Cambridge Assessment International Education

Cambridge Pre-U

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

9579583042

PHYSICS **9792/03**

Paper 3 Written Paper **May/June 2022**

3 hours

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Section 1: answer **all** questions.
- Section 2: answer **three** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 140.
- The number of marks for each question or part question is shown in brackets [ ].

This syllabus is regulated for use in England, Wales and Northern Ireland as a Cambridge International Level 3 Pre-U Certificate.

This document has **40** pages. Any blank pages are indicated.

DC (LK/CB) 302916/3

Data

gravitational field strength close to Earth's surface	$g = 9.81\,\mathrm{N\,kg^{-1}}$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
speed of light in vacuum	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
electron mass	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
proton mass	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
unified atomic mass constant	$u = 1.66 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
Stefan-Boltzmann constant	$\sigma = 5.67 \times 10^{-8}\,\mathrm{W\,m^{-2}\,K^{-4}}$

Formulae

uniformly accelerated motion

$$s = ut + \tfrac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

$$s = \left(\frac{u+v}{2}\right)t$$

heating

$$\Delta E = mc\Delta\theta$$

change of state

$$\Delta E = mL$$

refraction

$$n = \frac{\sin\theta_1}{\sin\theta_2}$$

$$n = \frac{v_1}{v_2}$$

diffraction

single slit, minima $n\lambda = b\sin\theta$

grating, maxima $n\lambda = d\sin\theta$

double slit interference $\lambda = \dfrac{ax}{D}$

Rayleigh criterion $\theta \approx \dfrac{\lambda}{b}$

photon energy $E = hf$

de Broglie wavelength $\lambda = \dfrac{h}{p}$

simple harmonic motion $x = A\cos\omega t$

$v = -A\omega\sin\omega t$

$a = -A\omega^2\cos\omega t$

$F = -m\omega^2 x$

$E = \frac{1}{2}mA^2\omega^2$

energy stored in a capacitor $W = \frac{1}{2}QV$

capacitor discharge $Q = Q_0 e^{-\frac{t}{RC}}$

electric force $F = \dfrac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$

electrostatic potential energy $W = \dfrac{Q_1 Q_2}{4\pi\varepsilon_0 r}$

gravitational force $F = -\dfrac{Gm_1 m_2}{r^2}$

gravitational potential energy $E = -\dfrac{Gm_1 m_2}{r}$

magnetic force $F = BIl\sin\theta$

$F = BQv\sin\theta$

electromagnetic induction $E = -\dfrac{\mathrm{d}(N\Phi)}{\mathrm{d}t}$

Hall effect $V = Bvd$

time dilation $t' = \dfrac{t}{\sqrt{1 - \dfrac{v^2}{c^2}}}$

length contraction $l' = l\sqrt{1 - \dfrac{v^2}{c^2}}$

kinetic theory $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$

work done on/by a gas $W = p\Delta V$

radioactive decay $\dfrac{\mathrm{d}N}{\mathrm{d}t} = -\lambda N$

$N = N_0 e^{-\lambda t}$

$t_{\frac{1}{2}} = \dfrac{\ln 2}{\lambda}$

attenuation losses $I = I_0 e^{-\mu x}$

mass-energy equivalence $\Delta E = c^2\Delta m$

hydrogen energy levels $E_n = \dfrac{-13.6\,\text{eV}}{n^2}$

Heisenberg uncertainty principle $\Delta p\Delta x \geqslant \dfrac{h}{2\pi}$

Wien's displacement law $\lambda_{\text{max}} \propto \dfrac{1}{T}$

Stefan's law $L = 4\pi\sigma r^2 T^4$

electromagnetic radiation from a moving source $\dfrac{\Delta\lambda}{\lambda} \approx \dfrac{\Delta f}{f} \approx \dfrac{v}{c}$

Section 1

Answer **all** questions in this section.
You are advised to spend about 1 hour 30 minutes on this section.

1 **(a)** Define capacitance.

.... [1]

(b) A capacitor of capacitance 250 μF and a resistor of resistance R are connected in a circuit with a two-way switch. The switch initially connects point S to point X, as shown in Fig. 1.1.

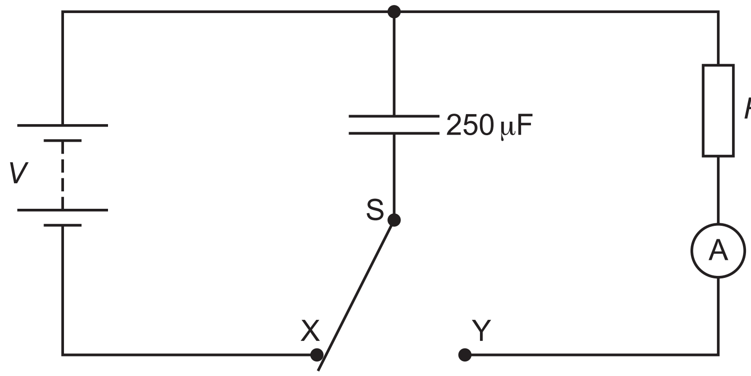

Fig. 1.1

The energy stored in the capacitor is 4.5 mJ.

Show that the electromotive force (e.m.f.) V of the battery is 6.0 V.

[2]

(c) The switch in Fig. 1.1 is now moved so that it connects point S to point Y. The current I in the ammeter varies with time t. At t = 0, the current is I_0. The variation of $\ln\left(\frac{I}{I_0}\right)$ with t is shown in Fig. 1.2.

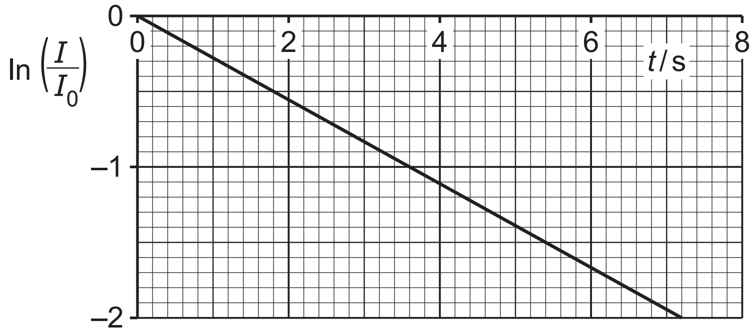

Fig. 1.2

(i) Determine the time constant for the discharge of the capacitor.

time constant = ... s [3]

(ii) Calculate *R*.

R = ... Ω [2]

(iii) On Fig. 1.3, sketch the variation of I with t between $t = 0$ and $t = 8.0\,s$.

