Name: ______________________________ (   )   Class: 24 / ______

ANDERSON SERANGOON JUNIOR COLLEGE

2024 JC2 Preliminary Examination

PHYSICS Higher 2 — 9749/03

Paper 3 Longer Structured Questions — **Thursday 12 September 2024**

2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class index number and class in the spaces provided above.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.

Section B
Answer **one** question only.

You are advised to spend about one and a half hours on Section A and half an hour on Section B.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Paper 3 (80 marks)	
1	
2	
3	
4	
5	
6	
7	
8	
9	
Deductions	
Total	

This document consists of **24** printed pages and **4** blank pages.

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall	$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -\dfrac{Gm}{r}$
temperature	$T/\text{K} = T/^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \dfrac{1}{3}\dfrac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm\omega\sqrt{x_o{}^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \dfrac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \dfrac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \dfrac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_o nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

Section A

Answer **all** the questions in this section in the spaces provided.

1 **(a)** Length, mass and amount of substance are all SI base quantities.

(i) State **two** other SI base quantities.

1. ....

2. ....
[2]

(ii) State **one** derived quantity.

.... [1]

(b) The acceleration of free fall g may be determined from an oscillating pendulum using the equation

$$g = \frac{4\pi^2 l}{T^2}$$

where l is the length of the pendulum and T is the period of oscillation.

In an experiment, the measured values for an oscillating pendulum are

$l = 1.50\ \text{m} \pm 2\%$
and $T = 2.48\ \text{s} \pm 3\%$.

(i) Determine the percentage uncertainty in g.

percentage uncertainty = ... [1]

(ii) Calculate g together with its uncertainty.

g = ... ± .... m s^{-2} [3]

[Total 7]

BLANK PAGE

2 A sky-diver jumps from a high-altitude balloon. The variation with time t of the vertical acceleration a of the sky-diver is shown in Fig. 2.1.

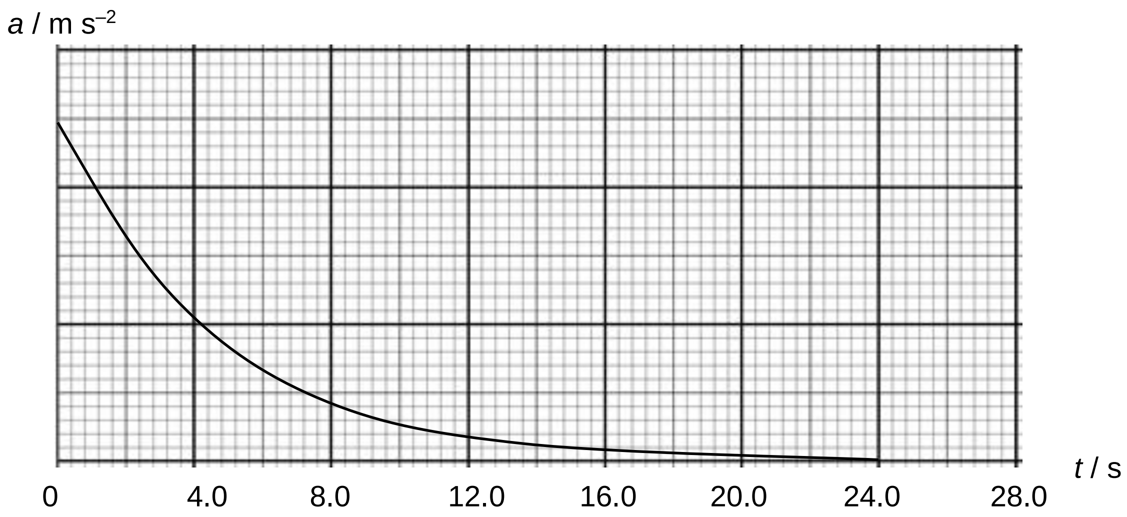

Fig. 2.1

(a) Explain why the acceleration of the sky-diver decreases with time.

…………………………………………………………………………………………………...

…………………………………………………………………………………………………...

………………………………………………………………………………………………….. [2]

(b) State and explain whether the acceleration at the start of the jump is greater than, equals to, or less than 9.81 m s^{-2}.

…………………………………………………………………………………………………...

…………………………………………………………………………………………………...

………………………………………………………………………………………………….. [2]

(c) Explain how you will use Fig. 2.1 to determine the terminal velocity of the sky-diver.

…………………………………………………………………………………………………...

…………………………………………………………………………………………..………[1]

(d) Sketch the graph of variation with time *t* of the displacement of the sky-diver on Fig. 2.2.

