Mock Exam 1

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

PHYSICS **9702**

Paper 4 A Level Structured Questions **2 hours 15 minutes**

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

The total mark for this paper is 123.

1 **(a)** State what is meant by *centripetal* acceleration.

....

....

.... [1]

(b) An unpowered toy car moves freely along a smooth track that is initially horizontal. The track contains a vertical circular loop around which the car travels, as shown in Fig. 1.1.

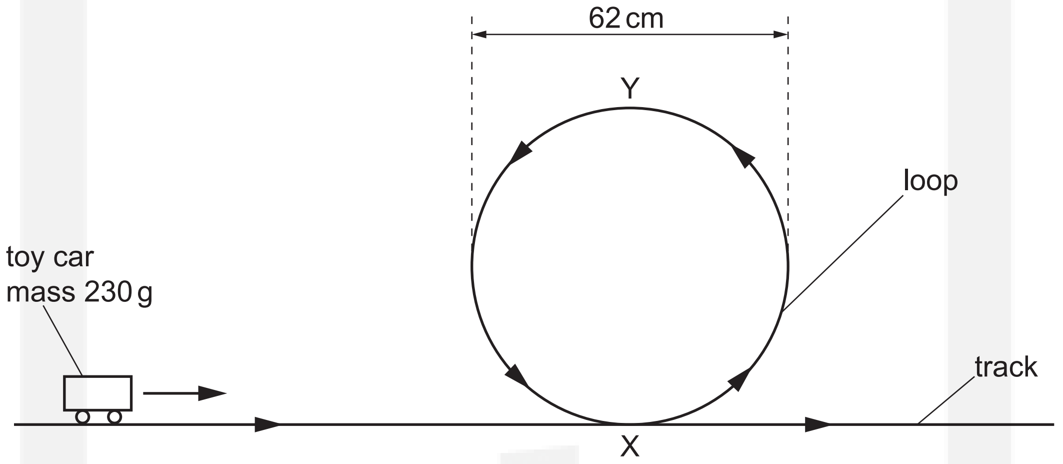

Fig. 1.1

The mass of the car is 230 g and the diameter of the loop is 62 cm. Assume that the resistive forces acting on the car are negligible.

(i) State what happens to the magnitude of the centripetal acceleration of the car as it moves around the loop from X to Y.

.... [1]

(ii) Explain, if the car remains in contact with the track, why the centripetal acceleration of the car at point Y must be greater than $9.8\,m\,s^{-2}$.

....

....

.... [2]

(c) The initial speed at which the car in **(b)** moves along the track is 3.8 m s^{-1}.

Determine whether the car is in contact with the track at point Y. Show your working.

[3]

(d) Suggest, with a reason but without calculation, whether your conclusion in **(c)** would be different for a car of mass 460 g moving with the same initial speed.

....

....

.... [1]

[Total: 8]

2 **(a)** Define *specific heat capacity*.

....

....

.... [2]

(b) A sealed container of fixed volume V contains N molecules, each of mass m, of an ideal gas at pressure p.

(i) State an expression, in terms of V, N, p and the Boltzmann constant k, for the thermodynamic temperature T of the gas.

.... [1]

(ii) Show that the mean translational kinetic energy E_K of a molecule of the gas is given by

$$E_K = \frac{3}{2}kT.$$

[2]

(iii) Explain why the internal energy of the gas is equal to the total kinetic energy of the molecules.

....

....

.... [2]

(c) The gas in **(b)** is supplied with thermal energy Q.

(i) Explain, with reference to the first law of thermodynamics, why the increase in internal energy of the gas is Q.

....

....

.... [2]

(ii) Use the expression in **(b)(ii)** and the information in **(c)(i)** to show that the specific heat capacity c of the gas is given by

$$c = \frac{3k}{2m}.$$

[2]

(d) The container in **(b)** is now replaced with one that does not have a fixed volume. Instead, the gas is able to expand, so that the pressure of the gas remains constant as thermal energy is supplied.

Suggest, with a reason, how the specific heat capacity of the gas would now compare with the value in **(c)(ii)**.

....

....

....

.... [2]

[Total: 13]

3 A sphere of mass 1.6×10^{-10} kg has a charge of +0.27 nC. The sphere is in a uniform electric field that acts vertically upwards, as shown in the side view in Fig. 2.1.

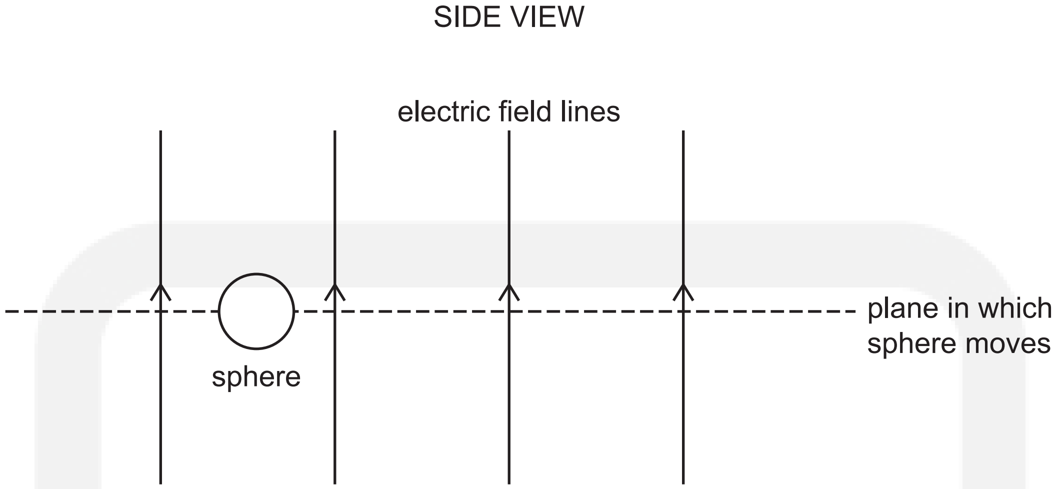

Fig. 2.1

The force exerted on the sphere by the electric field causes the sphere to remain at a fixed vertical height in a horizontal plane.