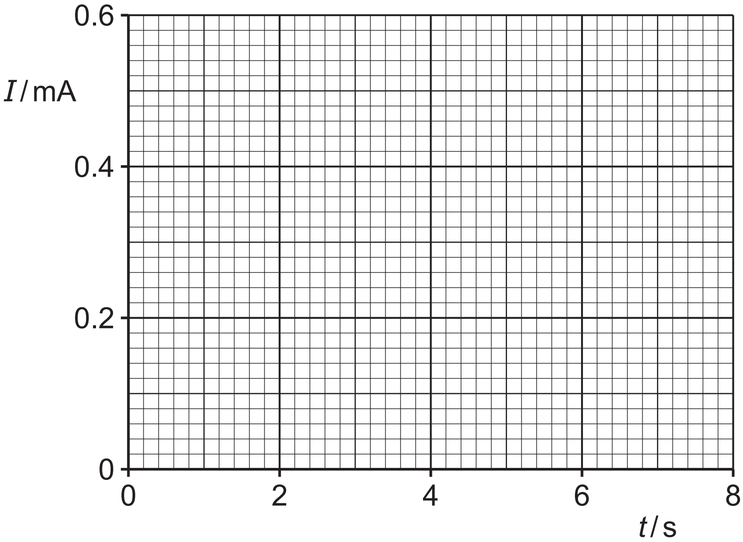

Fig. 1.3

[4]

[Total: 12]

2 A binary star system consists of two stars X and Y that orbit around their common centre of gravity C. The orbits are circular. Both stars can be considered as point masses.

The mass of star X is M and the mass of star Y is $2M$. The common centre of gravity is at a distance of D from star Y, and at a distance of $2D$ from star X, as shown in Fig. 2.1.

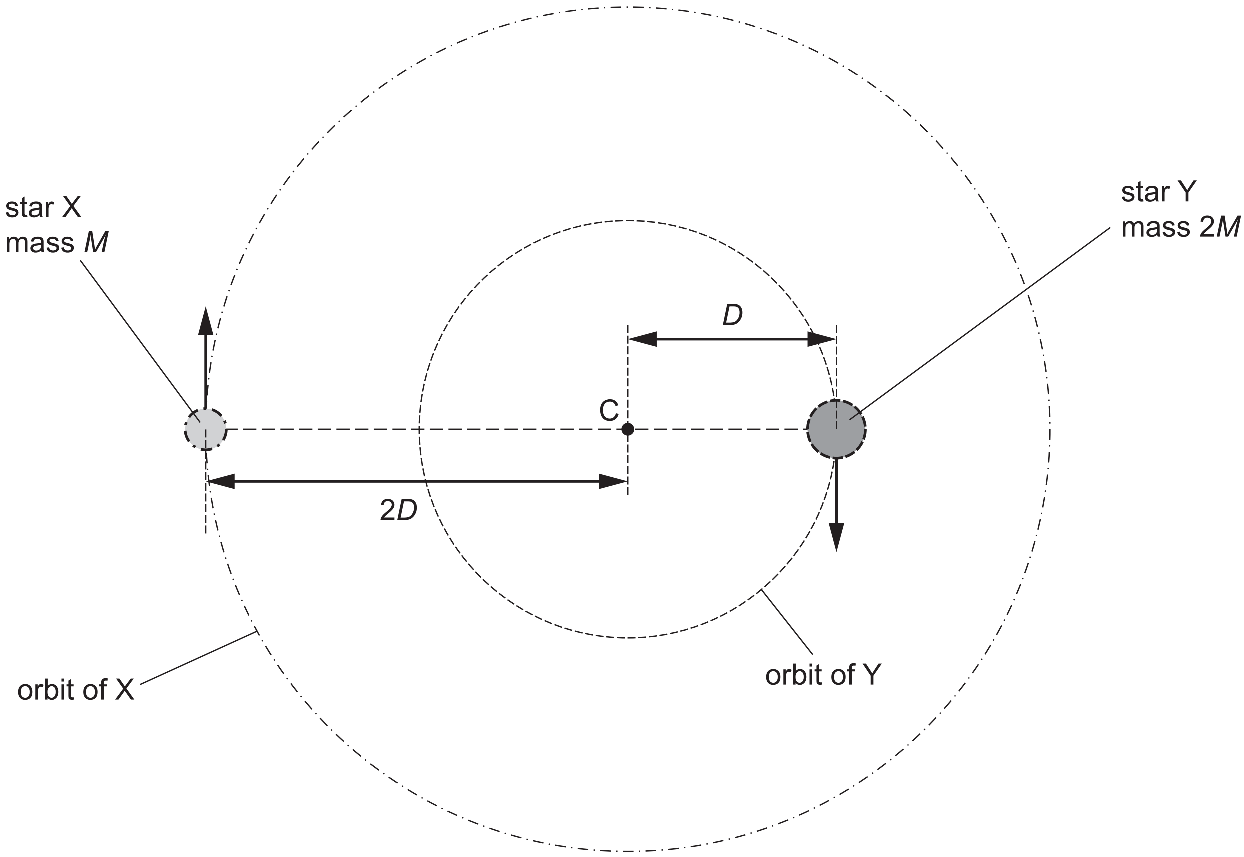

Fig. 2.1

(a) State the expression for the gravitational force F between the two stars, in terms of M, D and the universal gravitational constant G.

[2]

(b) Star X orbits with angular velocity ω.

Show that the angular velocity of the orbit of star Y is also ω.

[2]

(c) **(i)** Show that the kinetic energy E_X of star X is given by

$$E_X = \frac{2GM^2}{9D}.$$

[3]

(ii) Deduce an expression, in terms of G, M and D, for the total energy E of the binary star system.

[3]

(d) Suggest, with a reason, whether or not two identical electric charges could form a system in which the charges orbit around a common centre.

....

....

.... [2]

[Total: 12]

3 A circular copper ring of radius 9.3 cm is stationary in a uniform magnetic field of flux density 0.34 mT, as shown in Fig. 3.1.

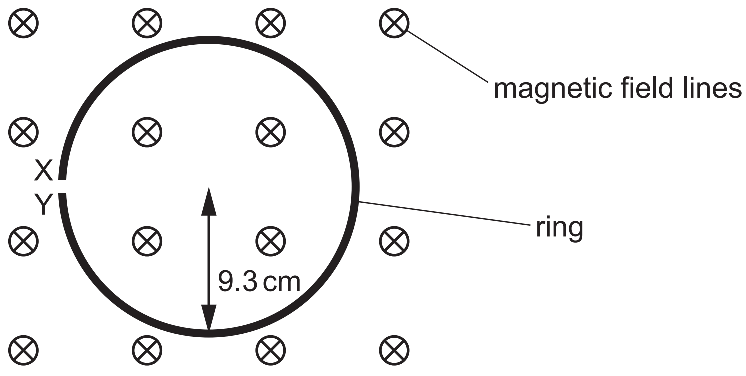

Fig. 3.1

There is a small gap in the ring between points X and Y. The direction of the magnetic field is into the plane of the paper.

(a) A potential difference (p.d.) is applied across the gap so that there is a current of 5.6 A in the ring from X to Y.

(i) Calculate the magnitude of the magnetic force per unit length acting on the ring.

force per unit length = ... $N\,m^{-1}$ [2]

(ii) On Fig. 3.1, draw arrows to indicate the directions of the magnetic force acting on the ring. [2]

(b) The potential difference applied in **(a)** is now removed.

(i) Calculate the magnetic flux linkage in the ring. Give a unit with your answer.

magnetic flux linkage = ... unit .... [3]

(ii) The ring is rotated 180° about an axis that is perpendicular to the magnetic field, so that the ring ends up with the gap on the opposite side, as shown in Fig. 3.2.

