RIVER VALLEY HIGH SCHOOL
JC 2 PRELIMINARY EXAMINATIONS

H2 PHYSICS 9749 / 03
PAPER 3

13 SEPTEMBER 2024

2 HOURS

CANDIDATE NAME										
CENTRE NUMBER	S					**INDEX NUMBER**				
CLASS	2	3	J							

INSTRUCTIONS TO CANDIDATES

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

Read these notes carefully.
Write your name, centre number, index number and class in the spaces at the top of this page and on all work you hand in.
Candidates answer on the Question Paper.

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 one and 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 EXAMINERS' USE	
Section A – do all questions	
1	**/ 8**
2	**/ 4**
3	**/ 7**
4	**/ 7**
5	**/ 12**
6	**/ 8**
7	**/ 8**
8	**/ 6**
Section B – do ONE question only	
9	**/ 20**
10	**/ 20**
Deduction	
TOTAL	**/ 80**

PAPER	1	2	3	4	TOTAL
SCORE	/30	/80	/80	/55	/245

This document consists of **24** printed pages.

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-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	$\phi = -GM/r$
temperature	T / K = T / °C + 273.15
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
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.,	$v = v_0 \cos \omega t$ $= \pm \omega\sqrt{(x_0^2 - x^2)}$
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,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire,	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil,	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid,	$B = \mu_0 nI$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 **(a)** A ball is projected with a horizontal velocity of 1.1 m s^{-1} from point A at the edge of a table, as shown in Fig. 1.1.

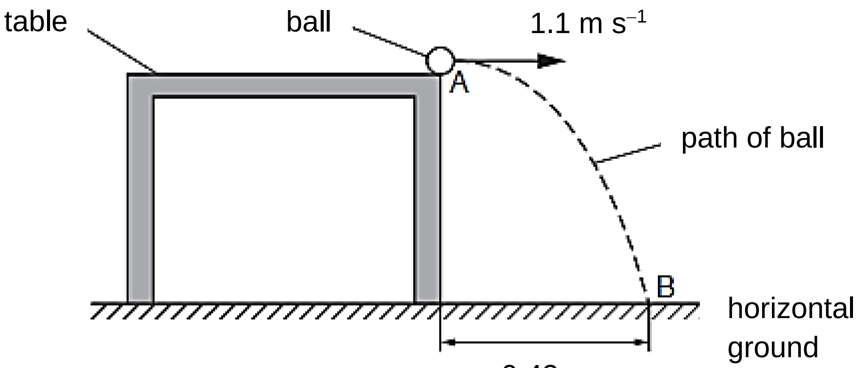

Fig. 1.1

The ball lands on horizontal ground at point B which is 0.43 m away from the base of the table. Air resistance is assumed to be negligible.

(i) Calculate the time taken for the ball to fall from A to B.

time = …………………. s [1]

(ii) Use your answer in **(a)(i)** to determine the height of the table.

height = …………………. m [2]

(ii) Determine the angle that the path of the ball makes to the horizontal when it reaches B.

angle = …………………. ° [2]

(iv) The ball leaves the table at time $t = 0$.

For the motion of the ball between A and B, sketch graphs on Fig. 1.2 to show the variation with time t of

1. the acceleration a of the ball,

2. the vertical component s_v of the displacement of the ball from A.

Numerical values are not required.

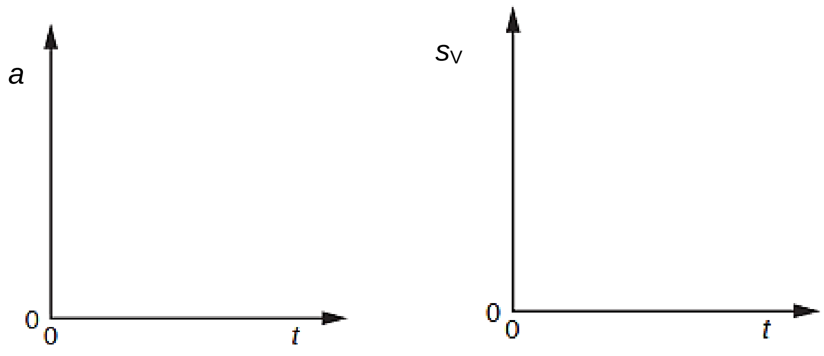

Fig. 1.2

[2]

(b) A ball of greater mass is projected from the table with the same velocity as the ball in **(a)**. Air resistance is still assumed to be negligible.

State and explain the effect, if any, of increased mass on the time taken for the ball to fall to the ground.

……………………………………………………………………………………………

…………………………………………………………………………………… [1]

2 Fig. 2.1 shows a body P supported by 3 wires under tension. The tension in each wire is represented by T_1, T_2 and T_3. Body Q sits on a flat surface.

