RIVER VALLEY HIGH SCHOOL
JC 2 PRELIMINARY EXAMINATIONS

H2 PHYSICS 9749 / 3
PAPER 3

15 SEPTEMBER 2023

2 HOURS

CANDIDATE NAME									
CENTRE NUMBER	S					**INDEX NUMBER**			
CLASS	2	2	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	**/ 9**
2	**/ 6**
3	**/ 7**
4	**/ 5**
5	**/ 6**
6	**/ 12**
7	**/ 7**
8	**/ 8**
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 26 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	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
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 this Section in the spaces provided.

1 **(a)** Define *random error* and state a method to reduce the effects of it.

....

....

....

....

.... [2]

(b) The theory of gas flow through small diameter tubes at low pressures is an important consideration of high vacuum technique.

One equation which occurs in the theory is

$$Q = \frac{kr^3(p_1 - p_2)}{L}\sqrt{\frac{M}{RT}}$$

where k is a number without units, r is the radius of the tube, p_1 and p_2 are the pressures at each end of the tube of length L, M is the molar mass of the gas, R is the molar gas constant and T is the thermodynamic temperature.

Use the equation to find the base SI units of Q.

base SI units of Q = ... [2]

(c) A factory produces solid copper cylinders. The length of a typical cylinder is measured as (28.0 ± 0.1) cm and diameter (6.0 ± 0.1) cm.

(i) Given the density of copper is 8.96 g cm^{-3}, determine the mass of a copper cylinder and its absolute uncertainty to the appropriate number of significant figures.

mass = ………………. ± ………………………. kg [4]

(ii) Explain the effect on the percentage uncertainty of the mass if the same length and diameter measurements were made using instruments of higher precision.

....

....

.... [1]

2 Fig. 2.1 shows a ball to be shot at an angle θ above the level ground towards a wall 20 m away from it. x is the displacement from the launching point in the direction of the wall.

Fig. 2.1

Fig. 2.2 shows the variation of the vertical component of the ball's velocity v_y with displacement x.

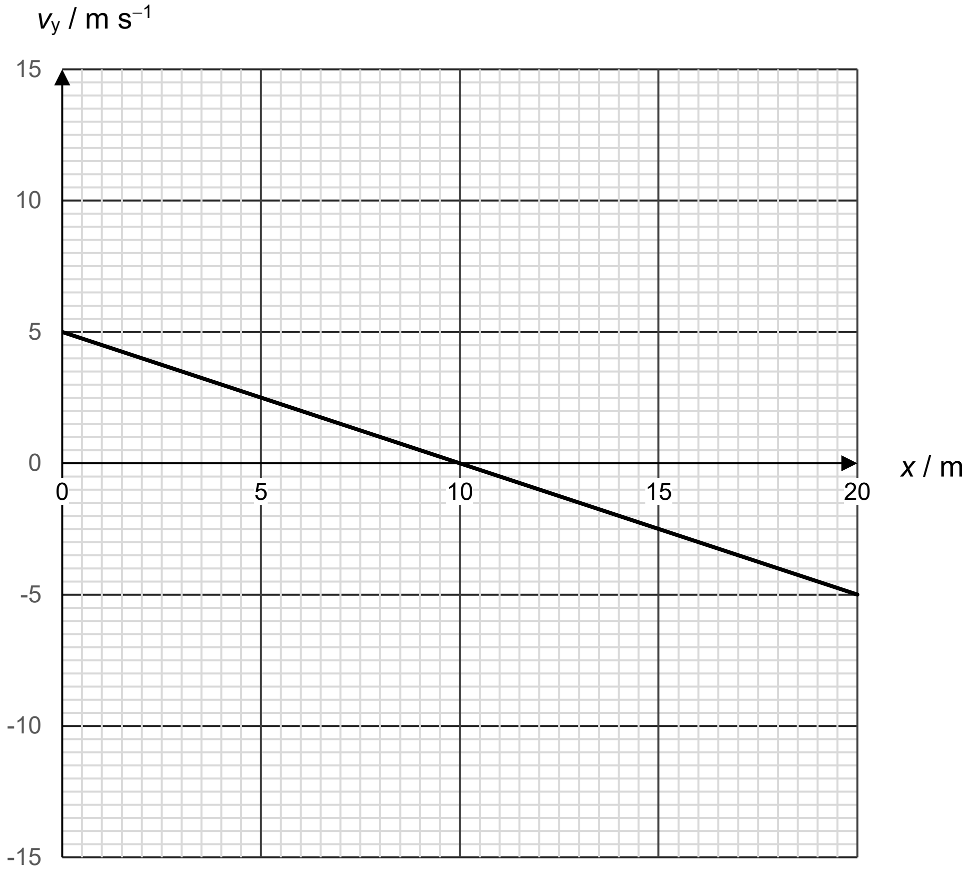

Fig. 2.2

(a) Show that the time taken for the ball to reach the wall is 1.02 s.