There is a uniform magnetic field in the region of the electric field. The sphere moves at a speed of 0.78 m s^{-1} in the horizontal plane. The magnetic field causes the sphere to move in a circular path of radius 3.4 m, as shown in the view from above in Fig. 2.2.

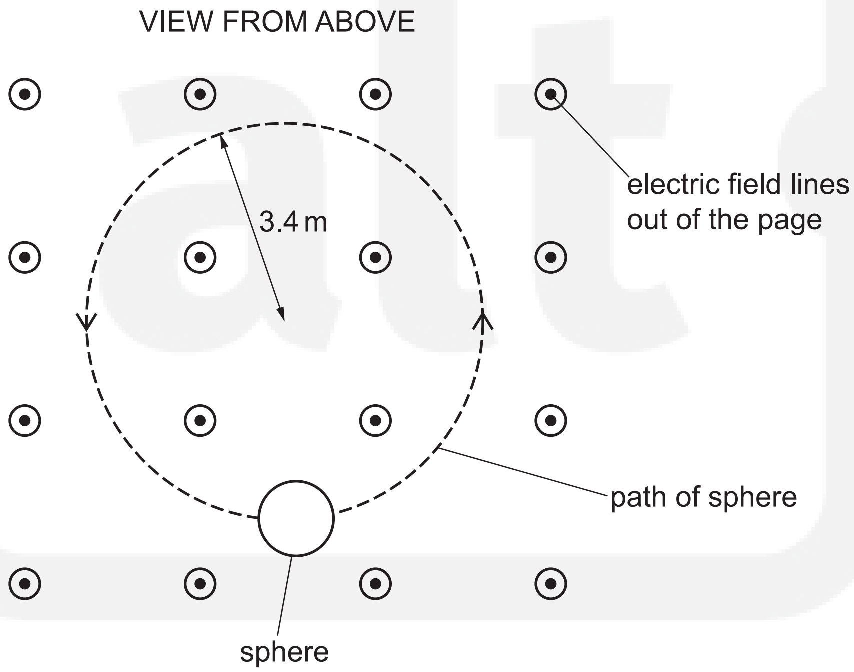

Fig. 2.2

(a) **(i)** Determine the direction of the uniform magnetic field.

.... [1]

(ii) Explain why the motion of the sphere in the horizontal plane is circular.

....

....

.... [2]

(b) Calculate the strength of the uniform electric field.

electric field strength = ... NC^{-1} [2]

(c) By considering the magnetic force on the sphere, show that the flux density of the uniform magnetic field is 0.14 T.

[3]

[Total: 8]

4 An ideal gas is contained in a cylinder by means of a movable frictionless piston, as illustrated in Fig. 2.1.

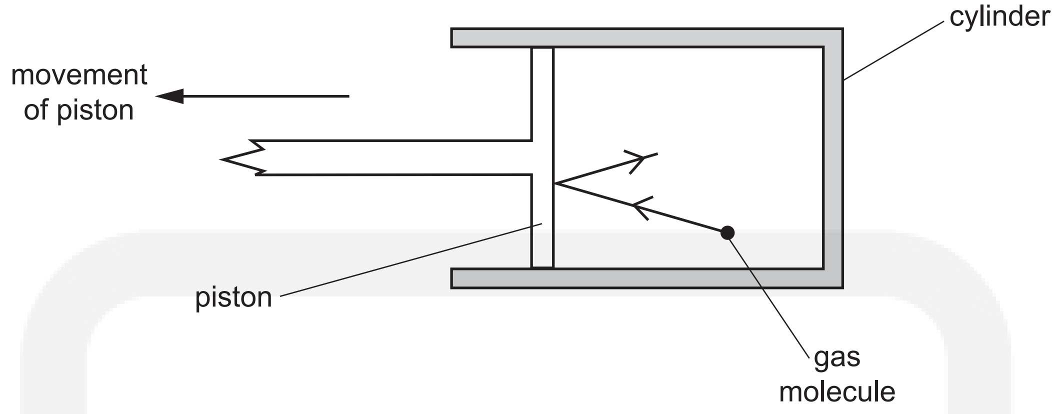

Fig. 2.1

Initially, the gas has a volume of $1.8 \times 10^{-3}\,m^3$ at a pressure of $3.3 \times 10^5\,Pa$ and a temperature of 310 K.

(a) Show that the number of gas molecules in the cylinder is 1.4×10^{23}.

[2]

(b) Use kinetic theory to explain why, when the piston is moved so that the gas expands, this causes a decrease in the temperature of the gas.

....

....

....

.... [3]

(c) The gas expands so that its volume increases to $2.4 \times 10^{-3}\,\text{m}^3$ at a pressure of $2.3 \times 10^5\,\text{Pa}$ and a temperature of 288 K, as shown in Fig. 2.2.

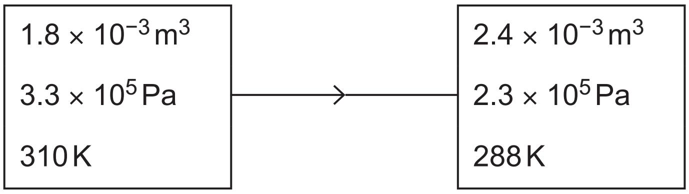

Fig. 2.2

(i) The average translational kinetic energy E_K of a molecule of an ideal gas is given by

$$E_K = \frac{3}{2}kT$$

where k is the Boltzmann constant and T is the thermodynamic temperature.