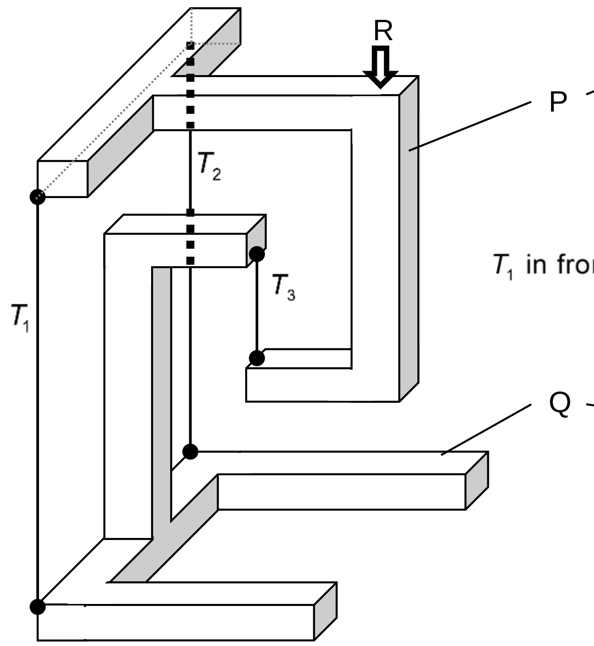

Fig. 2.1

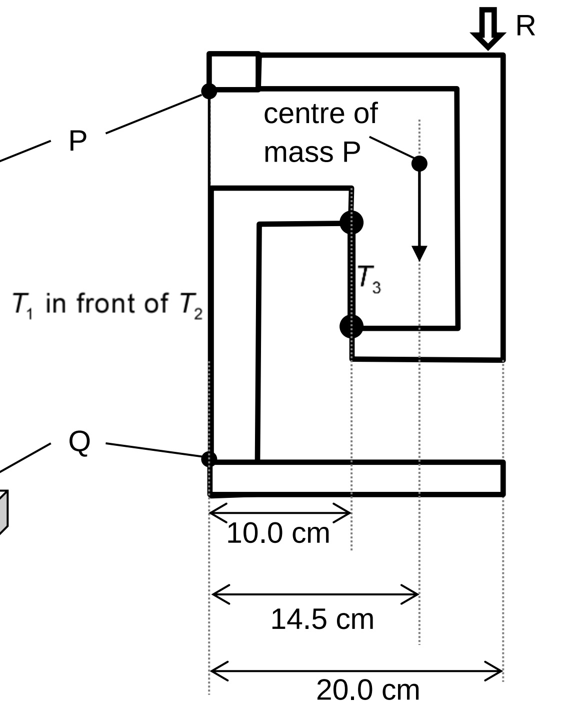

Fig. 2.2

Fig. 2.2 shows the side view of the 2 structures. The mass of body P is 350 g, and acts at a point along a vertical that is 14.5 cm away from wires under tension T_1 and T_2.

(a) On Fig. 2.1, draw arrows to indicate the direction of tensile forces in each of the 3 wires acting on body P. [1]

(b) At equilibrium, the magnitude of tensile forces in wire 1 and wire 2 is the same, $|T_1| = |T_2|$.

Determine the magnitude of T_3.

T_3 = …………………. N [2]

(c) Without further calculation, explain which of the wire(s) is/are more likely to break if a further load is placed onto the structure at location R.

…………………………………………………………………………………………

……………………………………………………………………………………… [1]

3 Fig. 3.1 shows a marble falling onto a spring when released from height of 6.0 cm above the top of the spring. The maximum compression of the spring is 5.0 cm. The spring obeys Hooke's law and has a spring constant of 25 N m^{-1}. You may assume that air resistance is negligible.

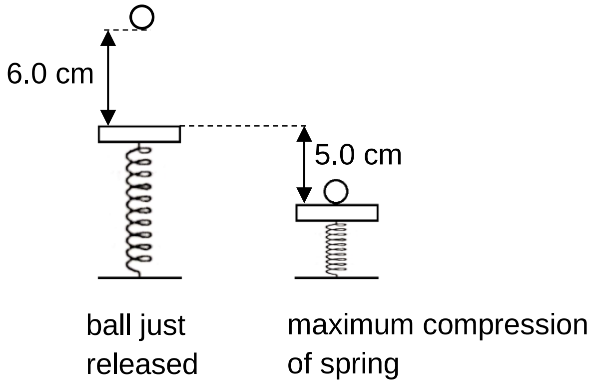

Fig. 3.1

(a) By using the principle of conservation of energy, show that the mass of the ball is 0.029 kg.

[1]

(b) Explain, in terms of forces, why the speed of the marble continues to increase for a period of time after hitting the surface of the spring.

....

....

....

.... [2]

(c) Hence, determine the maximum kinetic energy of the marble.

energy = ……………………………. J [4]

4 Fig. 4.1 shows the path of a charged particle in a uniform magnetic field.

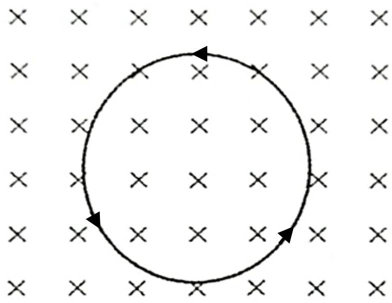

Fig. 4.1

(a) Explain why the charged particle travels in a circular path.