[2]

(b) Hence, or otherwise, determine the horizontal component of the ball's velocity.

horizontal velocity = ………………….. m s^{-1} [1]

(c) Determine θ.

θ = …………………..° [2]

(d) The ball is now projected at different θ with the same speed.

On Fig. 2.2, sketch the variation of v_y with x if the ball were to hit the wall when it is at its maximum height.

[1]

3 **(a)** Define *moment of a force*.

....

.... [1]

(b) A uniform rod of length L with weight 400 N is attached to a vertical wall by strong adhesive as shown in Fig. 3.1. The other end of the rod is fastened to an inextensible rope. The structure is used to support a metal load of weight 2000 N.

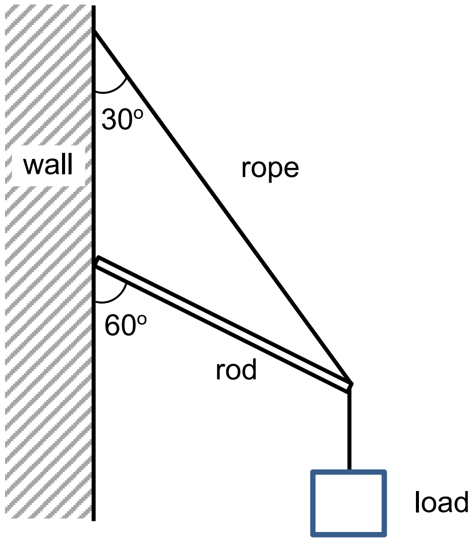

Fig. 3.1

(i) Calculate the tension in the rope.

tension = ……………………. N [3]

(ii) On Fig. 3.2, draw an arrow, ***R***, to show **the force on the wall** by the rod. Show your working clearly. Include the construction of line of forces.

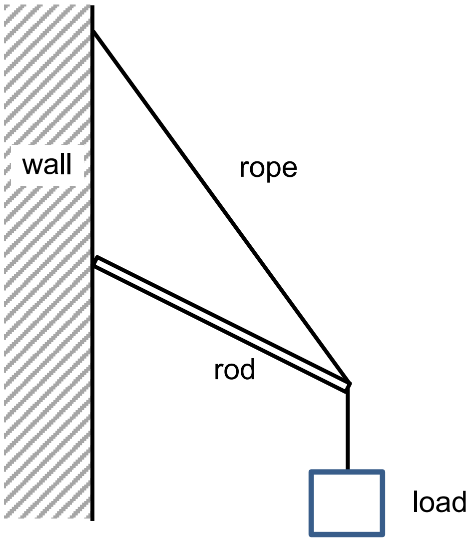

Fig. 3.2

[1]

(c) The metal load is now submerged in water as shown in Fig. 3.3.