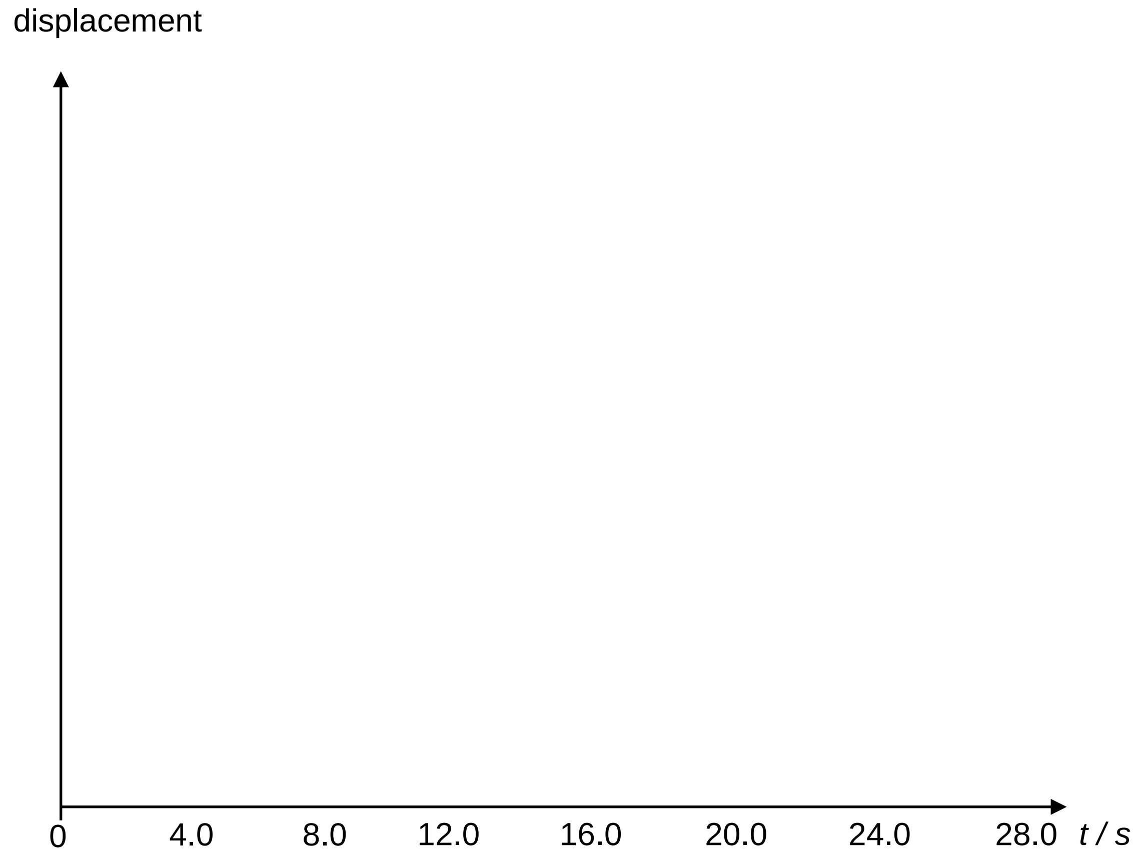

Fig. 2.2

[2]

[Total: 7]

3 A uniform beam AB is attached by a hinge to a wall at end A, as shown in Fig. 3.1.

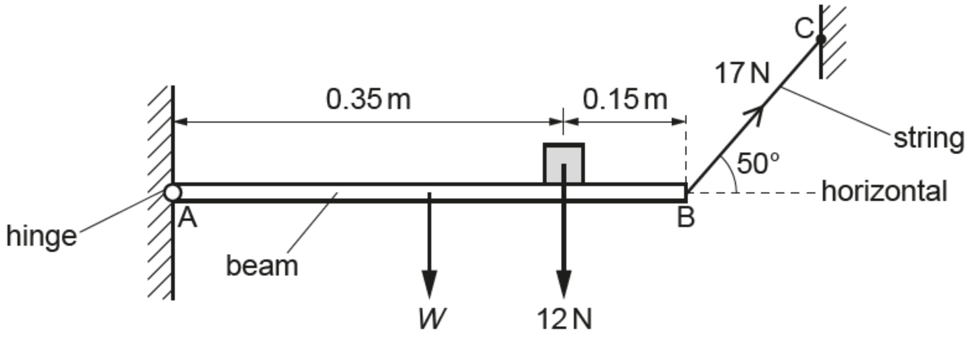

Fig. 3.1 (not to scale)

The beam has length 0.50 m and weight W. A block of weight 12 N rests on the beam at a distance of 0.15 m from end B.