Calculate the increase in internal energy ΔU of the gas during the expansion.

ΔU = ... J [3]

(ii) The work done by the gas during the expansion is 76 J.

Use your answer in **(i)** to explain whether thermal energy is transferred to or from the gas during the expansion.

....

....

.... [2]

[Total: 10]

5 A U-shaped tube contains some liquid. The liquid column in each half of the tube has length L, as shown in Fig. 3.1.

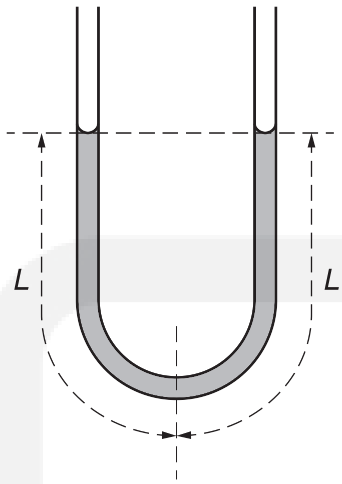

Fig. 3.1

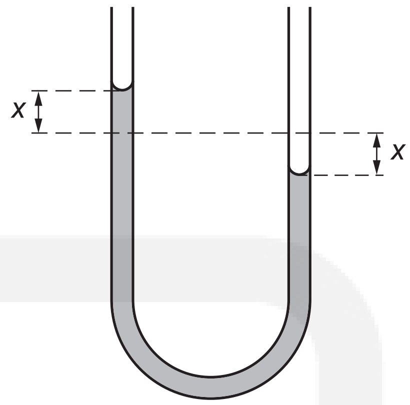

Fig. 3.2

The liquid columns are displaced vertically. The liquid then oscillates in the tube. The liquid levels are displaced from the equilibrium positions as shown in Fig. 3.2.

The acceleration a of the liquid in the tube is related to the displacement x by the expression

$$a = -\left(\frac{g}{L}\right)x$$

where g is the acceleration of free fall.

(a) Explain how the expression shows that the liquid in the tube is undergoing simple harmonic motion.

....

....

....

....

.... [3]

(b) The length L of each liquid column is 18 cm.

Determine the period T of the oscillations.

T = ... s [3]

(c) The oscillations of the liquid in the tube are damped.
In any one complete cycle of the oscillations, the amplitude decreases by 6.0% of its value at the beginning of the oscillation.

Determine the ratio

$$\frac{\text{energy of oscillations after 3 cycles}}{\text{initial energy of oscillations}}.$$

ratio = ... [3]

[Total: 9]

6 **(a)** Define *electric potential* at a point.

....

....

.... [2]

(b) Two point charges A and B are separated by a distance of 12.0 cm in a vacuum, as illustrated in Fig. 5.1.

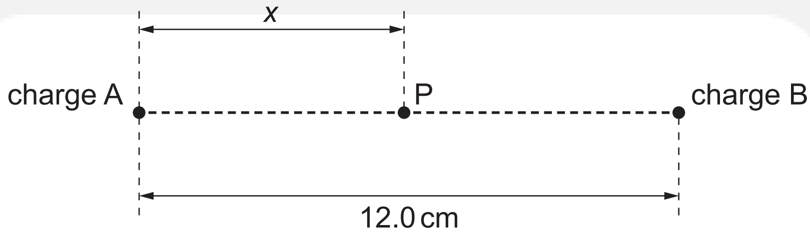

Fig. 5.1

The charge of A is $+2.0 \times 10^{-9}$ C.

A point P lies on the line joining charges A and B. Its distance from charge A is *x*.

The variation with distance *x* of the electric potential *V* at point P is shown in Fig. 5.2.