....

....

....

.... [2]

(b) Derive an expression for the time taken T for the charged particle to complete one full circle in terms of its mass m, charge q, and the magnetic flux density B of the uniform magnetic field.

[3]

(c) The mass of the charged particle is 4.5×10^{-26} kg and its speed is 4.8×10^{5} m s^{-1}. Given that the diameter of the circular path is 0.60 m, and that the magnetic flux density of the uniform magnetic field is 0.15 T, determine the charge of the particle.

charge = ……………………………. C [2]

5 The pressure p of an ideal gas is given by the expression

$$p = \frac{1}{3}\rho\langle c^2\rangle$$

where ρ is the density of the gas.

(a) State what is meant by:

(i) an ideal gas

……………………………………………………………………………………….

…………………………………………………………………………….. [1]

(ii) the symbol $\langle c^2\rangle$

……………………………………………………………………………………….

…………………………………………………………………………….. [1]

(iii) Use the expression above to show that the mean translational kinetic energy of the atoms of an ideal gas is given by:

$$\langle E_k\rangle = \frac{3}{2}kT$$

where $\langle E_k\rangle$ is the mean translational kinetic energy, T is the temperature.

Define any symbols that you use.

[4]

(b) **(i)** State what is meant by the internal energy of a system

……………………………………………………………………………………….

……………………………………………………………………………………….

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

(ii) Explain why, for an ideal gas, the change in internal energy is directly proportional to the change in thermodynamic temperature of the gas.

……………………………………………………………………………………….

……………………………………………………………………………………….

……………………………………………………………………………………….

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

(c) A fixed mass of ideal gas in a heat pump undergoes a cycle of changes of pressure, volume, and temperature as illustrated in Fig. 5.1.

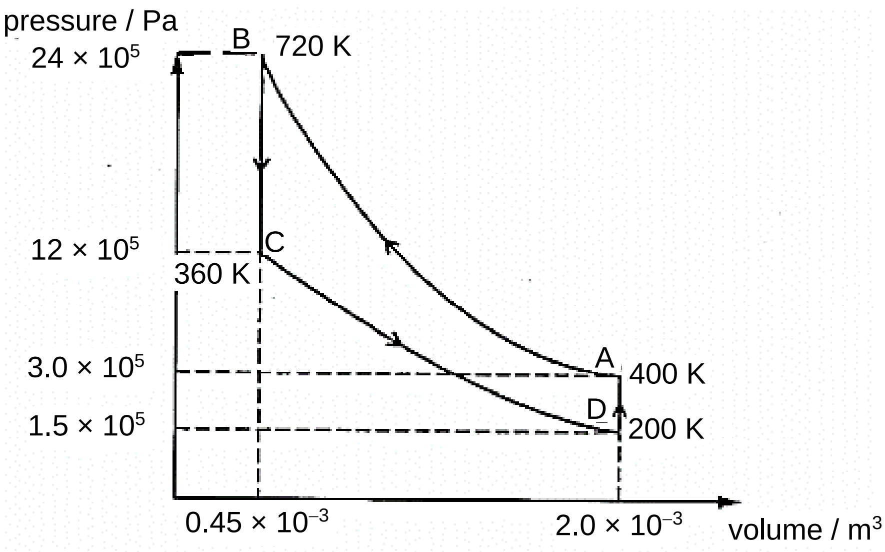

Fig. 5.1

The table below shows the increase in internal energy which takes place during each of the changes A to B, B to C and C to D. It also shows that in both of section A to B and C to D, there is no heat transfer to or from the gas.

Complete the table.

	Increase in internal energy / J	Heat supplied to gas / J	Work done on gas / J
A to B	1200	0	
B to C	–1350		
C to D	–600	0	
D to A			

[3]

6 **(a)** A thin slice of conducting material has its faces PQRS and VWXY normal to a uniform magnetic field of flux density *B*, as shown in Fig. 6.1.