The beam is held horizontal and in equilibrium by a string attached between end B and a fixed point C. The string has a tension of 17 N and is at an angle of 50° to the horizontal.

(a) State **two** conditions for an object to be in equilibrium.

1 ....

....

2 ....

.... [2]

(b) Show that the weight W of the beam is 9.2 N.

[2]

(c) A force F acts on the beam at A. Calculate the magnitude of F.

F = ... N [3]

(d) The block is now moved closer to end A of the beam. Assume that the beam remains horizontal.

State and explain whether this change will increase, decrease or have no effect on the horizontal component of the force exerted on the beam by the hinge.

……..

……..

……………………………………………………………………………………………………...... [2]

[Total: 9]

4 A long strip of springy steel is clamped at one end so that the strip is vertical. A mass of 65 g is attached to the free end of the strip, as shown in Fig. 4.1.

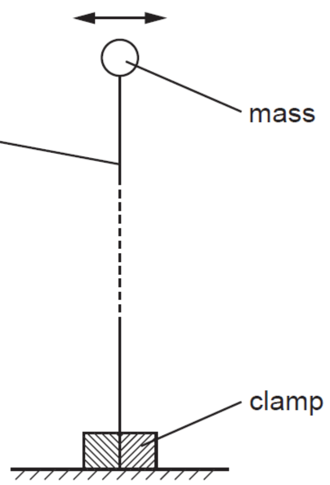

Fig. 4.1

The mass is pulled to one side and then released. The variation with time *t* of the horizontal displacement of the mass is shown in Fig. 4.2.

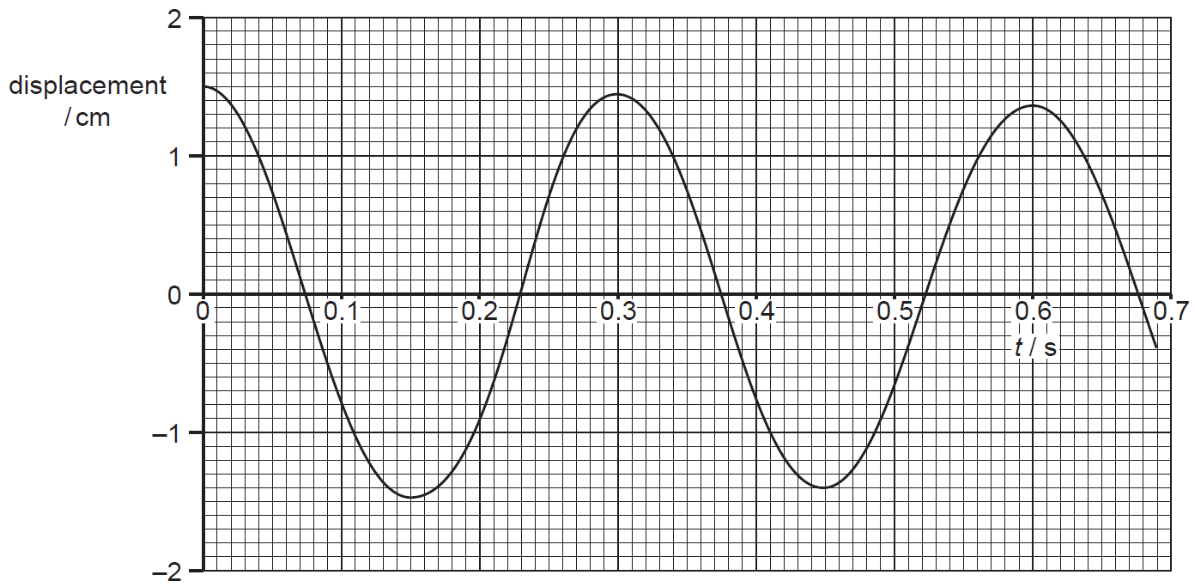

Fig. 4.2

The mass undergoes damped simple harmonic motion.

(a) **(i)** Explain what is meant by *damping*.

....

....

.... [2]

(ii) Suggest, with reason, whether the damping is light, critical or heavy.

……………………………………………………………………………………………….........

……………………………………………………………………………………………….........

…………………………………………………………………………………………….…..... [2]

(b) **(i)** Use Fig. 4.2 to determine the frequency of vibration of the mass.

frequency = …………………………. Hz [1]

(ii) Hence show that the initial energy stored in the steel strip before the mass is released is approximately 3.2 mJ.

[2]

(c) After eight complete oscillations of the mass, the amplitude of vibration is reduced from 1.5 cm to 1.1 cm. State and explain whether, after a further eight complete oscillations, the amplitude will be 0.7 cm.

……………………………………………………………………………………………..................