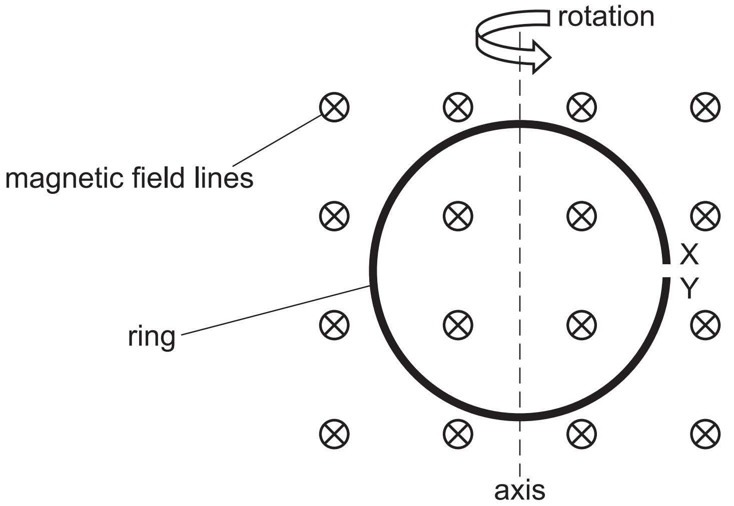

Fig. 3.2

It takes a time of 0.20 ms for the gap XY to move from its original position shown in Fig. 3.1 to its final position shown in Fig. 3.2.

Calculate the average electromotive force (e.m.f.) induced across XY during this process.

e.m.f. = ... V [3]

[Total: 10]

4 A student is investigating how the volume V of an ideal gas under certain conditions varies with its absolute temperature T. The student uses a syringe that has a volume of $100\,cm^3$, as shown in Fig. 4.1.

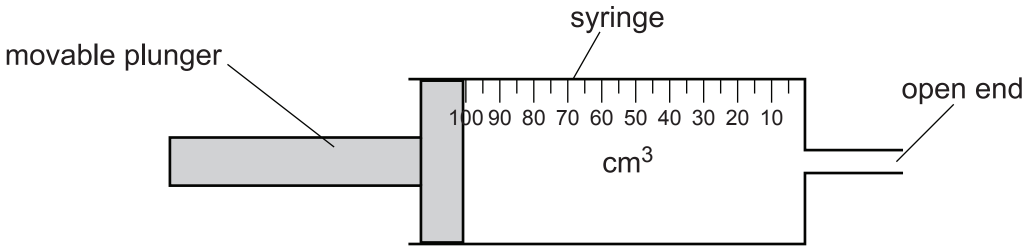

Fig. 4.1

The student moves the plunger of the syringe so that the volume of the air in the syringe is approximately $50\,cm^3$. The student then seals the open end of the syringe and clamps the syringe so that it is immersed in a large beaker of water, as shown in Fig. 4.2. The plunger is air-tight but free to move up and down.

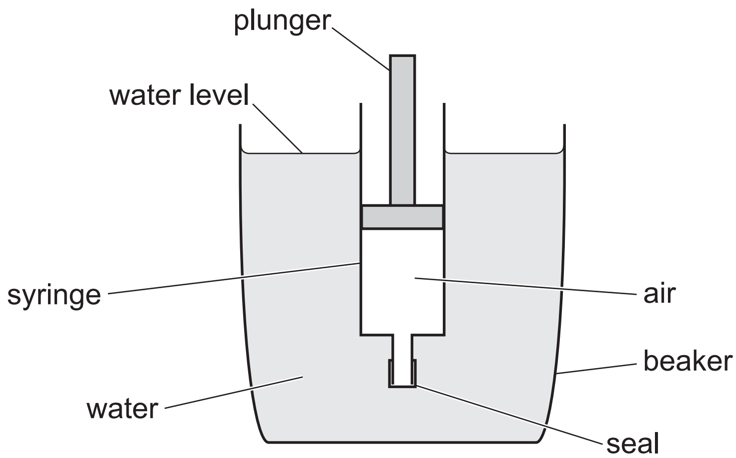

Fig. 4.2

The water in the beaker is heated, and the volume of air in the syringe is recorded at different temperatures of the water.

(a) **(i)** State **two** physical quantities that the experimental set-up ensures remain constant, so that the investigation is a fair test.

1. ....

2. ....
[2]

(ii) For each of your two quantities in **(a)(i)**, describe how the set-up of the experiment controls them to ensure that they remain constant.

1. ....

....

2. ....

.... [2]

(b) The results obtained by the student are shown in Table 4.1.

Table 4.1

temperature / °C	volume / cm^3
29	50.1
41	52.1
58	54.8

(i) State the reason why increasing the temperature from 29 °C to 58 °C does not result in the volume of air in the syringe doubling.

.... [1]

(ii) Determine, with a reason, whether or not the results in Table 4.1 support Charles's law.

....

....

.... [2]

(c) State **three** improvements that the student could make to the experiment in order for it to more strongly support a conclusion.

1. ....

....

2. ....

....

3. ....

.... [3]

(d) Use the kinetic theory to explain the variation of V with T when all other variables remain constant.

....

....

....

.... [3]

[Total: 13]

5 **(a)** Define the activity of a radioactive sample.

....

.... [1]

(b) A radioisotope X decays into stable isotope Y.

A sample initially contains 2.0 mol of atoms of X and no atoms of Y.

Fig. 5.1 shows the variation with time t of the ratio $\frac{N_Y}{N_X}$, where N_Y is the number of atoms of Y present in the sample and N_X is the number of atoms of X present.

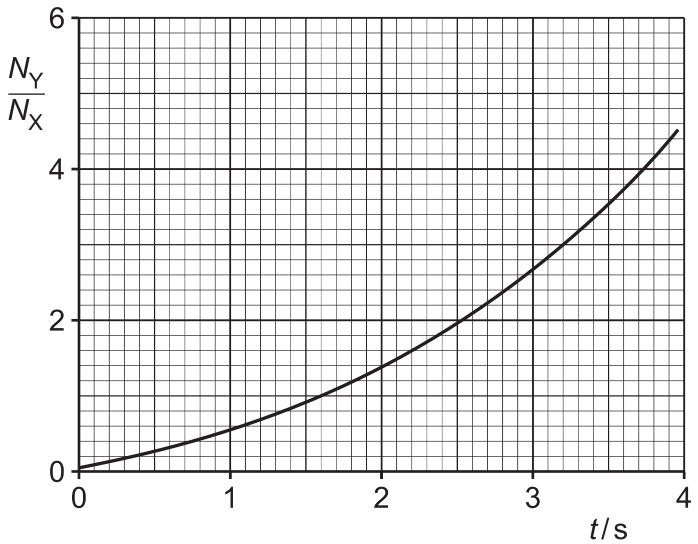

Fig. 5.1

(i) Show that, when t = 4 half-lives, the ratio $\dfrac{N_Y}{N_X}$ is equal to 15.

[3]

(ii) Use Fig. 5.1 to determine the half-life of X.

half-life = ... s [2]

(iii) Calculate the decay constant λ of X. Give a unit with your answer.

λ = ... unit .... [2]

(iv) Calculate the activity A_0 of the sample at time t = 0.

A_0 = ... Bq [3]

[Total: 11]

6 A cosmologist observing astronomical objects that act as standard candles takes measurements of the radiant flux intensity F of the light received from each object. The cosmologist also analyses the light from each object to determine its speed v of movement away from the Earth. The values of F and v for each object, along with its luminosity L, are shown in Table 6.1.

