigation.

Diameter *D* / mm	**Terminal velocity v_T / m s^{-1}**
12.0	0.65
10.0	0.49
6.0	0.25
4.0	0.11
2.4	0.04

For a sphere falling through a viscous medium it is suggested that

$$v_T \propto D^2$$

Use data points from the table to propose and carry out a test of this relationship and state your conclusion.

proposal	working	conclusion

[5]

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38 **Fig. 38.1** shows a displacement *s* against time *t* graph for the motion of a swing in simple harmonic motion.

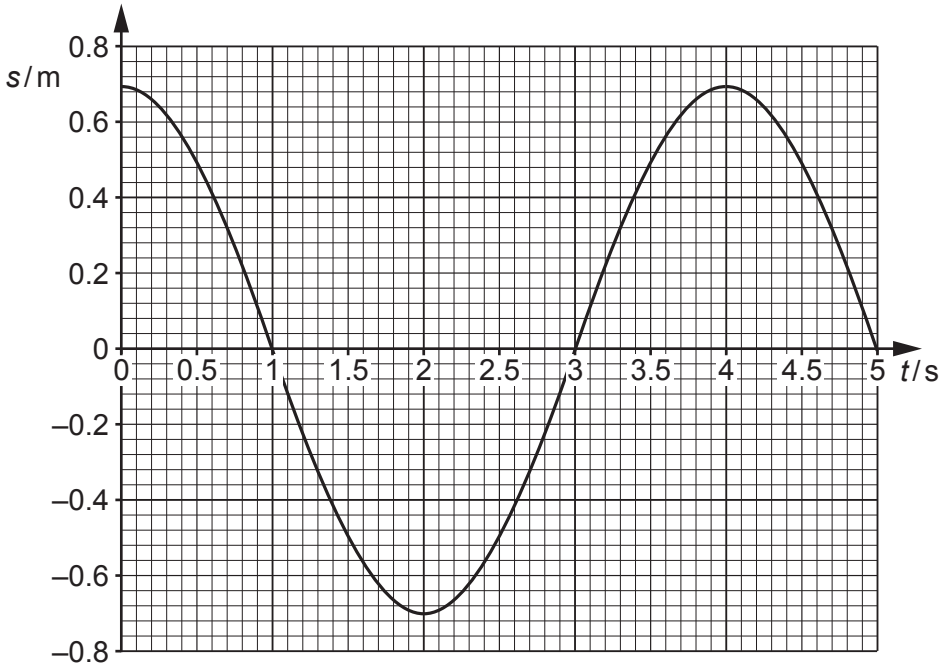

Fig. 38.1

(a) Use **Fig. 38.1** to find the magnitude of the maximum velocity of the swing.
Make your method clear.

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

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(b) On **Fig. 38.2** scale the *y*-axis suitably and draw the velocity *v* against time *t* graph for this motion.

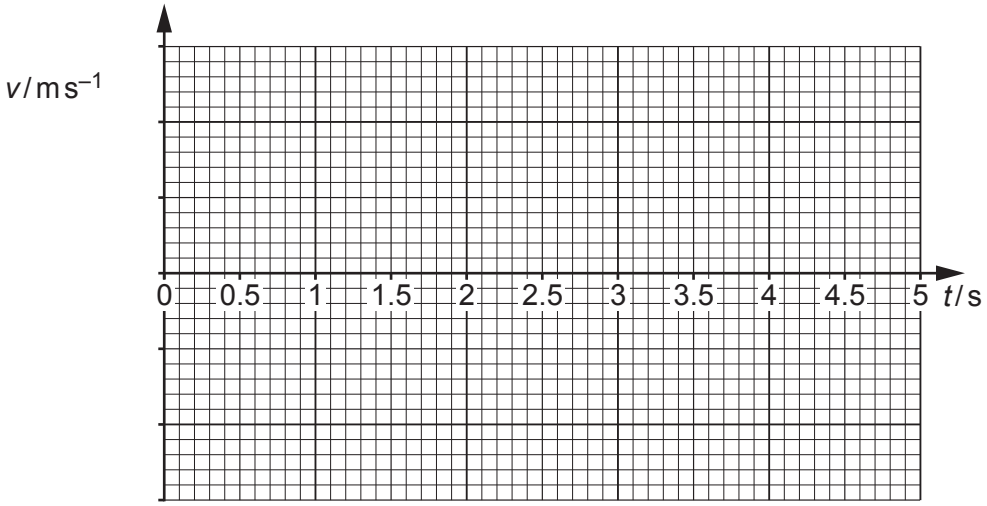

Fig. 38.2

[2]

(c) Show that the length of the simple pendulum having the same time period as the swing in **Fig. 38.1** is less than 4.0 m.