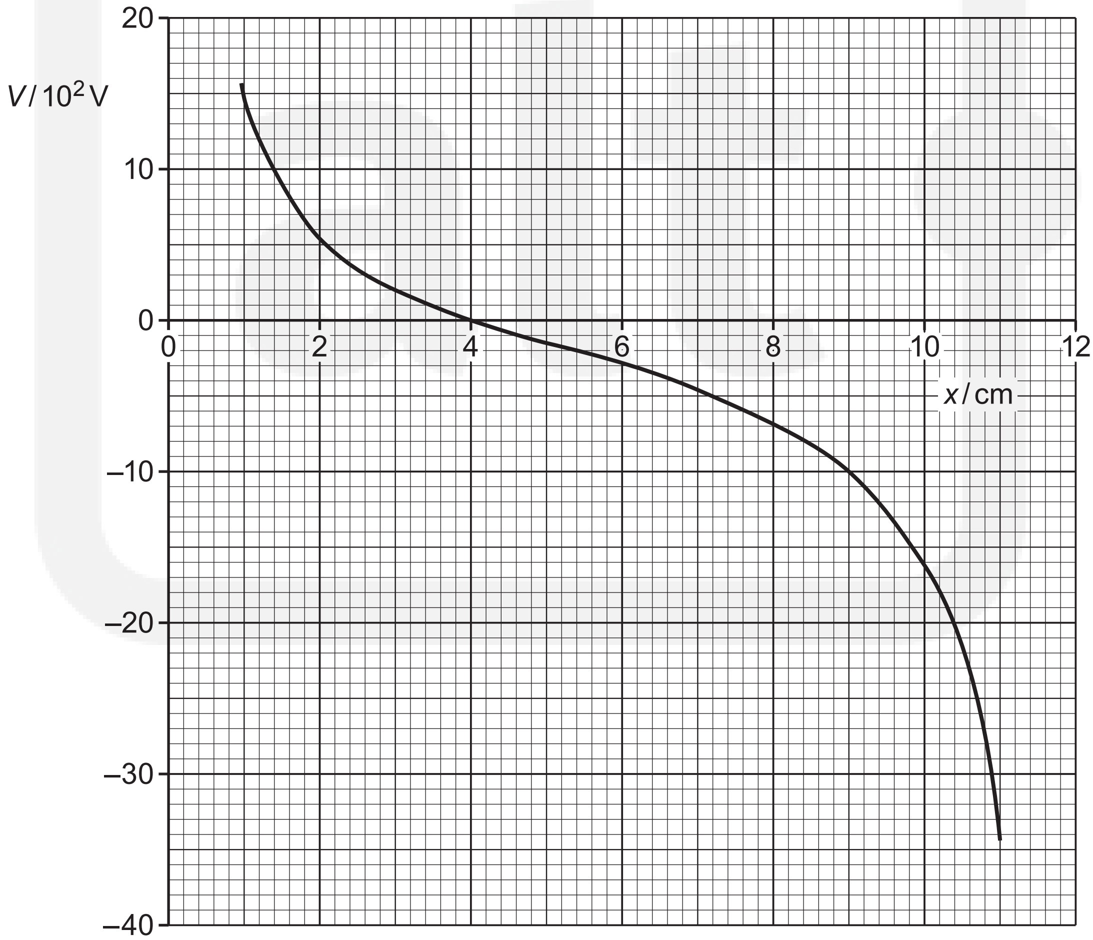

Fig. 5.2

Use Fig. 5.2 to determine:

(i) the charge of B

charge = ... C [3]

(ii) the change in electric potential when point P moves from the position where x = 9.0 cm to the position where x = 3.0 cm.

change = ... V [1]

(c) An α-particle moves along the line joining point charges A and B in Fig. 5.1.

The α-particle moves from the position where x = 9.0 cm and just reaches the position where x = 3.0 cm.

Use your answer in **(b)(ii)** to calculate the speed v of the α-particle at the position where x = 9.0 cm.

v = ... $m\,s^{-1}$ [3]

[Total: 9]

7 **(a)** State what is meant by a *gravitational force*.

....

.... [1]

(b) A binary star system consists of two stars S_1 and S_2, each in a circular orbit.

The orbit of each star in the system has a period of rotation T.

Observations of the binary star from Earth are represented in Fig. 1.1.

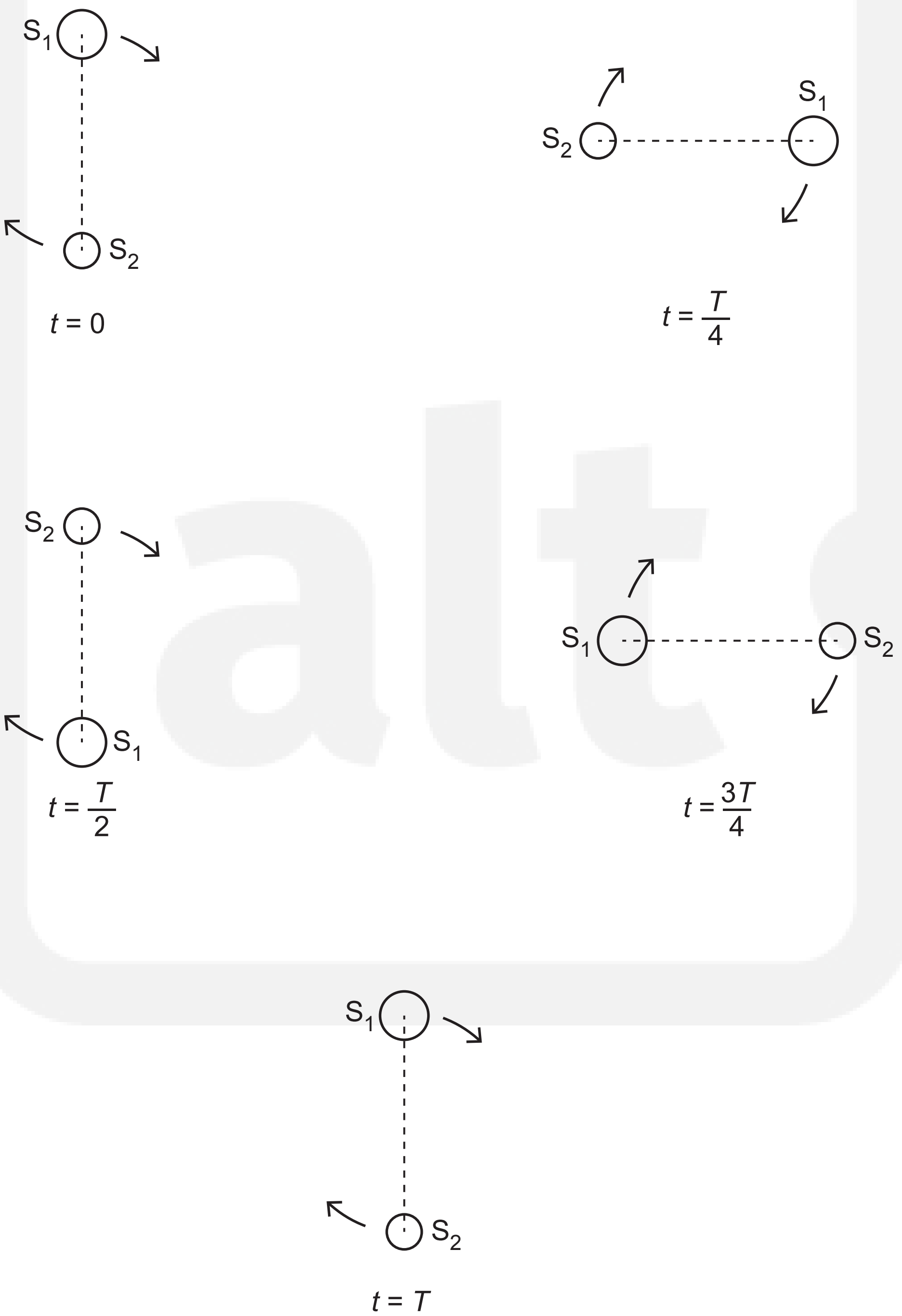

Fig. 1.1 (not to scale)

Observed from Earth, the angular separation of the centres of S_1 and S_2 is 1.2×10^{-5} rad. The distance of the binary star system from Earth is 1.5×10^{17} m.