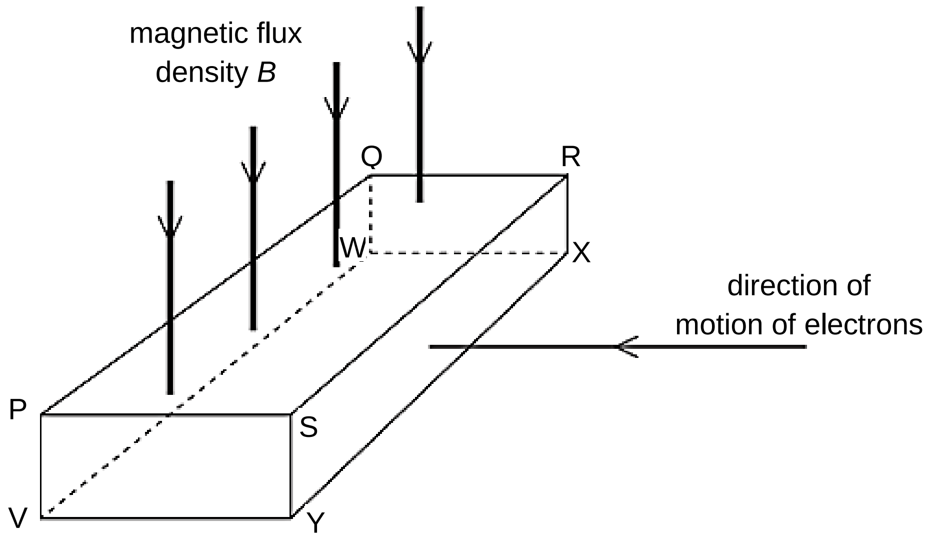

Fig. 6.1

Electrons enter the slice at right-angles to SRXY.

A potential difference is developed between two faces of the slice.

(i) Use letters from Fig. 6.1 to name the two faces between which the potential difference is developed.

……………………………………………………………………………………….

…………………………………………………………………………….. [1]

(ii) State and explain which of the two faces named in **(a)(i)** is more positive.

……………………………………………………………………………………….

…………………………………………………………………………….. [2]

(b) Negative-charged particles are moving through a vacuum in a parallel beam. The particles have speed *v*.

The particles enter a region of uniform magnetic field of flux density 930 μT. Initially, the particles are travelling at right-angles to the magnetic field. The path of a single particle is shown in Fig. 6.2.

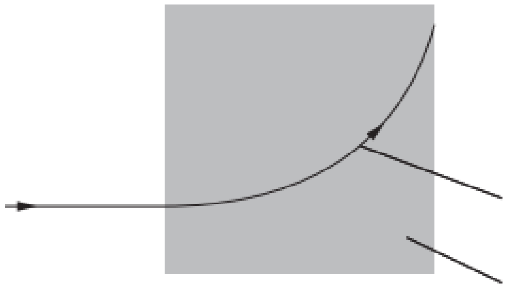

Fig. 6.2

The negatively-charged particles follow a curved path of radius 7.9 cm in the magnetic field.

A uniform electric field of strength 12 kV m^{-1} is then applied in the same region as the magnetic field. The particles then travel in a straight line.

(i) On Fig. 6.2, mark with an arrow, the direction of the electric field. [1]

(ii) Calculate, for the negatively charged particles,

1. the speed *v*,

v = …………………. m s^{-1} [2]

2. the ratio $\frac{\text{charge}}{\text{mass}}$

ratio = …………………. C kg^{-1} [2]

7 **(a)** A sinusoidal alternating current source is connected to a diode and a resistor as shown in Fig. 7.1 below.

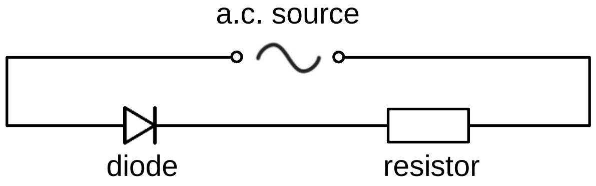

Fig. 7.1

The variation with time of the potential difference in the diode is shown in Fig. 7.2 below.

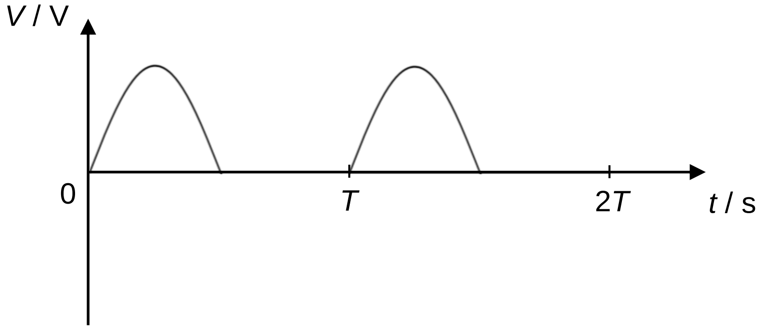

Fig. 7.2

(i) On Fig. 7.3, sketch the variation with time of the potential difference across the resistor.

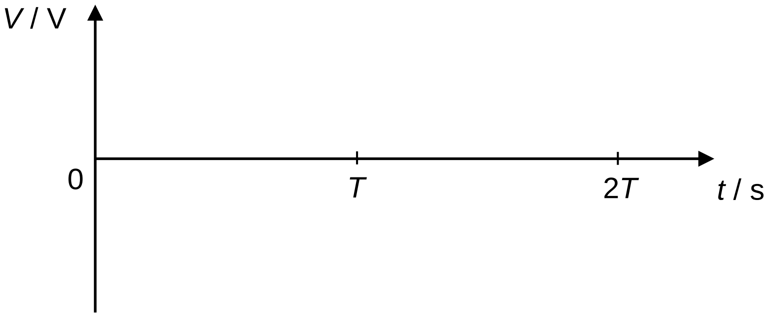

Fig. 7.3

[1]

(ii) On Fig. 7.4, sketch the variation with time of the power in the resistor.