[2]

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39 A class observes the absorption of α, β and γ radiation.
A Geiger tube is placed 1.0 cm from radioactive sources **X**, **Y** and **Z** as shown in **Fig. 39.1**.

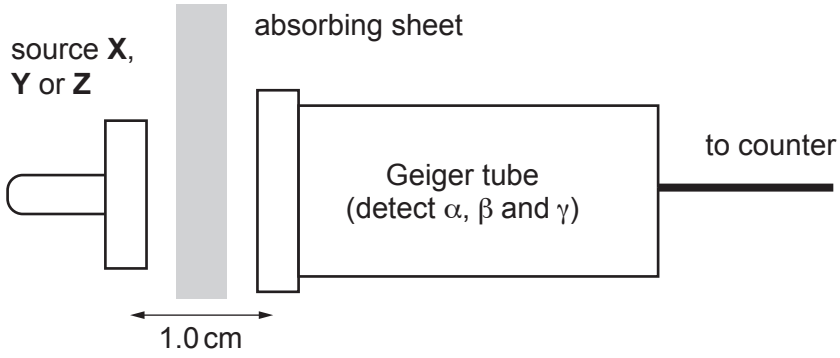

Fig. 39.1

The time to reach 10^4 counts is recorded and the count rate C per second is calculated with an uncertainty of ± 1%. The data has been corrected for background radiation.

	count rate C / s^{-1}			
Absorbing material	**1.0 cm air**	**0.1 mm paper**	**2 mm aluminium**	**5 mm lead**
Source X	395	397	22	background
Source Y	950	420	138	35
Source Z	550	547	238	27

(a) One of the sources emits α, β and γ radiation,
one source emits β and γ
and one source emits pure β.

For each source below state which radiations are emitted. Justify your choices using data from the table.

X emits ..... justification .....

.....

Y emits ..... justification .....

.....

Z emits ..... justification .....

.....

.....

[3]

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(b) A source emits α, β and γ radiation. The corrected count rate C from the source is plotted against distance R from a thin window Geiger tube as shown in **Fig. 39.2**.
Fig. 39.3 shows the same data in log / log graph form.

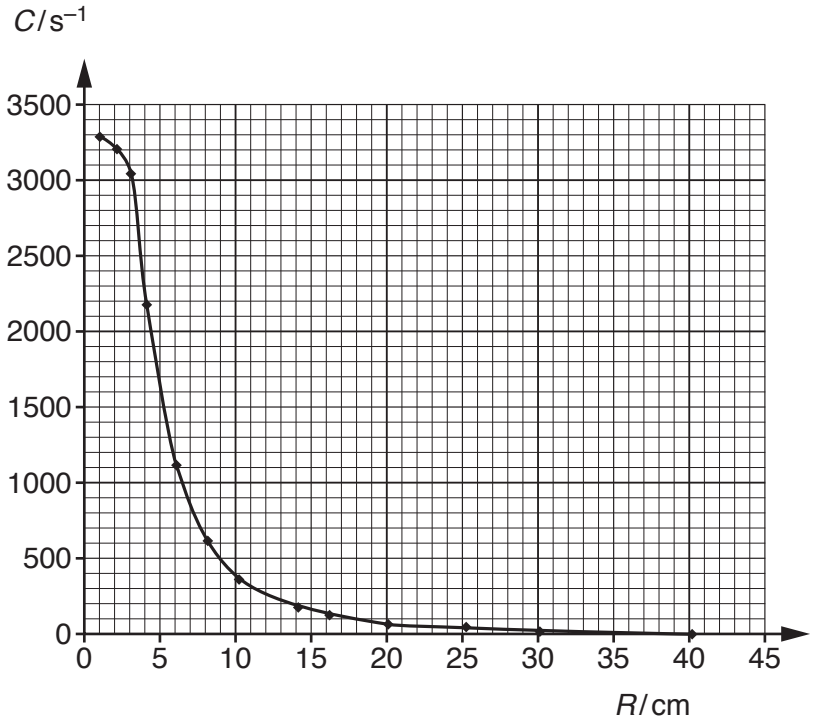

Fig. 39.2

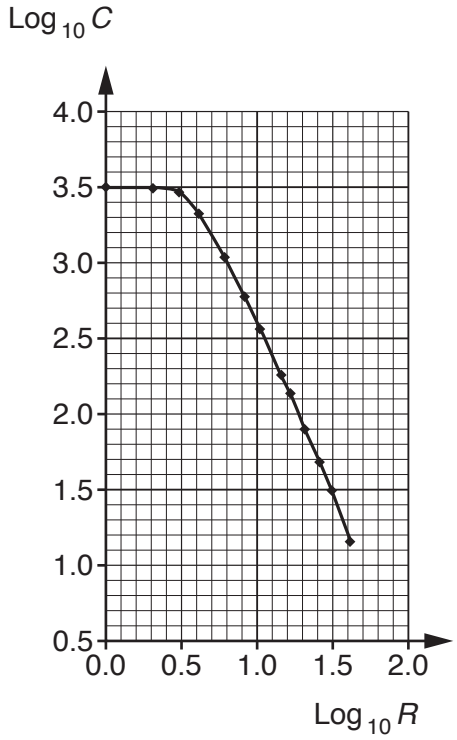

Fig. 39.3

(i) Calculate the gradient of the sloping part of the log / log graph in **Fig. 39.3**.