Show that the separation d of the centres of S_1 and S_2 is 1.8×10^{12} m.

[1]

(c) The stars S_1 and S_2 rotate with the same angular velocity ω about a point P, as illustrated in Fig. 1.2.

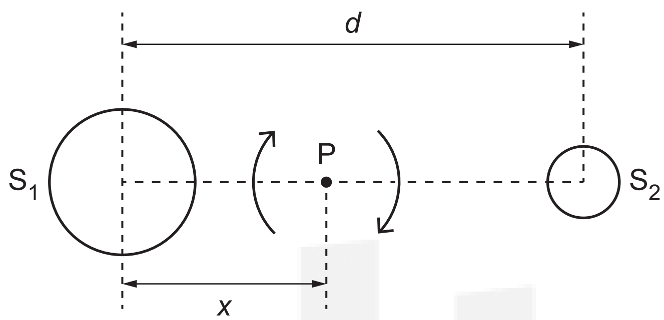

Fig. 1.2 (not to scale)

Point P is at a distance x from the centre of star S_1.
The period of rotation of the stars is 44.2 years.

(i) Calculate the angular velocity ω.

ω = ... rad s^{-1} [2]

(ii) By considering the forces acting on the two stars, show that the ratio of the masses of the stars is given by

$$\frac{\text{mass of } S_1}{\text{mass of } S_2} = \frac{d - x}{x}.$$

[2]

(iii) The mass M_1 of star S_1 is given by the expression

$$GM_1 = d^2(d - x)\,\omega^2$$

where G is the gravitational constant.

The ratio in **(ii)** is found to be 1.5.

Use data from **(b)** and your answer in **(c)(i)** to determine the mass M_1.

M_1 = ... kg [3]

[Total: 9]

8 **(a)** Define *magnetic flux linkage*.

....

....

.... [2]

(b) A solenoid of diameter 6.0 cm and 540 turns is placed in a uniform magnetic field as shown in Fig. 9.1.

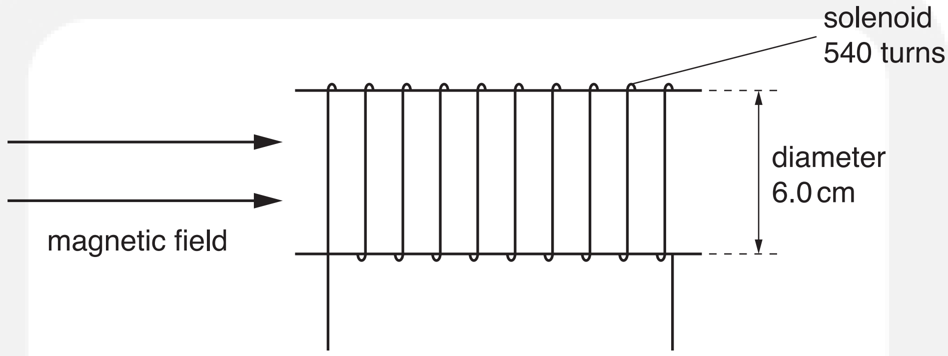

Fig. 9.1

The variation with time *t* of the magnetic flux density is shown in Fig. 9.2.

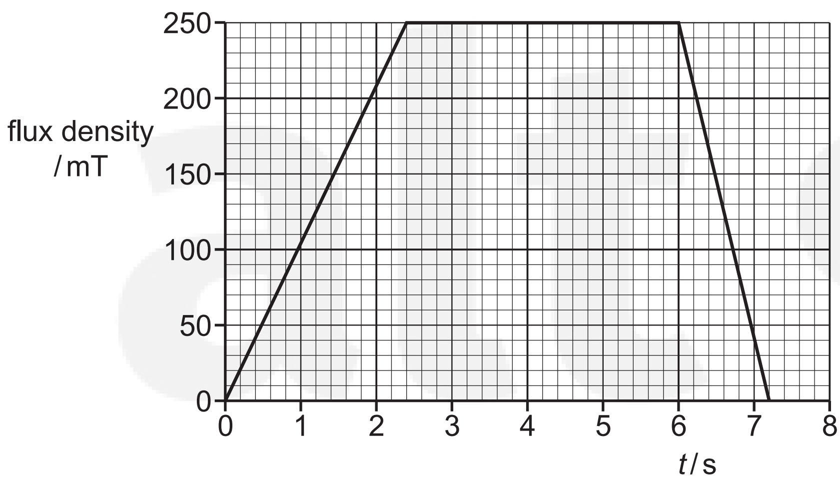

Fig. 9.2

Calculate the maximum magnitude of the induced electromotive force (e.m.f.) in the solenoid.

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

(c) A thin copper sheet X is supported on a rigid rod so that it hangs between the poles of a magnet as shown in Fig. 9.3.