……………………………………………………………………………………………..................

…………………………………………………………………………………………….............. [2]

(d) State an example and its associated type of damping that is useful in the real world.

…………………………………………………………………………………….………….. [1]

[Total: 10]

5 A wire BD has length 100 cm and resistance of 4.0 Ω. The ends B and D of the wire are connected to a cell X, as shown in Fig. 5.1.

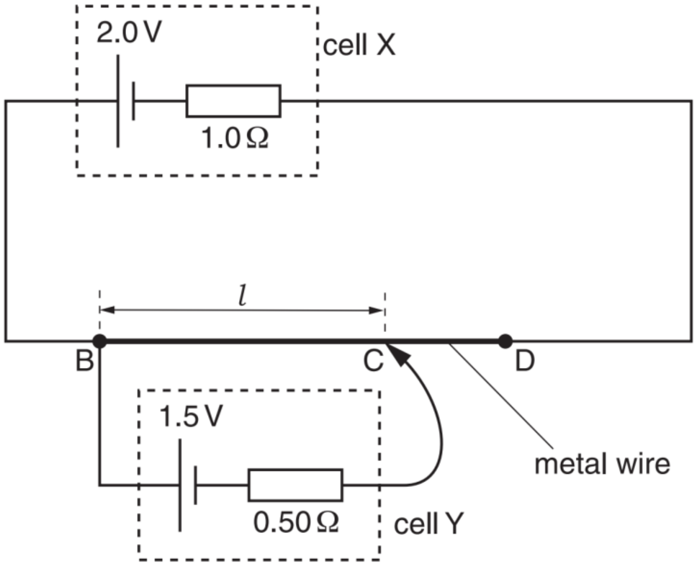

Fig. 5.1

The cell X has electromotive force (e.m.f.) 2.0 V and internal resistance 1.0 Ω.

A cell Y of e.m.f. 1.5 V and internal resistance 0.50 Ω is connected to the wire at points B and C, as shown in Fig. 5.1.

When the point C is at a distance l from point B, the current in cell Y is zero.

(a) Calculate

(i) the potential difference (p.d.) across the wire BD,

p.d. = ……………………………V [2]

(ii) the distance l.

l = ……………………………cm [2]

(b) Suggest and explain one way in which the circuit in Fig. 5.1 may be modified so that, when current in cell Y is zero, the distance l will be less than the value calculated in **(a)(ii)**.

…………………………………………………………………………………………………..

…………………………………………………………………………………………………..

……………………………………………………………………………………………........[2]

(c) From Fig. 5.1, cell Y is replaced with cell Z of the same e.m.f. but greater internal resistance.

State and explain, for the current in cell Z to be zero, whether the distance l will be greater than, equal to or less than the value calculated in **(a)(ii)**.

…………………………………………………………………………………………………..

…………………………………………………………………………………………………..

……………………………………………………………………………………………........[2]

[Total: 8]

6 **(a)** Explain the use of a uniform electric field and a uniform magnetic field for the selection of the velocity of a charged particle. You may draw a diagram if you wish.

……………………………………………………………………………………………………..

……………………………………………………………………………………………………..

…………………………………………………………………………………………........ [3]

(b) Ions, all of the same isotope, are travelling in a vacuum with a speed of 9.6×10^{4} m s^{-1}. The ions are incident normally on a uniform magnetic field of flux density 640 mT. The ions follow semicircular paths A and B before reaching a detector, as shown in Fig. 6.1.

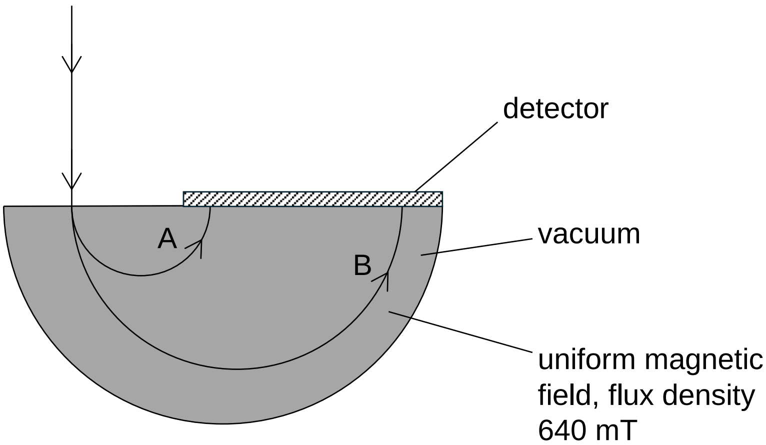

Fig. 6.1

Data for the diameters of the paths are shown in Fig. 6.2.

path	diameter / cm
A	4.1
B	12.3

Fig. 6.2

The ions in path B each have charge $+1.6 \times 10^{-19}$ C.