gradient = ... **[2]**

(ii) State whether the graph shows that the count rate C varies as $C \propto \frac{1}{R^2}$

and explain which radiation(s) α, β or γ might be responsible for such a variation.

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..... **[4]**

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40 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.

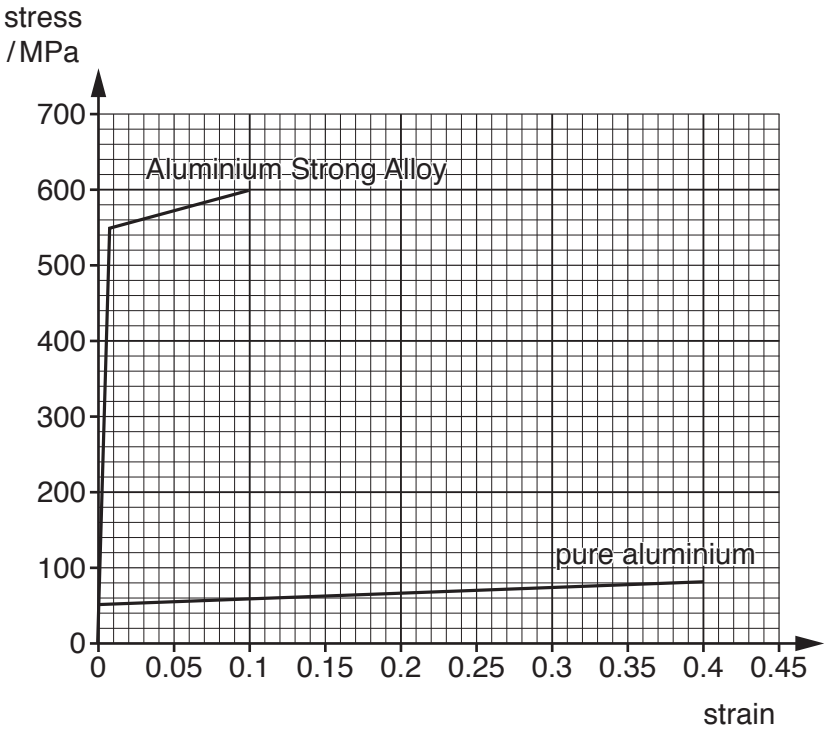

Fig. 40.1

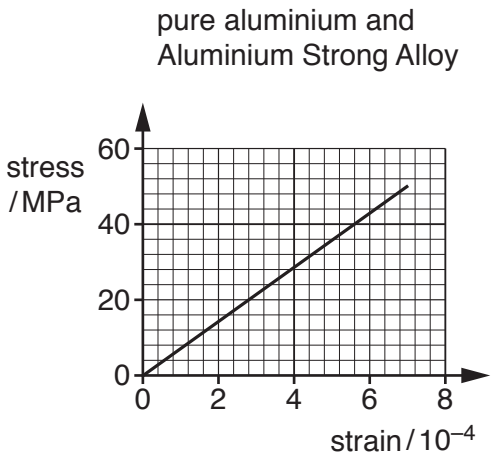

Fig. 40.2

(a) 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.

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..... **[2]**

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

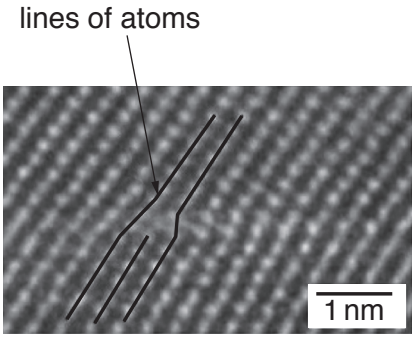

Fig. 40.3

(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 structure ..... **[1]**

(d)* Use ideas about bonding and structures in pure metals and alloys to explain the similarities and differences in elastic and plastic properties of aluminium and its strong alloy shown in **Fig. 40.1**.

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..... **[6]**

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41 **Fig. 41.1** shows the electric field pattern near two protons and **Fig. 41.2** the electric field pattern near a proton and an electron.