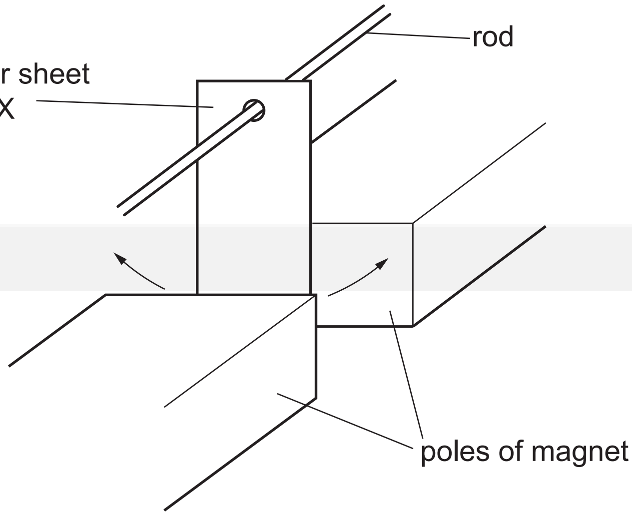

Fig. 9.3

Sheet X is displaced to one side and then released so that it oscillates. A motion sensor is used to record the displacement of X.

A second thin copper sheet Y replaces sheet X. Sheet Y has the same overall dimensions as X but is cut into the shape shown in Fig. 9.4.

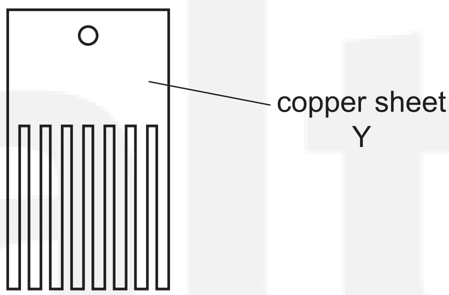

Fig. 9.4

The motion sensor is again used to record the displacement.

The graph in Fig. 9.5 shows the variation with time *t* of the displacement *s* of each copper sheet.

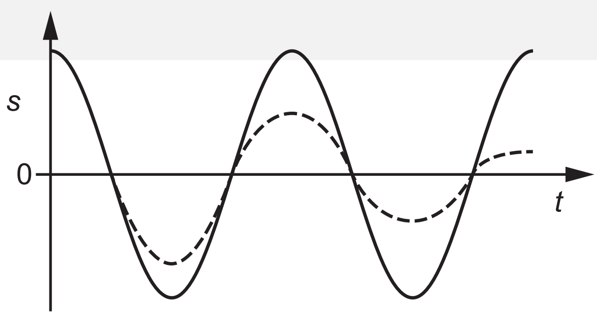

Fig. 9.5

(i) State the name of the phenomenon illustrated by the gradual reduction in the amplitude of the dashed line.

.... [1]

(ii) Deduce which copper sheet is represented by the dashed line. Explain your answer using the principles of electromagnetic induction.

....

....

....

....

....

.... [4]

[Total: 10]

9 **(a)** **(i)** Explain how X-rays are produced for use in medical diagnosis.

....

....

....

.... [3]

(ii) State why X-ray images are taken of multiple sections of the body during computed tomography (CT) scanning.

....

.... [1]

(b) An X-ray image is taken of the structure shown in Fig. 9.1.

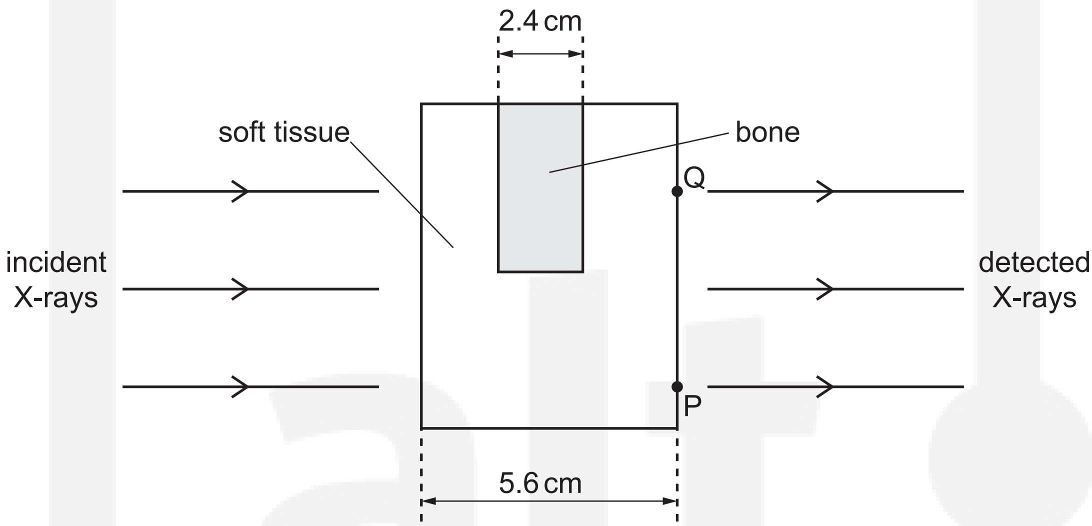

Fig. 9.1

The linear attenuation coefficient of bone is 3.4 cm^{-1}.
The linear attenuation coefficient of soft tissue is 0.89 cm^{-1}.

The incident X-rays are parallel and have a uniform intensity I_0 across the structure.

Determine, in terms of I_0, the intensity of the detected X-rays from:

(i) point P

detected intensity = ... I_0 [2]

(ii) point Q.

detected intensity = ... I_0 [2]

(c) Explain, with reference to your answers in **(b)**, whether the X-ray image of the structure in Fig. 9.1 has good contrast.

....

....

.... [1]

[Total: 9]

10 **(a)** State **two** situations in which a charged particle in a magnetic field does **not** experience a force.

1. ....

....

2. ....

.... [2]

(b) A loosely coiled metal spring is suspended from a fixed point, as shown in Fig. 9.1.