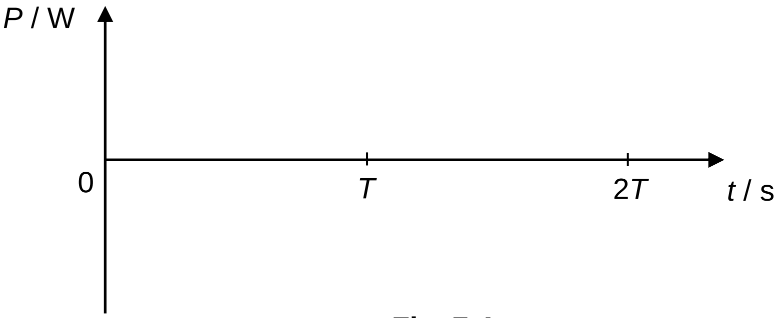

Fig. 7.4

[1]

(iii) Given that the resistance of the resistor is 2.0 Ω, and that the peak voltage in it is 5.0 V, calculate the average power dissipated.

average power = ... W [2]

(b) Fig. 7.5 shows an ideal iron-cored transformer. The ratio of the secondary turns to the primary turns is 1:20.

A 230 V alternating current supply is connected to a primary coil and a 7.0 Ω resistor is connected to the secondary coil.

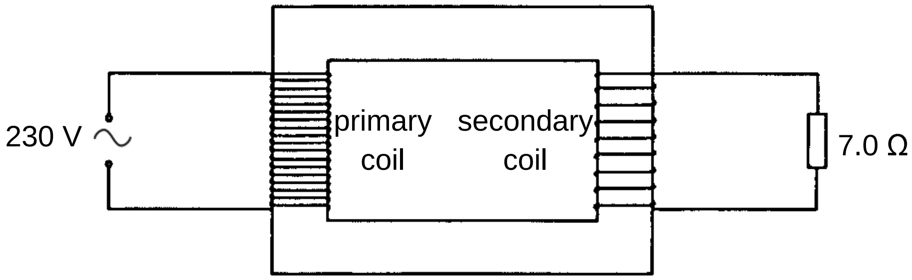

Fig. 7.5

(i) Explain how an alternating current in the primary coil induces an electromotive force in the secondary coil.

....

....

....

....

.... [2]

(ii) Determine the current in the primary coil.

current = ... A [2]

8 X-rays are produced when electrons are accelerated through a potential difference towards a metal target such as tungsten. Fig. 8.1 shows a typical X-ray intensity spectrum that can be produced from an X-ray tube.

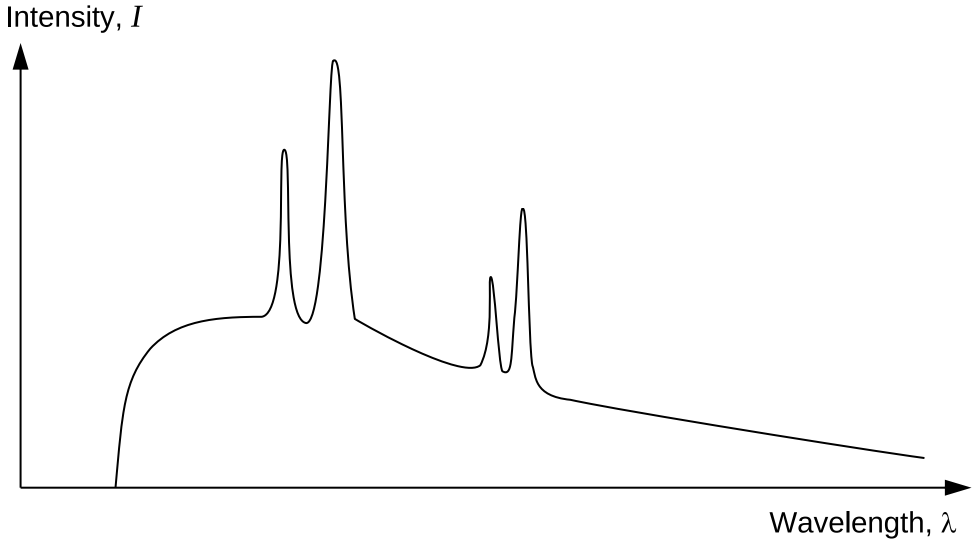

Fig. 8.1

(a) Using conservation of energy, explain why there is a minimum wavelength for the emitted X-rays as shown in Fig. 8.1.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

……………………………………………………………………………………… [1]

(b) Explain the broad, almost continuous, spectrum shown in Fig. 8.1.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

……………………………………………………………………………………… [2]

(c) In a chest X-ray, a photographic film receives photons which have travelled through flesh and bone from a source.

(i) Estimate the area of a film which covers the chest of an adult.

area = …………….. m^2 [1]

(ii) Assume that on average, 10 x-ray photons fall on each grain of the photographic film and the grains are about 1.0 µm apart as shown in Fig. 8.2.