(i) Determine the mass, in u, of the ions in path B. Explain your working.

mass = ………………………….... u [3]

(ii) Suggest and explain quantitatively a reason for the difference in the radii of the paths A and B of the ions.

……………………………………………………………………………………………........

……………………………………………………………………………………………........

……………………………………………………………………………………………........

……………………………………………………………………………………………........

……………………………………………………………………………………………........

………………………………………………………………………………………………..[3]

[Total: 9]

7 **(a)** A nucleus Z undergoes nuclear fission to form strontium-93 ($^{93}_{38}\text{Sr}$) and xenon-139 ($^{139}_{54}\text{Xe}$) according to

$$^{1}_{0}\text{n} + \text{Z} \rightarrow {}^{93}_{38}\text{Sr} + {}^{139}_{54}\text{Xe} + 2\,^{1}_{0}\text{n}$$

Fig. 7.1 shows the binding energies of the strontium-93 and xenon-139 nuclei.

Nucleus	binding energy / J
$^{93}_{38}\text{Sr}$	1.25×10^{-10}
$^{139}_{54}\text{Xe}$	1.81×10^{-10}

Fig. 7.1

The fission of 1.00 mol of Z releases 1.77×10^{13} J of energy.

Determine the binding energy per nucleon, in MeV, of Z.

binding energy per nucleon = …………………………….MeV [4]

(b) Plutonium-238 ($^{238}_{94}Pu$) is unstable and undergoes alpha decay.

The power source in a space probe contains 0.874 kg of plutonium-238. The half-life of plutonium-238 is 87.7 years.

(i) Show that the initial number N_0 of nuclei of plutonium-238 in the power source is 2.21×10^{24}.

[1]

(ii) Determine the initial activity of the source.

activity = ……………………………Bq [2]

(iii) The space probe will continue to function until the power output from the plutonium in the source decreases to 65.3% of its initial value.

Calculate the time, in years, for which the space probe will function.

time = ……………………………years [2]

(iv) An alternative power source uses energy generated from the radioactive decay of polonium-210. This isotope has a half-life of 0.378 years. The mass of the isotope needed for the same initial power output as produced by plutonium-238 is 3.37 g.

Suggest one disadvantage of using polonium-210 as the source of energy.

……………………………………………………………………………………...................

……………………………………………………………………………………………..... [1]

[Total: 10]

Section B

Answer **one** question from this section in the spaces provided.

8 **(a)** A steel sphere of mass 0.29 kg is suspended in equilibrium from a vertical spring. The centre of the sphere is 8.5 cm from the top of the spring, as shown in Fig. 8.1.

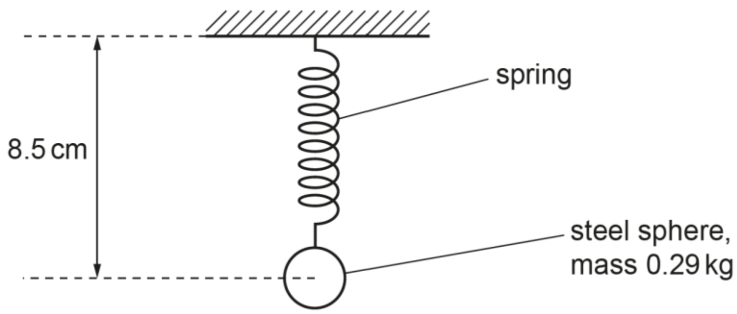

Fig. 8.1

The sphere is now set in motion so that it is moving in a horizontal circle at constant speed, as shown in Fig. 8.2.

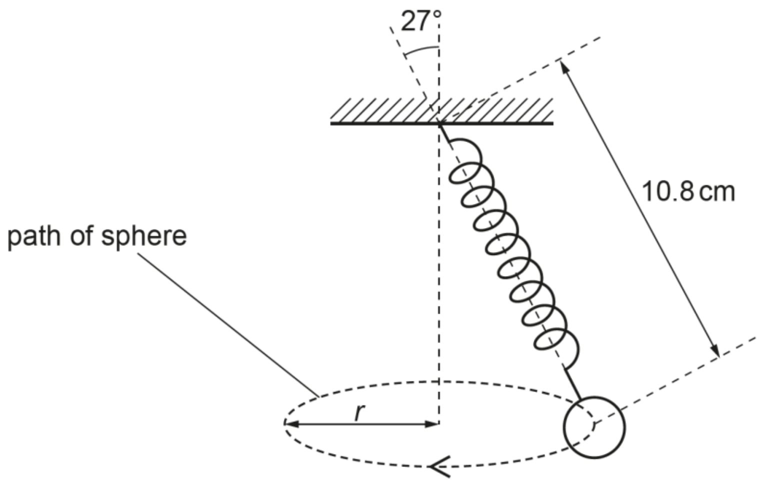

Fig. 8.2

The distance from the centre of the sphere to the top of the spring is now 10.8 cm.