Table 6.1

astronomical object	$L / 10^{31}\,\mathrm{W}$	$F / 10^{-17}\,\mathrm{W\,m^{-2}}$	$v / 10^{4}\,\mathrm{m\,s^{-1}}$	$\lg(v / \mathrm{m\,s^{-1}})$	$\lg\left(\frac{L}{F} / \mathrm{m^2}\right)$
A	3.8	1.4	98	5.99	48.43
B	3.8	9.3	39		
C	3.8	59	16		
D	190 000	78	3100		
E	190 000	1100	860		
F	190 000	7400	320		

(a) State what is meant by a standard candle.

....

.... [1]

(b) Explain how the cosmologist uses the light from an astronomical object to determine its speed of movement away from Earth.

....

....

.... [2]

(c) Calculate the values of $\lg(v / \mathrm{m\,s^{-1}})$ and $\lg\left(\frac{L}{F} / \mathrm{m^2}\right)$, for each of the objects B to F, and enter them into the spaces in the final two columns of Table 6.1. Give each value to two decimal places. [2]

(d) On Fig. 6.1, plot a graph of $\lg\left(\frac{L}{F}/\mathrm{m}^2\right)$ against $\lg(v/\mathrm{m\,s^{-1}})$ using the data in Table 6.1. Include the line of best fit.

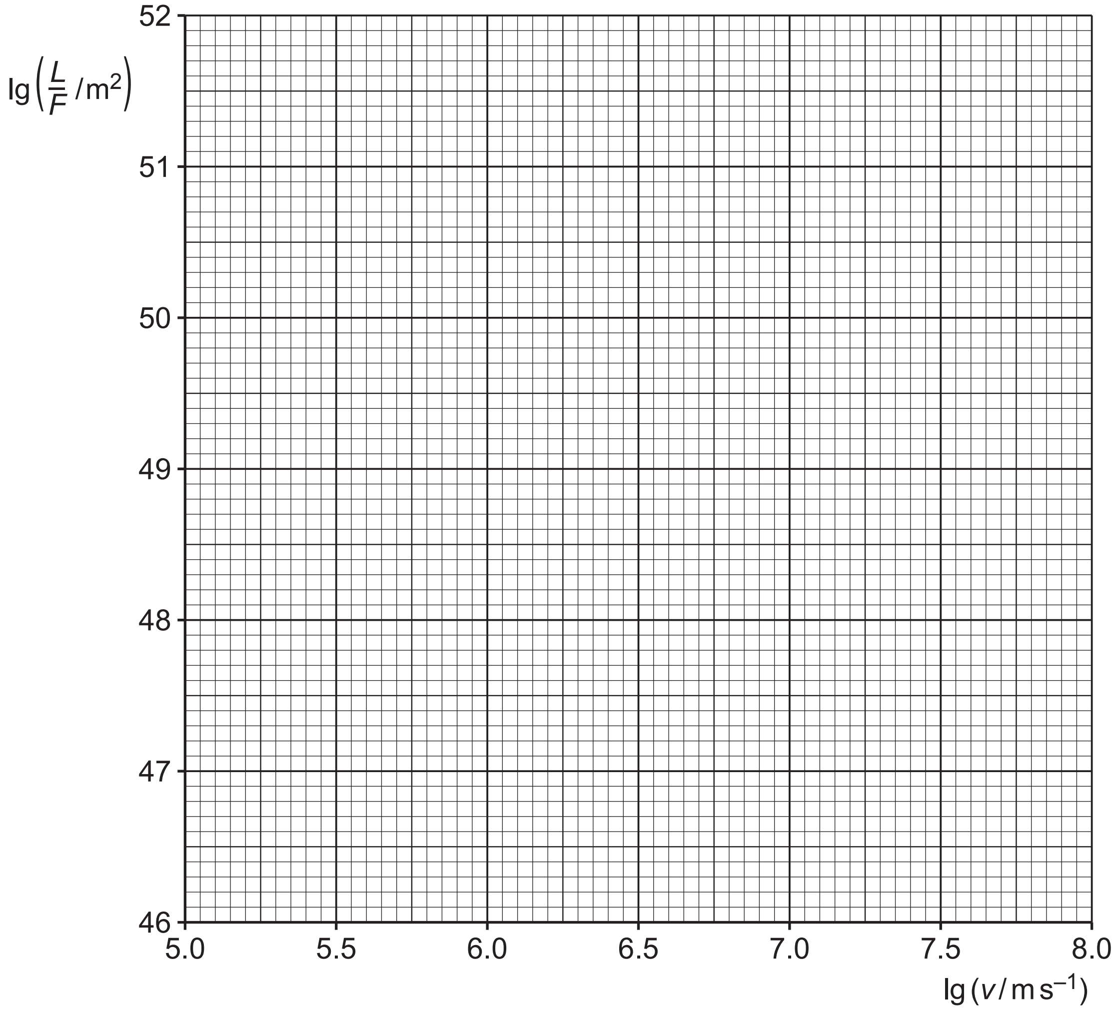

Fig. 6.1

[3]

(e) For your line of best fit in **(d)**, determine the gradient *m* and *y*-intercept *c*.

m = ...

c = ...

[2]

(f) **(i)** Use the relationship between radiant flux intensity and luminosity, as well as Hubble's law, to show that

$$\lg\left(\frac{L}{F}\right) = \lg(4\pi) - 2\lg(K) + n\lg(v)$$

where n is a dimensionless constant and K is a constant with SI unit s^{-1}.

[3]

(ii) State the meaning of K.

....

.... [1]

(g) Use your answers in **(e)** and the information in **(f)(i)** to determine a value for K.

K = ... s^{-1} [2]

[Total: 16]

7 Fig. 7.1 shows the lowest four energy levels of the electron in a hydrogen atom.

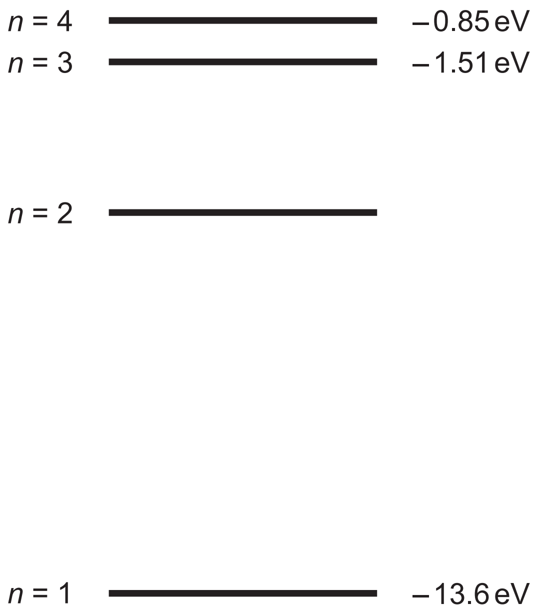

Fig. 7.1

(a) **(i)** Show that the energy level corresponding to $n = 2$ is equal to –3.40 eV.

[1]

(ii) State the name of the series of lines in the emission spectrum of hydrogen that arises from transitions to the level $n = 2$.