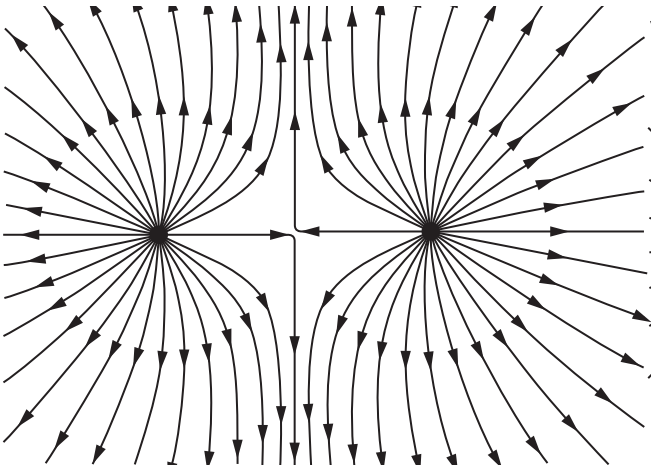

Fig. 41.1

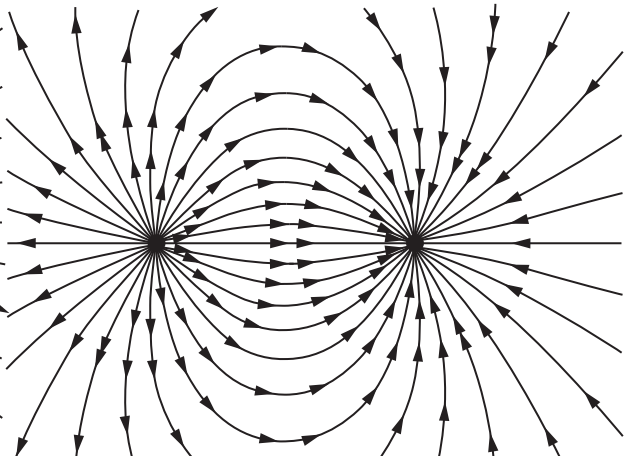

Fig. 41.2

(a) On the appropriate figure(s) mark a point • **N** where the electric field is zero and a point • **V** where the electric potential is zero. **[2]**

(b) On each of **Fig. 41.1** and **41.2** draw **three** complete equipotential lines. **[2]**

(c) **Fig. 41.2** can also represent two spherical charge distributions of +1 C and –1 C situated 1 km apart.

Calculate the electric field midway between the charge centres, at 500 m from each.

electric field = ... $V\,m^{-1}$ **[2]**

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(d)* **Fig. 41.3** shows the electrical potential V and the magnitude of the electric field E against distance R for an isolated –1 C charge.

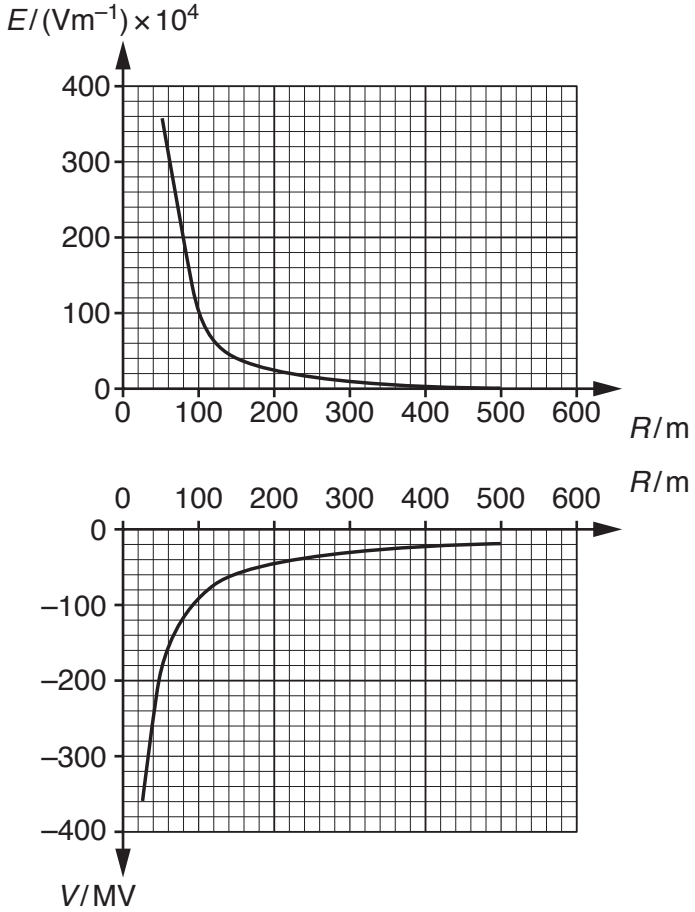

Fig. 41.3

By considering a unit positive charge being moved from R = 100 m to 300 m explain the relationship between the electric field and the electric potential.
You may annotate the graphs in **Fig. 41.3** if it is helpful.

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..... **[6]**

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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