(i) Explain, with reference to the forces acting on the sphere, why the length of the spring in Fig. 8.2 is greater than in Fig. 8.1

....

....

....

....

....[3]

(ii) The angle between the linear axis of the spring and vertical is 27°.

1. Show that the radius *r* of the circle is 4.9 cm.

[1]

2. Show that the tension in the spring is 3.2 N.

[2]

3. The spring obeys Hooke's law.

Calculate the spring constant, in N cm^{-1} of the spring.

spring constant = ………………………… N cm^{-1} [2]

(iii) **1.** Use the information in **a(ii)** to determine the centripetal acceleration of the sphere.

centripetal acceleration = ………………………… m s^{-2} [2]

2. Calculate the period of the circular motion of the sphere.

period = ………………………… s [2]

(b) Two stars A and B have their surfaces separated by a distance of 1.4 x 10^{12} m, as illustrated in Fig. 8.3.

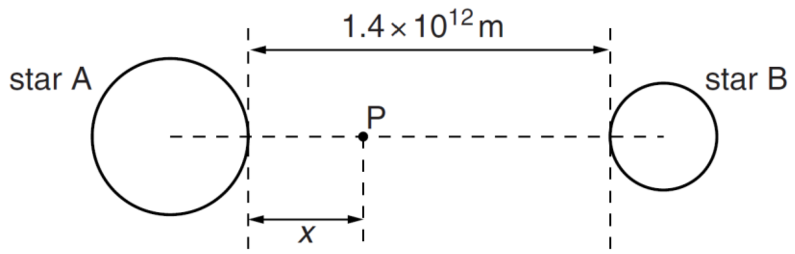

Fig. 8.3

Point P lies on the line joining the centres of the two stars. The distance *x* of point P from the surface of star A may be varied.

The variation with distance *x* of the gravitational potential ϕ at point P is shown in Fig. 8.4.

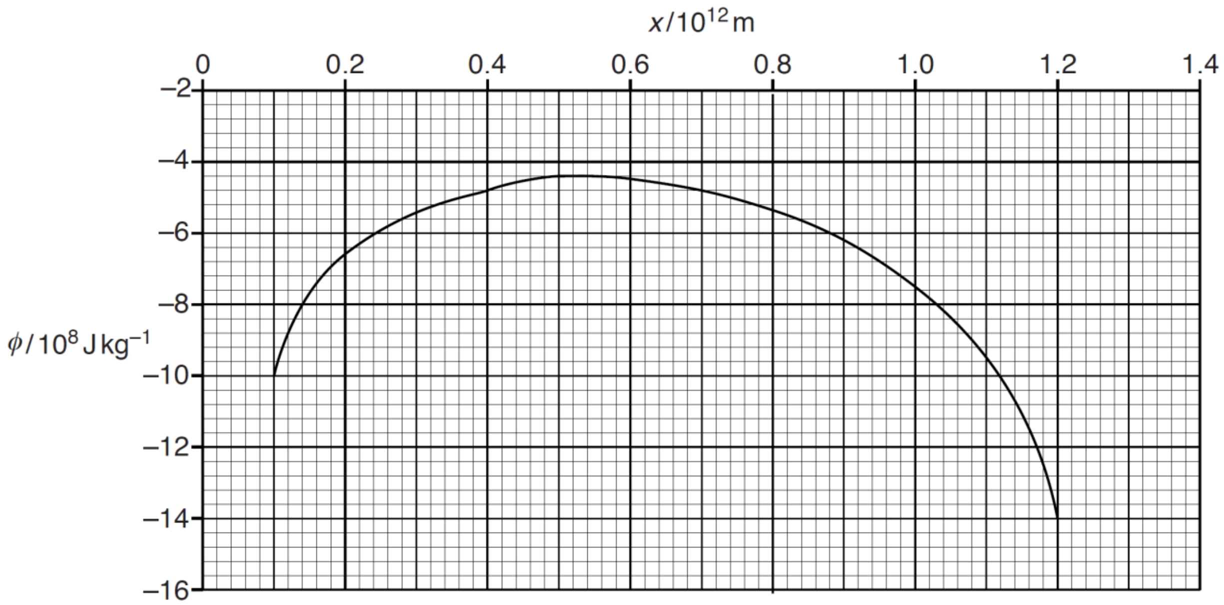

Fig. 8.4

(i) Using Fig. 8.4, state and explain the distance *x* at which the gravitational field strength is zero.