.... [1]

(b) Calculate the wavelength, in nm, of the line in the emission spectrum of hydrogen that represents the largest wavelength arising from transitions to the level $n = 1$.

wavelength = ... nm [4]

[Total: 6]

Section 2

Answer any **three** questions in this section.
You are advised to spend about 1 hour 30 minutes on this section.

8 **(a)** Fig. 8.1 shows a rod rotating about an axis through its centre and at right angles to the rod.

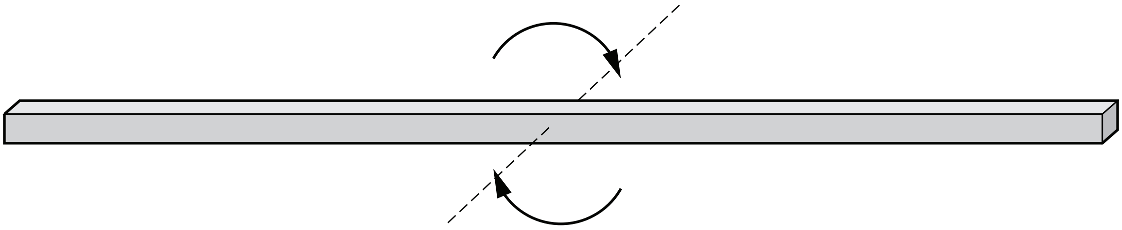

Fig. 8.1

The moment of inertia I of a thin uniform rod of mass m and length L rotating about an axis through its centre and at right angles to the rod, as shown in Fig. 8.1, is given by:

$$I = \frac{1}{12} mL^2.$$

(i) The wooden uniform rod in Fig. 8.1 has length 1.4 m and cross-sectional area $5.0 \times 10^{-4}\,\mathrm{m}^2$. The density of the wood is $800\,\mathrm{kg\,m^{-3}}$.

Show that the moment of inertia about its centre of mass is about $0.09\,\mathrm{kg\,m^2}$.

[2]

(ii) A small hole is drilled through the centre of the rod. The rod is placed over a fixed horizontal pin so that it is free to rotate in the vertical plane with negligible frictional force. The rod is initially at rest. A force of 0.20 N is applied at one end at right angles to the rod for 0.50 s.

Calculate the final angular velocity of the rod.

angular velocity = ... $\mathrm{rad\,s^{-1}}$ [3]

(iii) Calculate the final rotational kinetic energy of the rod.

rotational kinetic energy = ... J [2]

(iv) Fig. 8.2 shows a thin uniform rod of mass m and length L rotating about a point at one end of the rod.

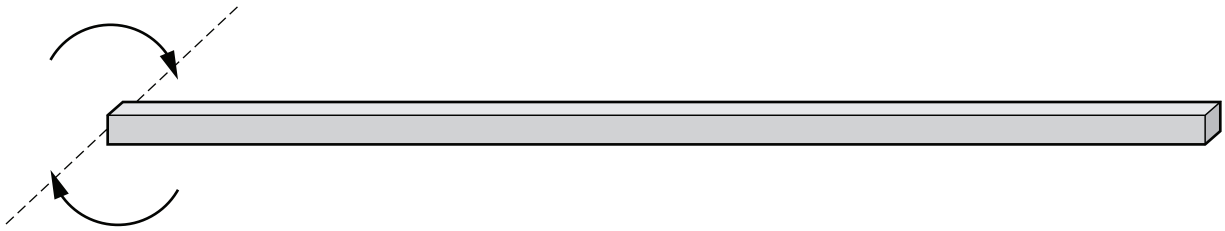

Fig. 8.2

By integration, or otherwise, determine an expression for the moment of inertia of the rod rotating about an axis at one end of the rod and at right angles to the rod.

[3]

(v) It is quite easy to balance a 1.4 m long wooden rod with a cross-sectional area of $5.0 \times 10^{-4}\,\mathrm{m}^2$ vertically on the horizontal palm of your hand. The rod may wobble but by moving your hand a little you can keep it almost vertical. It is very difficult for most people to do the same with a small rod, like a pencil, 0.14 m long with cross-sectional area $5.0 \times 10^{-5}\,\mathrm{m}^2$ and made from the same wood.

Explain using calculations why this is so.

....

....

....

....

....

....

.... [4]

(b) A cylinder is a thick disc, so the moment of inertia of a cylinder radius r and mass m about an axis through its centre and at right angles to the flat surface is given by $I = \frac{1}{2}mr^2$.

The moment of inertia of a hollow cylinder of mass m is given by $I = \frac{1}{2}m(a^2 + b^2)$ where a is the outer radius and b the inner radius.

The cylinder P shown in Fig. 8.3 has radius 30.0 mm, length 60.0 mm and mass 1.528 kg. Cylinder P has a solid cylindrical core of mass 0.193 kg of a metal of density $4000\,\mathrm{kg\,m^{-3}}$ inside an outer sleeve of mass 1.335 kg made of a metal of density $11\,000\,\mathrm{kg\,m^{-3}}$.

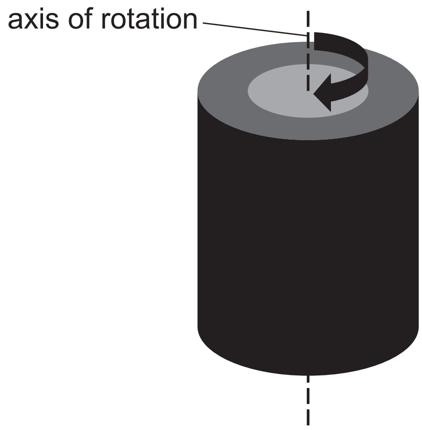

Fig. 8.3

(i) Show that the radius of the cylindrical core of cylinder P is 16 mm.

[1]

(ii) Calculate the moment of inertia of cylinder P.

moment of inertia of P = ... $kg\,m^2$ [3]

(iii) A second solid cylinder Q is made of a different metal but has the same radius, length and mass as cylinder P. Q has a lower moment of inertia than P. The cylinders are placed at the top of a gentle slope. They are released from rest at the same time and allowed to roll, as shown in Fig. 8.4.

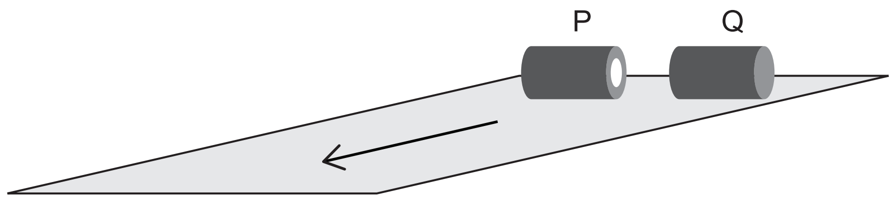

Fig. 8.4

Cylinder Q reaches the bottom end of the slope first.

Explain why by considering energy.

....

....

....

.... [2]

[Total: 20]

9 The electric potential V at a point a distance r from a point charge Q is given by

$$V = k\frac{Q}{r}$$

where k is a positive constant equal to $\frac{1}{4\pi\varepsilon_0}$.

(a) **(i)** Explain what is meant by the electric potential of a point in a field.

....

....

.... [2]

(ii) The electric potential V of a point is a scalar quantity.

Explain what is meant by a scalar quantity.

....

.... [1]

(iii) Explain why electric field strength E is not a scalar quantity.