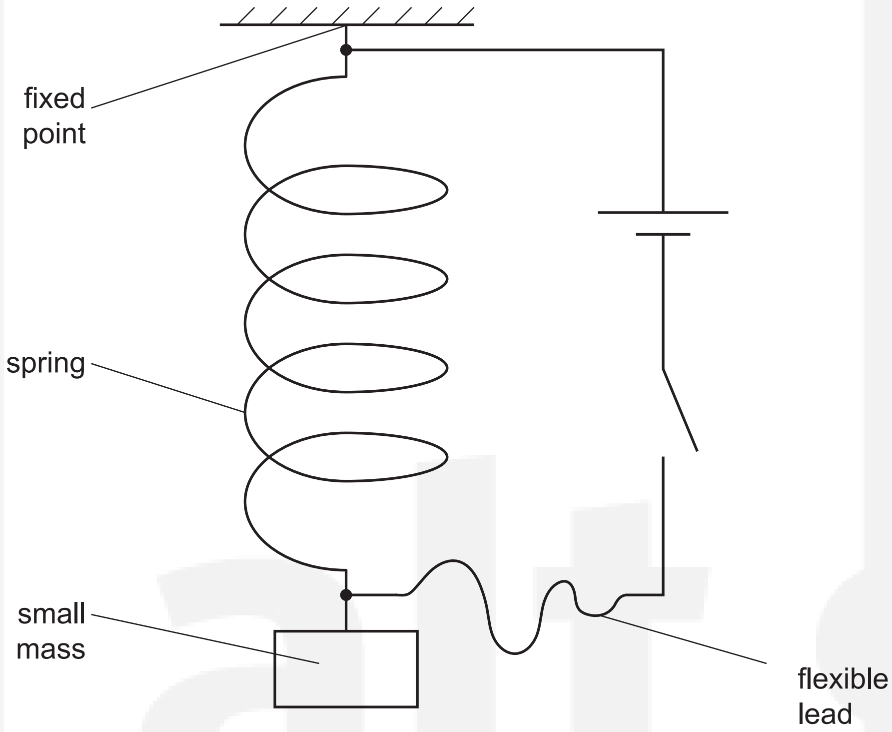

Fig. 9.1

Electrical connections are made to the ends of the spring by means of a flexible lead.

The length of the spring is measured before the switch is closed and then again after the switch is closed.

When the switch is closed, a magnetic field is set up around each coil of the spring.

By reference to these magnetic fields, explain why there is a change in length of the spring. State whether the spring extends or contracts.

....

....

....

....

....

.... [4]

(c) With the switch in **(b)** closed, the small mass on the free end of the spring is now made to oscillate vertically.

Use the principles of electromagnetic induction to explain why small fluctuations in the current in the spring are found to occur.

....

....

....

.... [3]

[Total: 9]

11 **(a)** Define the *tesla*.

....

....

....

.... [3]

(b) A magnet produces a uniform magnetic field of flux density B in the space between its poles.

A rigid copper wire carrying a current is balanced on a pivot. Part PQLM of the wire is between the poles of the magnet, as illustrated in Fig. 8.1.

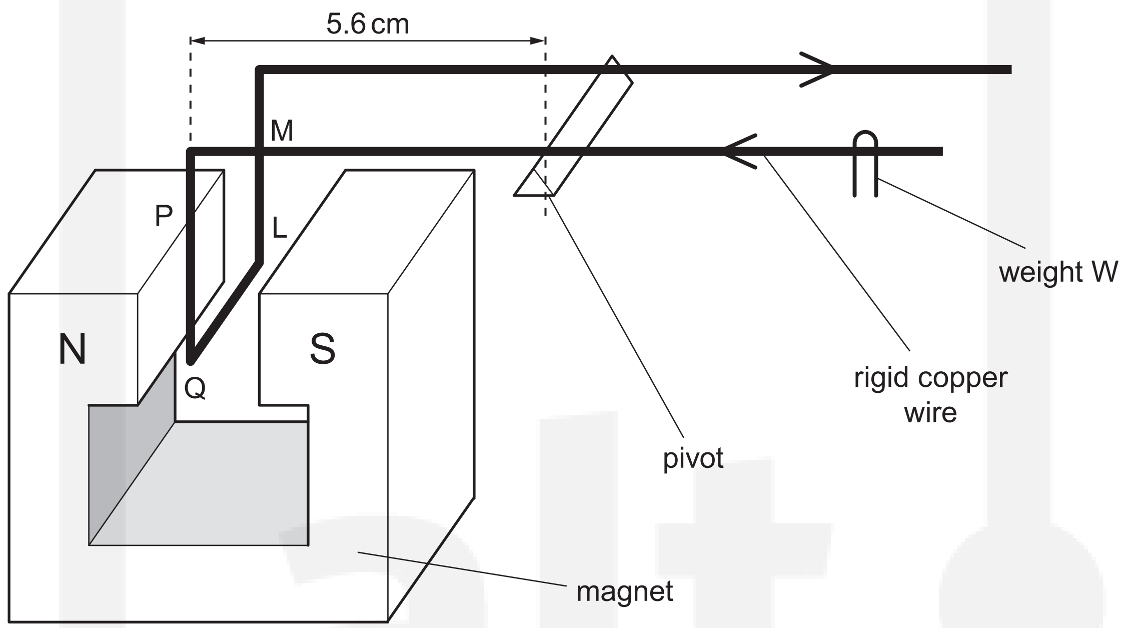

Fig. 8.1 (not to scale)

The wire is balanced horizontally by means of a small weight W.

The section of the wire between the poles of the magnet is shown in Fig. 8.2.