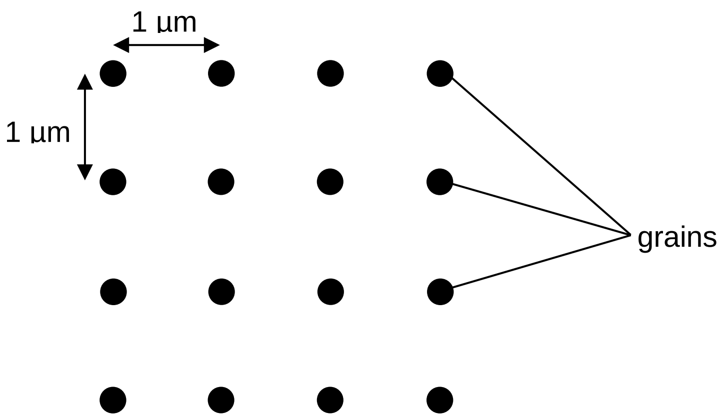

Fig. 8.2

Use your estimate in **(c)(i)** to determine the total x-ray energy falling on the film. Each x-ray photon has a quantum energy of 10^{-15} J.

total energy = …………….. J [2]

Section B

Answer **one** question in this Section in the spaces provided.

9 **(a)** **(i)** Explain what is meant by

1. *diffraction*

……………………………………………………………………………………..

…………………………………………………………………………… [1]

2. *interference*; and

……………………………………………………………………………………..

…………………………………………………………………………… [1]

3. *coherence*

……………………………………………………………………………………..

…………………………………………………………………………… [1]

(ii) State two conditions for observable interference of two waves.

……………………………………………………………………………………….

……………………………………………………………………………………….

……………………………………………………………………………………….

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

(b) To help guide large ships berth properly into docks, an engineer proposed using interference of electromagnetic (EM) waves. The proposal suggests installing two EM wave emitters P and Q positioned 95 m apart at the edges of the dock gates. The two emitters can be taken to be point sources and they emit radio waves of frequency f_1 in phase.

The ship can be guided by searching for the strong signal radiated along the lines of constructive interference, also known as anti-nodal lines. For safety, it is important for the ship to ensure that it is sailing along the centre-line of the gates, as such the ship needs to "lock on" to the central anti-nodal line.

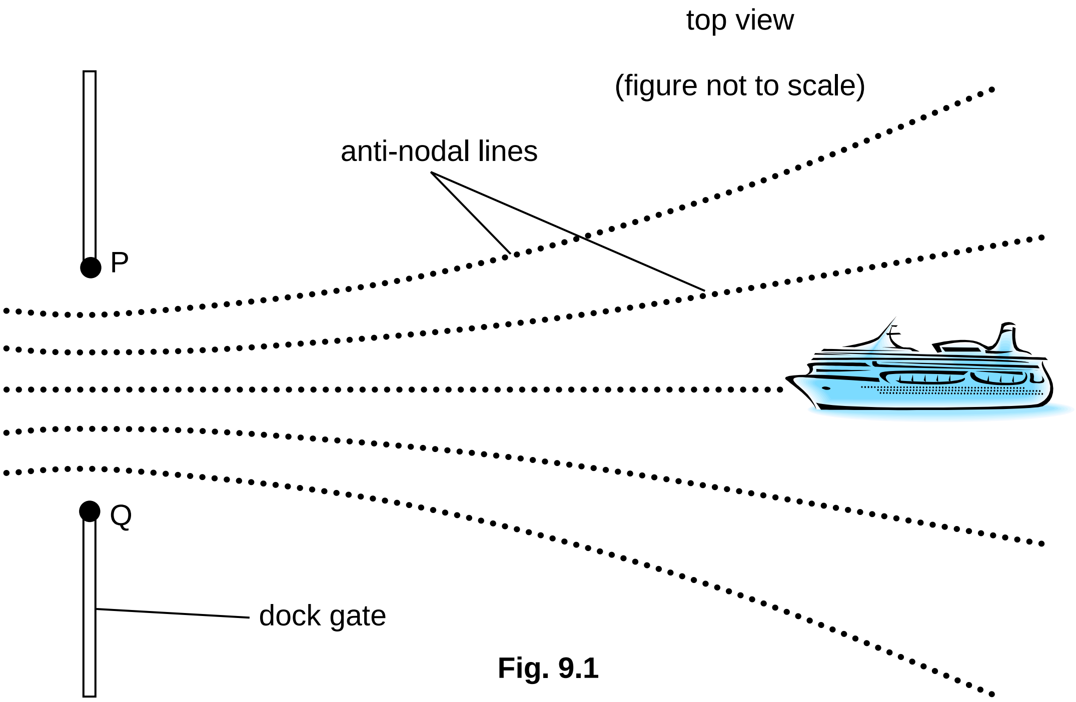

Fig. 9.1

(i) Explain why the centre-line will always be an anti-nodal line regardless of the frequency of the radio waves used.