....

....

....

....

.... [2]

(ii) A rock of mass 180 kg moves along the line joining the centres of the two stars, from star A towards star B.

1. Use data from Fig. 8.4 to calculate the change in kinetic energy of the rock when it moves from the point where x = 0.1 x 10^{12} m to the point where x = 1.2 x 10^{12} m.

State whether this change is an increase or a decrease.

change = ………………………… J

……………………………………[3]

2. At a point where x = 0.1 x 10^{12} m, the speed of the rock is v.

Determine the minimum speed v such that the rock reaches the point where x = 1.2 x 10^{12} m.

minimum speed = ... m s^{-1} [3]

[Total: 20]

9 **(a)** An alternating voltage of period 10 ms is being applied directly across a resistor of 5.0 Ω in a circuit. The variation with time t of voltage V is shown in Fig. 9.1.

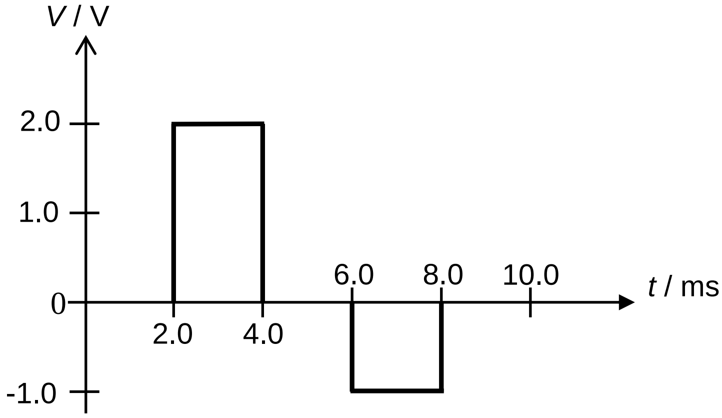

Fig. 9.1

Calculate the steady voltage passing through the same resistor that would produce an identical heating effect.

voltage = ... V [2]

(b) Explain why it is necessary to use high voltages for the efficient transmission of electrical energy.

....

....

.... [2]

(c) A sinusoidal root-mean-square voltage input of 6.5 mV and 50 Hz is now connected to the primary coil of a transformer as shown in Fig. 9.2. The transformer is assumed to be ideal and its turns ratio, $\frac{N_s}{N_p}$ is 71. The secondary coil is connected to a resistor R. An average power of 0.040 W is produced in resistor R.

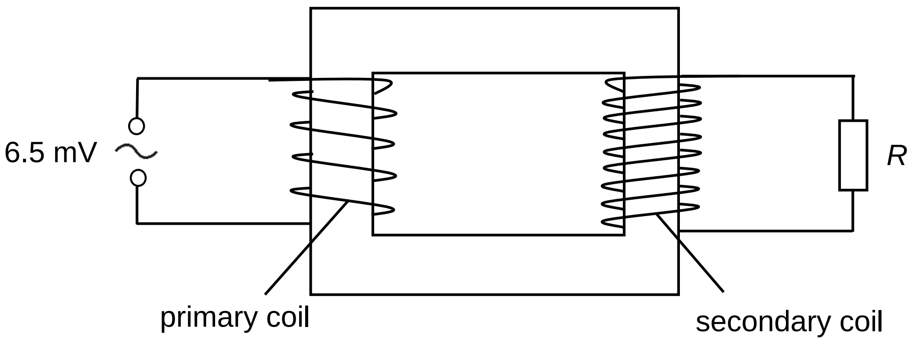

Fig. 9.2

(i) Calculate the r.m.s output voltage supplied to resistor *R*.

r.m.s. voltage = …………………... V [1]

(ii) In Fig. 9.3, sketch the variation with time *t* of the power *P* dissipated in the resistor *R* over one period. Label all values on the axes.

[2]

Fig. 9.3

(iii) An ideal diode is now connected to the secondary coil with resistor *R* as shown in Fig. 9.4.