....

.... [1]

(b) The repulsive force F between charges Q_1 and Q_2 is given by:

$$F = \frac{kQ_1Q_2}{r^2}.$$

Use integration to show that the work W done on the charges when the distance between them decreases from a to b is:

$$W = \frac{kQ_1Q_2(a-b)}{ab}.$$

[3]

(c) Fig. 9.1 shows three point charges arranged at the corners of an equilateral triangle ABC with N at the centre. The charges are of magnitude 4.00 nC. The charge at A is negative and the charges at B and C are positive. The three sides of the triangle are each 80.0 mm long.

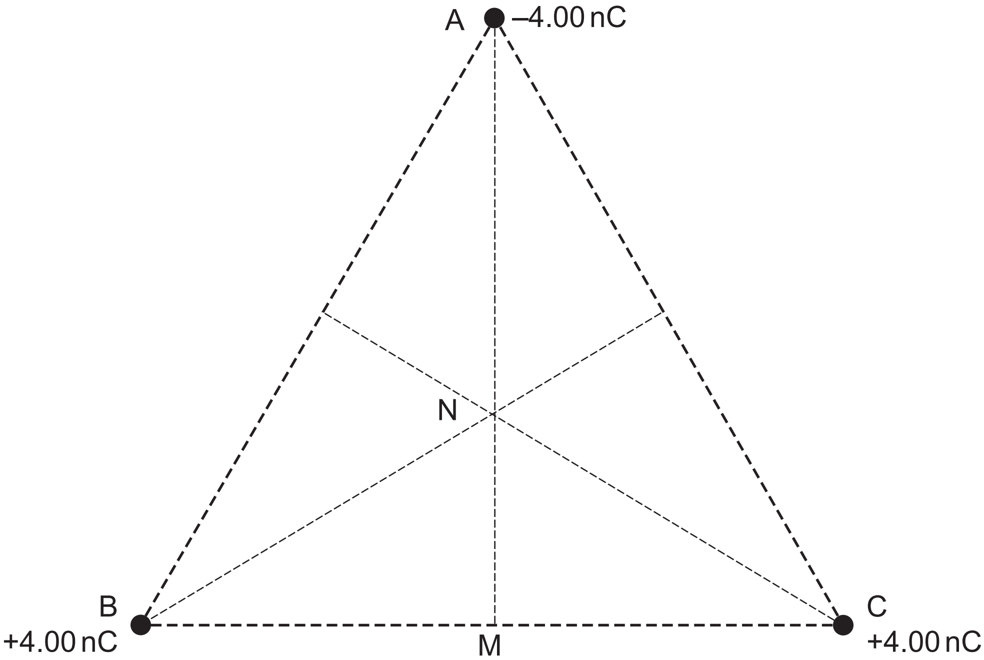

Fig. 9.1

(i) Point M is a point midway between B and C.

Show that the potential at point M is 1.3 kV. Take k to be $8.99 \times 10^9\,\mathrm{m\,F^{-1}}$.

[3]

(ii) On Fig. 9.1, mark with an X the approximate position of the point where the potential is zero. [1]

(d) The –4.00 nC charge at point A in Fig. 9.1 is replaced with a 8.00 nC charge, as shown in Fig. 9.2. The side lengths are still 80.0 mm and the distance between A and N is 46.2 mm.

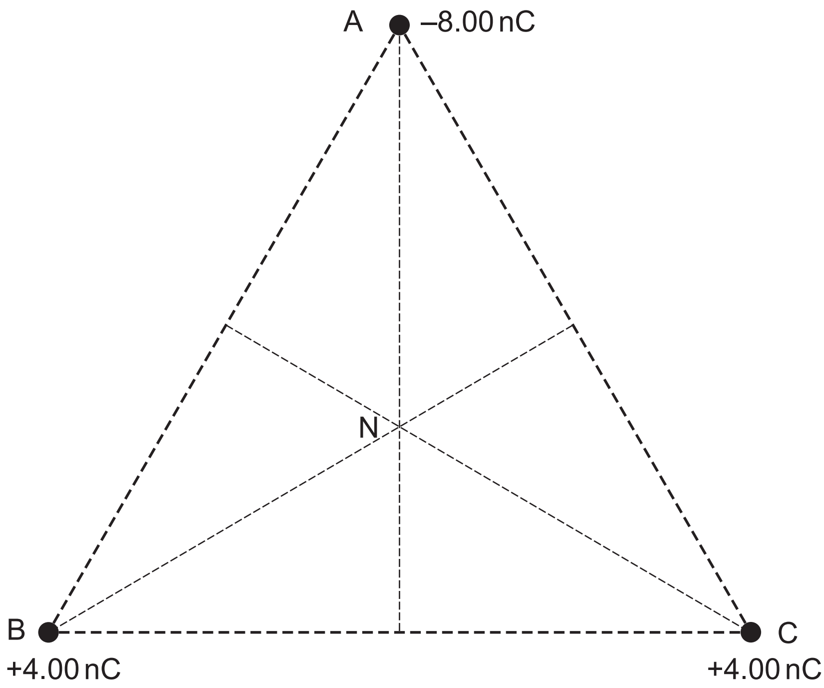

Fig. 9.2

(i) Explain why the potential at the central point N in Fig. 9.2 is zero.

....

.... [1]

(ii) Determine the magnitude and direction of the electric field strength at point N due to the charge at A.

magnitude of electric field strength due to A = ... $V\,m^{-1}$

direction ....
[3]

(iii) Calculate the magnitude of the electric field strength at N due to the charge at B.

magnitude of electric field strength due to B = ... $V\,m^{-1}$ [1]

(iv) A +1.00 nC charge is placed at N.

Determine the magnitude and direction of the force on the +1.00 nC charge.

force = ... N

direction ....
[4]

[Total: 20]

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10 A teacher has told their students that there are several equations for energy of the form:

energy = *half* × *something* × *something else squared*.

The best known is the equation for kinetic energy.

(a) A constant force F is applied for time t to a mass m initially at rest until it reaches velocity v.

(i) Write an expression for the final velocity of the mass in terms of F, m and t.

[2]

(ii) Write an expression for the work done on the mass in terms of F, m and t.

[2]

(iii) From your expressions in **(i)** and **(ii)**, show that the work done in accelerating the mass m from rest to velocity v is $\frac{1}{2}mv^2$.

[2]

(b) A tower of height h is built of bricks of total mass m which were initially on the ground with what may be taken as zero gravitational potential energy. If the tower is of uniform cross-sectional area, the total gravitational potential energy of the bricks in the tower is $\frac{1}{2}mgh$.

Explain the reason for the $\frac{1}{2}$ in the equation.

....

....

....

.... [2]

(c) An object of mass 0.20 kg is suspended on a light spring with spring constant $80\,\mathrm{N\,m^{-1}}$.

(i) Calculate the elastic strain energy in the spring.

elastic strain energy = ... J [2]

(ii) The object is now pulled down a further distance of 15 mm.

Calculate the change in the elastic strain energy stored in the spring.

change in elastic strain energy = ... J [2]

(iii) Calculate the change in the gravitational potential energy of the object in **(ii)** when it was pulled down a further 15 mm.

change in gravitational potential energy = ... J [2]

(iv) The object in **(ii)** is now released.