………………………………………………………………………………………….

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

(ii) State and explain why radio waves are suitable for such a system.

………………………………………………………………………………………….

………………………………………………………………………………………….

………………………………………………………………………………………….

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

(iii) Assuming that the ship is sailing along the centre-line, state and explain how the intensity of the resultant signal varies as it approaches the dock gates.

…………………………………………………………………………………….

…………………………………………………………………………………….

…………………………………………………………………………………….

…………………………………………………………………………….. [2]

(c) One particular large cargo ship strays off the centre-line as shown in Fig. 9.2.

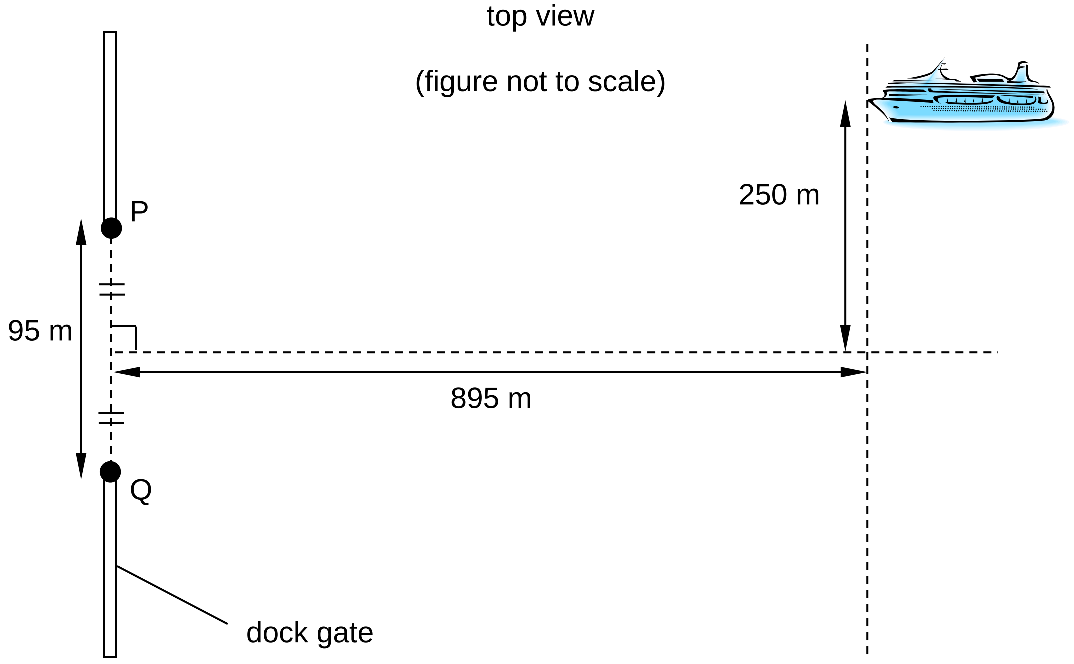

Fig. 9.2

Explain quantitatively (with calculations) whether the ship is on an anti-nodal line, given that f_1 is 23.5 MHz.

………………………………………………………………………………………………

………………………………………………………………………………………………

……………………………………………………………………………………… [3]

(d) As an additional precaution to ensure that the ship "locks on" to the central anti-nodal line, the emitters can simultaneously emit another radio wave of a different frequency f_2.

(i) Explain how this precaution helps to prevent the ship from "locking on" to the wrong anti-nodal line.

…………………………………………………………………………………….

…………………………………………………………………………………….

…………………………………………………………………………………….

…………………………………………………………………………….. [1]

(ii) Discuss why this additional precaution may still not be fool proof.

…………………………………………………………………………………….

…………………………………………………………………………………….

…………………………………………………………………………………….

…………………………………………………………………………….. [1]

(e) The large cargo ship is carrying loads of new cars. As the cargo ship is cruising, a car which is not secured properly starts to move. A small piece of chewing gum is stuck to the edge of the wheel as shown in Fig. 9.3. A camera records the motion of the car's wheel from the rear view as it is rotating. Assume that the angular velocity of the wheel is constant.

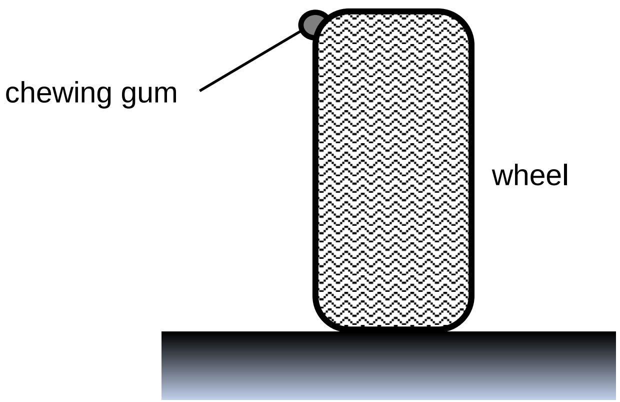

Fig. 9.3

(rear view)

(i) State the type of motion exhibited by the chewing gum from this viewpoint as shown in Fig. 9.3 when the wheel rotates.