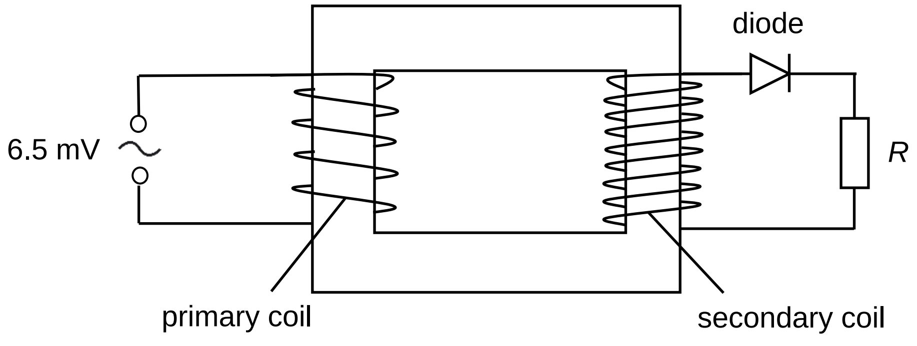

Fig. 9.4

Describe the variation with time of the direction of the current flow through resistor *R*.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………………………………………………………………… [2]

(iv) In practice, the core of some transformers is made of laminated soft iron.

Explain how the lamination of the core reduces energy losses.

....

....

.... [2]

(d) A cycle of changes in pressure, volume and temperature of a mixture of gases inside a cylinder of a petrol engine is illustrated in Fig. 9.5. The mixture of gases is assumed to be ideal.

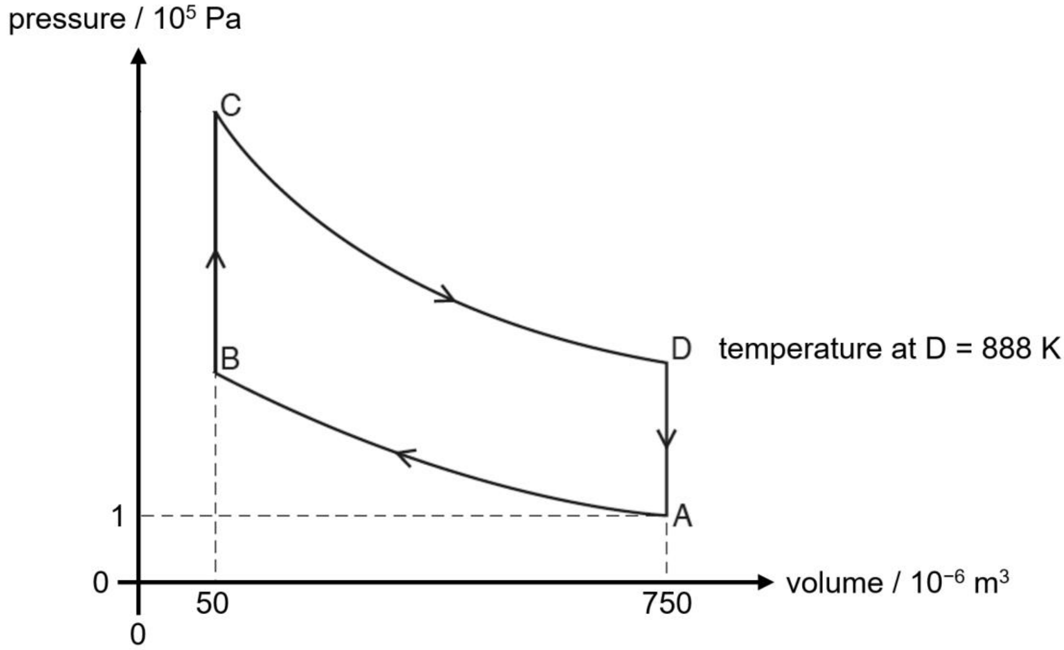

Fig. 9.5 (not to scale)

process	**description**
A to B	Rapid compression of the gaseous petrol and air mixture with both temperature and pressure rising from A to B.
B to C	The petrol and air mixture is combusted, resulting in an almost instant rise in pressure.
C to D	Rapid expansion and cooling of the hot gases.
D to A	Return to the starting point of the cycle.

(i) State what is meant by an *ideal gas*.

....

.... [1]

(ii) Complete the table in Fig. 9.6 showing the work done on the gas, the heat supplied to the gas and the increase in the internal energy of the gas, during the four stages of one cycle.

[4]

process	work done **on** gas / J	heat supplied **to** gas / J	**increase** in internal energy of gas /J
A to B	+ 360	0	
B to C		+ 670	
C to D		0	− 810
D to A			

Fig. 9.6

(iii) Use Fig. 9.5 and your answers in **(d)(ii)** to determine the number of moles present in the gases in the cycle.

number of moles = …………………....... mol [2]

(iv) Explain qualitatively how molecular movement causes the fall in temperature of the gas during the process C to D.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

………………………………………………………………………………………………… [2]

[Total: 20]

BLANK PAGE

BLANK PAGE

BLANK PAGE