Calculate the magnitude of the resultant force on the object at the instant after release.

resultant force = ... N [1]

(v) The object in **(iv)** now oscillates with simple harmonic motion.

Calculate the angular frequency of the oscillations.

angular frequency = ... rad s^{-1} [2]

(vi) Use your answer to **(v)** to calculate the energy of the oscillations.

energy of oscillations = ... J [2]

(vii) Show that your answer to **(vi)** is consistent with your answers to **(ii)** and **(iii)**.

[1]

[Total: 20]

11 **(a)** **(i)** Fig. 11.1 shows an isolated long straight wire passing, at right angles, through a rectangular card. There is a constant current in the wire.

Fig. 11.2 shows a view of the card looking along the wire.

On Fig. 11.2, sketch the magnetic field lines at the card.

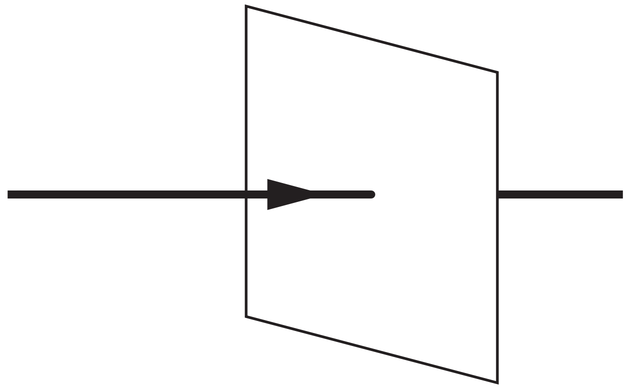

Fig. 11.1

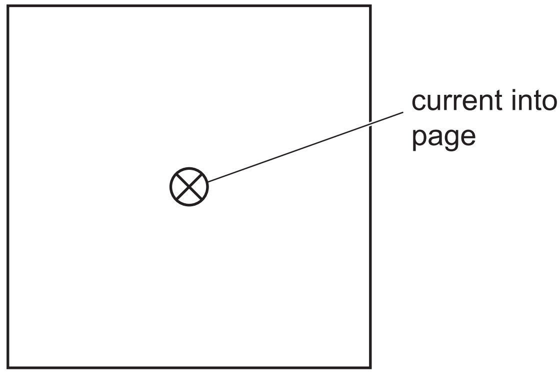

Fig. 11.2

[2]

(ii) Electric field lines start at a positive charge and end at a negative charge.

State **one** difference between magnetic field lines and electric field lines.

....

.... [1]

(iii) A sinusoidal alternating current now replaces the direct current in the wire.

Describe how the magnetic field differs from the magnetic field produced by a direct current.

....

....

.... [2]

(b) In a thought experiment, a long straight wire is broken by a parallel plate capacitor as shown below in Fig. 11.3. There is an alternating current in the wire. Since the magnetic field created by the wire cannot suddenly break, it seems likely the magnetic field is the same around the capacitor as around the wire.

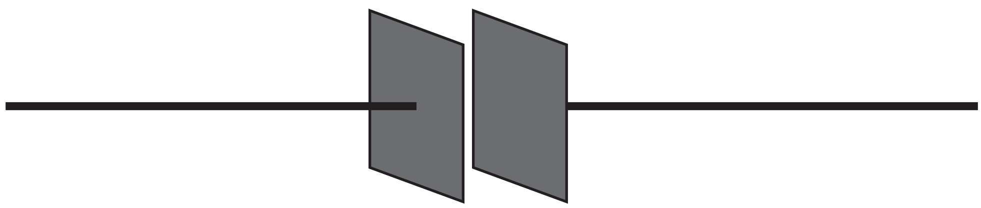

Fig. 11.3

(i) Describe the electric current between the capacitor plates.

.... [1]

(ii) Describe the electric field between the capacitor plates as the current in the wire alternates.

....

.... [2]

(iii) The equation $E = -d(N\Phi)/dt$ is an expression of Faraday's law and Lenz's law.

Explain in words what the equation states about the induced electromotive force.

....

....

....

.... [2]

(iv) The electric field is uniform and the plates are a distance x apart.

State the relationship between electric field E, electric potential difference V and the distance x between the plates.

[1]

(v) A changing magnetic field can create a changing electric field.

Suggest what is creating the changing magnetic field in the space around the capacitor in Fig. 11.3.

.... [1]

(c) Maxwell was able to predict the existence of electromagnetic waves and their speed in a vacuum. But if these were waves, like the others then known, they needed a medium.

(i) State the name given to the medium suggested for electromagnetic waves.

.... [1]

(ii) Experiments could not detect motion of the Earth through this medium. Einstein later transformed the classical view of time and space in his 1905 paper on what is now called special relativity.

State Einstein's two postulates of the special principle of relativity.

....

....

.... [2]

(d) Spacecraft A is moving at a speed of $1.3 \times 10^8\,\mathrm{m\,s^{-1}}$ relative to spacecraft B. A lamp is flashing on spacecraft A set at a frequency of 5.00 Hz.

Calculate the frequency of flash that is observed by spacecraft B.

frequency = ... Hz [2]

(e) A car has a length of 4.00 m when stationary.

Determine the change in length of the car observed from the side of the road when its speed is $30.0\,\mathrm{m\,s^{-1}}$.

When x is very small compared with 1 then $(1 - x)^n \approx 1 - nx$.

change in length = ... m [3]

[Total: 20]

12 Unlike energy, the idea of entropy can tell us the direction of possible changes.

(a) A sample of an ideal gas is contained in a cylinder. The cylinder is attached via a closed valve to an identical cylinder empty of gas. The arrangement is shown in Fig. 12.1.

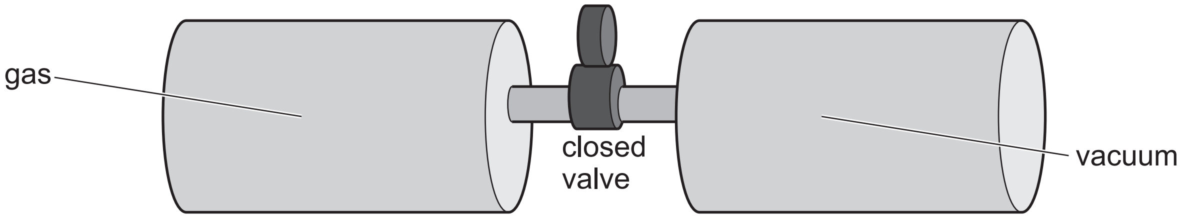

Fig. 12.1

The valve is opened.

State and explain, in terms of the molecules of the gas, what happens to:

(i) the temperature of the gas

....

....

.... [2]

(ii) the pressure of the gas

....

....

....

.... [2]

(iii) the entropy of the gas.

....

....

.... [1]

(b) The gas in the two cylinders in **(a)** will never all spontaneously return to the single original cylinder.

Explain why this is the case.

....

....

.... [1]

(c) A sample of ideal gas is contained in a cylinder with a piston as shown in Fig. 12.2.

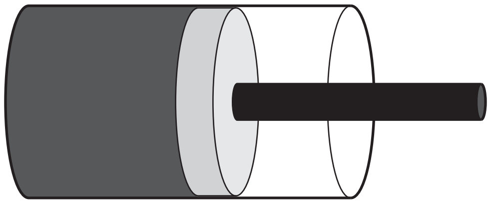

Fig. 12.2

The piston is moved in very quickly to compress the gas so that no energy is transferred by heating through the walls of the cylinder.