…………………………………………………………………………….. [1]

(ii) The car moves at a speed of 5.0 km h^{-1}. Determine the period of the chewing gum, given that the wheel has a diameter of 0.45 m.

period = …………….. s [2]

(iii) Hence, determine the maximum vertical acceleration of the chewing gum.

maximum vertical acceleration = …………….. m s^{-2} [2]

10 **(a)** Fig. 10.1 shows the variation with nucleon number of the binding energy per nucleon of a nucleus.

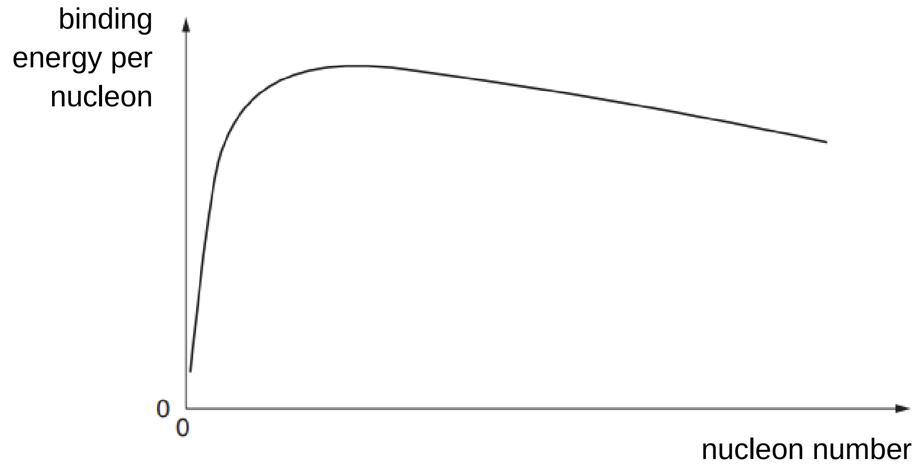

Fig. 10.1

(i) On Fig. 10.1, mark with the letter S the position of the nucleus with the greatest stability. [1]

(ii) One possible fission reaction is

$$^{235}_{92}\text{U} + ^{1}_{0}\text{n} \rightarrow ^{144}_{56}\text{Ba} + ^{90}_{36}\text{Kr} + 2^{1}_{0}\text{n}$$

On Fig. 10.1, mark possible positions for

1. the Uranium-235 nucleus (label this position U),
2. the Krypton-90 nucleus (label this position Kr). [1]

(iii) The binding energy per nucleon of each nucleus is as follows.

$^{235}_{92}\text{U}$	: 1.2191×10^{-12} J
$^{144}_{56}\text{Ba}$	: 1.3341×10^{-12} J
$^{90}_{36}\text{Kr}$	: 1.3864×10^{-12} J

Determine the energy released in the fission reaction, give your answer to 5 significant figures.

energy = …………………. J [2]

(iv) Hence, determine the mass equivalent of the energy

mass = …………………. kg [2]

(v) Explain why a release of energy occurs during such a fission reaction.

…………………………………………………………………………………….

………………………………………………………………………………….. [1]

(vi) Suggest why the neutrons were not included in your calculation in **(a)(iii).**

…………………………………………………………………………………….

………………………………………………………………………………….. [1]

(b) Carbon-14 is a radioactive isotope of carbon. Its presence in organic materials is the basis of radiocarbon dating.

(i) State what an isotope is.

…………………………………………………………………………………….

………………………………………………………………………………….. [1]

(ii) Carbon-14 is unstable and goes through the following process.

$$^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{Y}_{X}D + \bar{\nu}$$

Determine X, Y and hence state the identity of particle D.

Y = ………………….

X = ………………….

D = …………………. [2]

(iii) A student has a sample of Carbon-14. The student defined the half-life of Carbon-14 as the time taken for the number of nuclei inside the box to decay to one half of its initial value.

State and explain one reason why this definition is inappropriate.

……………………………………………………………………………………….

……………………………………………………………………………………….

…………………………………………………………………………….. [2]

(c) Measurements are made of the activity of a specimen of carbon from pieces of wood found in a fireplace at an archaeological site. The specimen is found to contain one Carbon-14 atom per 8.6×10^{10} Carbon-12 atoms. Another sample was obtained from carbon from a modern fire, the concentration of Carbon-14 atoms is greater at one Carbon-14 atom per 3.3×10^{10} Carbon-12 atoms.

(i) Explain why the concentration of the two samples of carbon is different.

……………………………………………………………………………………….

…………………………………………………………………………….. [1]

(ii) Given that the half-life of Carbon-14 is 5700 years, calculate the age of the wood from the ancient fire.

age = …………………. years [4]

(iii) Suggest two constraints of this method of determining the age of a sample.

……………………………………………………………………………………….

……………………………………………………………………………………….

…………………………………………………………………………….. [2]

End of Paper