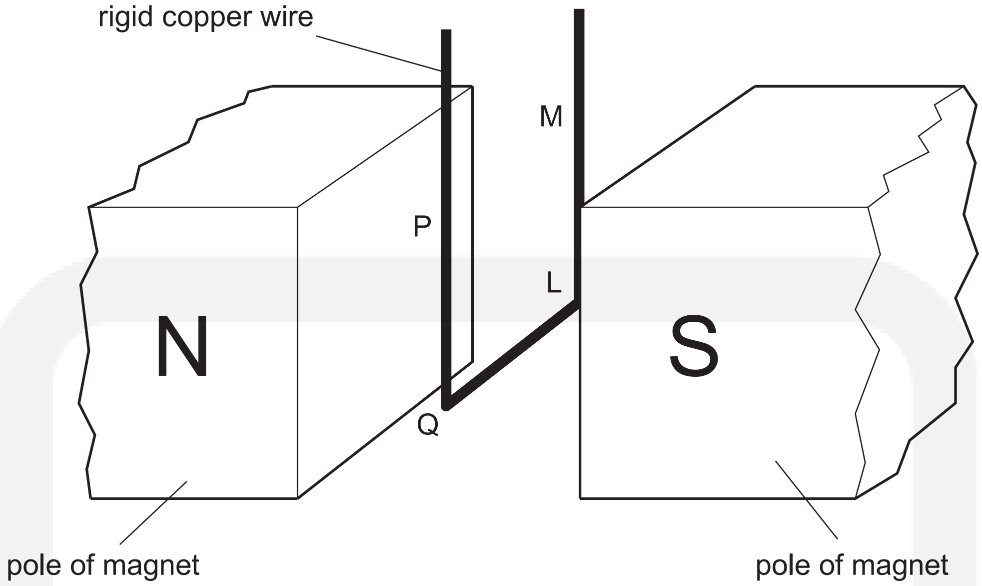

Fig. 8.2 (not to scale)

Explain why:

(i) section QL of the wire gives rise to a moment about the pivot

....

....

....

.... [3]

(ii) sections PQ and LM of the wire do not affect the equilibrium of the wire.

....

....

....

.... [2]

(c) Section QL of the wire has length 0.85 cm.

The perpendicular distance of QL from the pivot is 5.6 cm.

When the current in the wire is changed by 1.2 A, W is moved a distance of 2.6 cm along the wire in order to restore equilibrium. The mass of W is 1.3×10^{-4} kg.

(i) Show that the change in moment of W about the pivot is 3.3×10^{-5} N m.

[2]

(ii) Use the information in **(i)** to determine the magnetic flux density *B* between the poles of the magnet.

B = ... T [3]

[Total: 13]

12 **(a)** **(i)** Define nuclear *binding energy*.

....

....

.... [2]

(ii) Explain what is meant by a *nuclear fission* reaction.

....

....

.... [2]

(b) A student suggests that one possible nuclear reaction is

$$^{56}_{26}\text{Fe} + ^{1}_{0}\text{n} \rightarrow ^{20}_{9}\text{F} + ^{37}_{17}\text{C}l.$$

The binding energy per nucleon of a nucleus varies with the nucleon number.
Use this variation to explain why the reaction would **not** result in an overall release of energy.

....

....

....

....

.... [3]

[Total: 7]

13 **(a)** State Wien's displacement law.

....

.... [1]

(b) Fig. 10.1 shows the wavelength distributions of electromagnetic radiation emitted by two stars A and B.

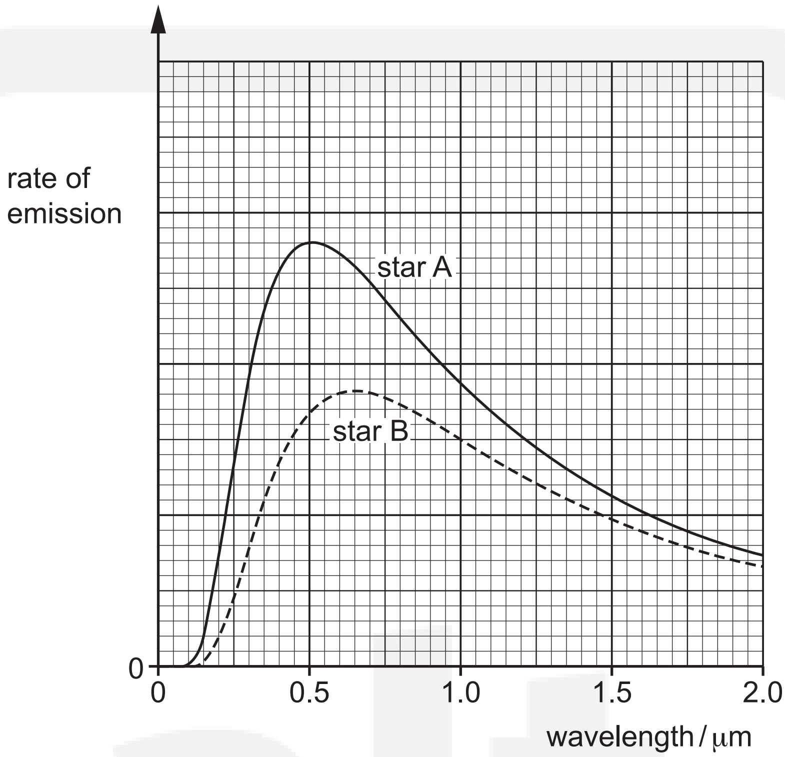

Fig. 10.1

The surface temperature of star A is known to be 5800 K.

(i) Determine the surface temperature of star B.

surface temperature = ... K [2]

(ii) Star B appears less bright than star A when viewed from the Earth.

Use Fig. 10.1 to suggest, with a reason, how else the physical appearance of star B compares with that of star A.

....

....

.... [2]

(c) The lines in Fig. 10.1 have been corrected for redshift.

(i) State what is meant by redshift.

....

....

.... [2]

(ii) Explain how cosmologists are able to determine that light from a distant star has undergone redshift.

....

....

.... [2]

[Total: 9]