State and explain, in terms of the molecules of the gas, what happens to:

(i) the temperature of the gas

....

....

.... [2]

(ii) the pressure of the gas

....

....

.... [2]

(iii) the entropy of the gas.

....

....

.... [2]

(d) When a small amount of energy Q is transferred to an object at absolute temperature T by heating, the change in entropy ΔS of the object is given by the equation

$$\Delta S = \frac{Q}{T}.$$

(i) Calculate the entropy change when 6.0 kJ of energy is transferred by heating to a large object at 27 °C.

change in entropy = ... JK^{-1} [1]

(ii) A particular system consists of two solid objects made of the same material and in the same state that are in thermal contact. The larger object A is at a temperature of –20 °C. The smaller object B is at a temperature of +20 °C.

If 4.0 J of energy were to be transferred by heating from object A to object B, calculate the change in entropy of the system.

change in entropy = ... $J K^{-1}$ [3]

(iii) With reference to your answer to **(ii)**, explain to which object the energy is spontaneously transferred by heating.

....

.... [1]

(iv) The contents of a freezer are at –20 °C. The freezer is in a room at +20 °C. An electric motor uses 10 000 J of energy to remove 50 000 J of energy from the contents of the freezer.

Show that the change in entropy of the whole freezer–room system has magnitude 7.1 $J K^{-1}$ and explain why the process is possible.

....

....

....

....

.... [3]

[Total: 20]

13 **(a)** Fig. 13.1 shows two routes a photon of light might take to travel from point A to point B. The photon crosses a boundary between medium V in which its speed is $3.00 \times 10^8\,\mathrm{m\,s^{-1}}$ and medium G in which its speed is $2.00 \times 10^8\,\mathrm{m\,s^{-1}}$. The positions of A and B are shown in Fig. 13.1.

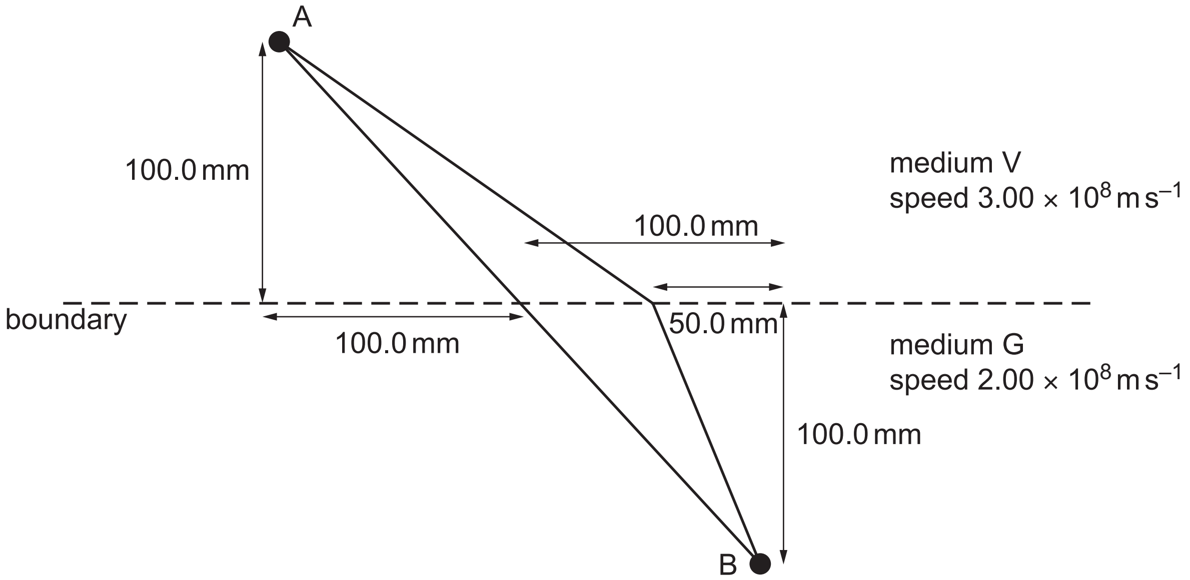

Fig. 13.1

(i) Show that the time for the photon's journey when the photon travels straight and does not change direction at the boundary is 1.18 ns.

[2]

(ii) Calculate the time for the photon's journey when it travels from A to B changing direction at the boundary as shown in Fig. 13.1.

time = ... ns [3]

(iii) The route for a ray of light is predicted by using classical physics equation

$$n = \frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2}.$$

The route predicted by the formula is the route taking the shortest time.

Use the equation to determine whether your answer to **(ii)** is the shortest possible time for the journey.

[4]

(b) The experiment traditionally known as Young's double slit experiment is an important one in the history of scientific ideas. It is illustrated in Fig. 13.2.

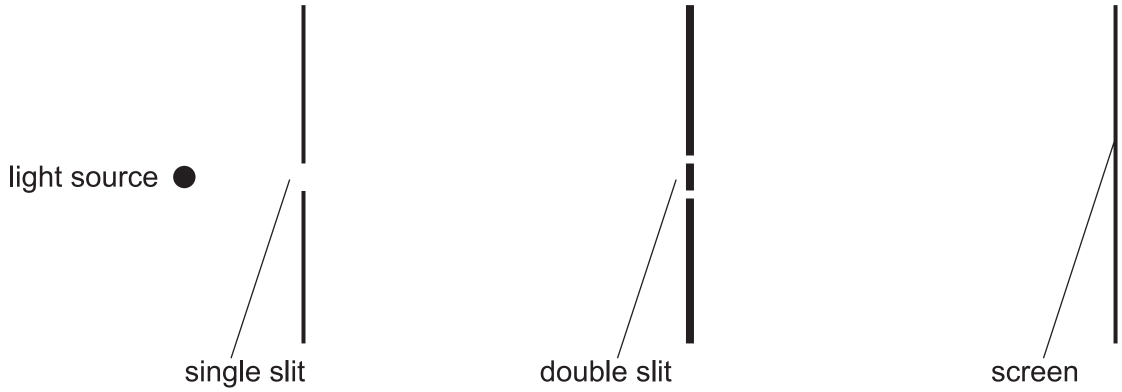

Fig. 13.2 (not to scale)

(i) Newton's model of light was that it was a stream of tiny particles he called corpuscles.

State what Newton would have expected to see on the screen.

....

.... [1]

(ii) Young used the idea of light as a wave. The light source is monochromatic with wavelength 600 nm. The distance from the double slit to the screen is 3.00 m and the slit separation is 0.40 mm.

Describe what will be seen on the screen, giving the appropriate distances.

[4]

(c) Light is thought to have a particle nature as well as a wave nature. When an interference experiment is conducted using light so dim that only one photon will be passing through the equipment at any time, the same pattern is formed on the screen over time.

Describe briefly how the double slit pattern as seen by Young is explained by

(i) the Copenhagen interpretation

....

....

....

.... [2]

(ii) Feynman's sum-over-histories approach

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....

.... [2]

(iii) Everett's many-worlds theory.

....

....

....

.... [2]

[Total: 20]

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