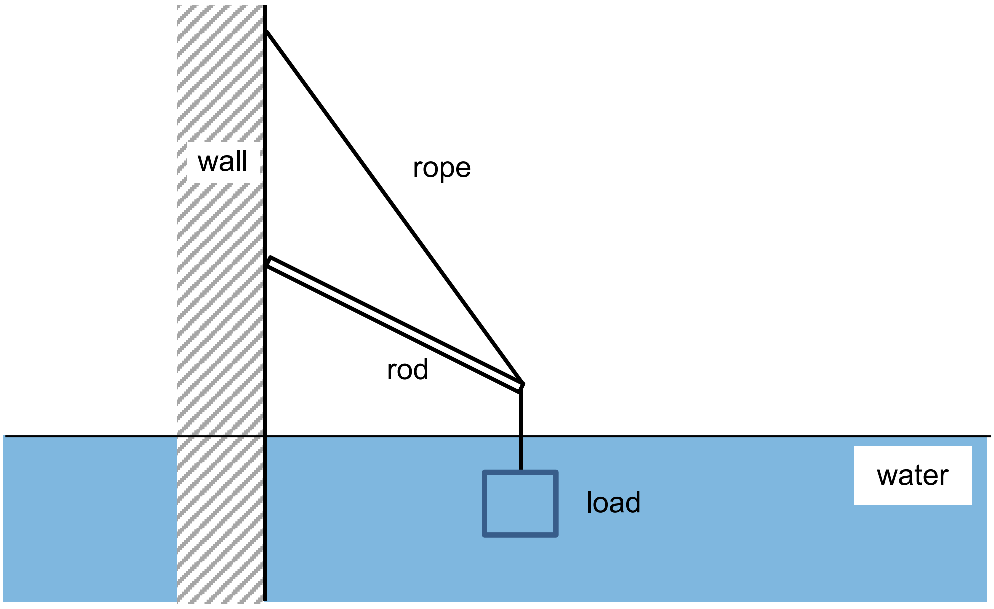

Fig. 3.3

The positions of the rope and rod remain the same.

Suggest how this affects your answer in **(b)(ii)**, if any.

....

....

.... [2]

4 A mass m is given an initial speed of 10 m s^{-1} up a rough inclined plane with an angle 0.57° above the horizontal. It travelled 150 m before it stopped.

(a) Describe the conversion of energy as the mass travelled up the inclined plane and stopped.

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………… [1]

(b) **(i)** Write down the gain in gravitational potential energy of the mass in terms of m. Show your working.

gain in gravitational potential energy = ………………….. [2]

(ii) Hence, calculate the proportion of energy lost due to friction.

proportion of energy = ………………….. [2]

5 Fig. 5.1 shows a mass of 8.0 kg on a rotating platform. The mass stays at a fixed position on the slope of the rotating platform and rotates about in a horizontal circle of radius r = 12 m and at constant angular speed. The frictional force acting up the slope on the mass is 61 N.

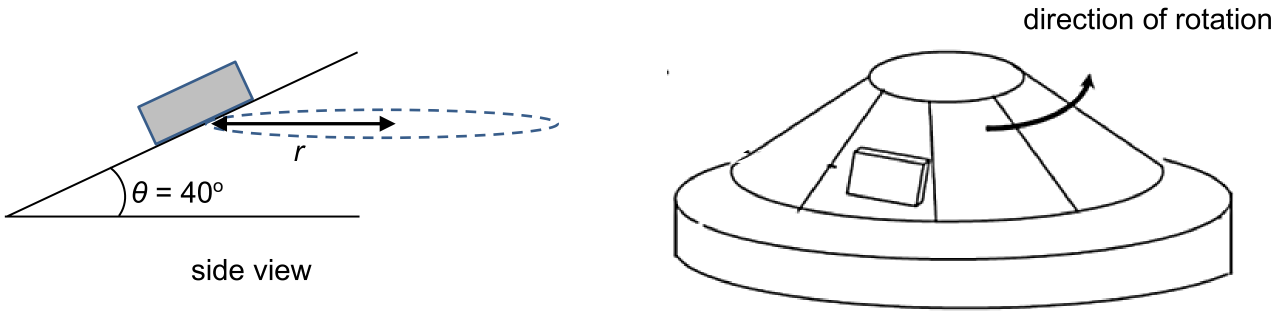

Fig. 5.1

(a) Using Newton's laws, explain why the baggage will experience a net force towards the centre of the circle.

....

....

....

.... [2]

(b) Show that the normal contact force on the baggage is 51 N.

[2]

(c) Calculate the time taken for the suitcase to complete one full rotation.

time taken = …………………… s [2]

6 **(a)** State what is meant by a *field of force* around a mass and hence define *gravitational field strength.*

....

....

....

....

.... [2]

(b) Using Newton's laws, show that, for a circular orbit of an object about the centre of a planet,

$$T^2 = \frac{4\pi^2 r^3}{GM}$$

where T is the orbital period of the object,
M is the mass of the planet, and
r is the distance between the centre of mass of the object and the planet.

[3]

(c) The planet Jupiter has several moons. Deriving from the expression in **(b)**, data for some of these moons are plotted on a graph of $\log_{10}$ (T/days) against $\log_{10}$ (r/m) on Fig. 6.1.

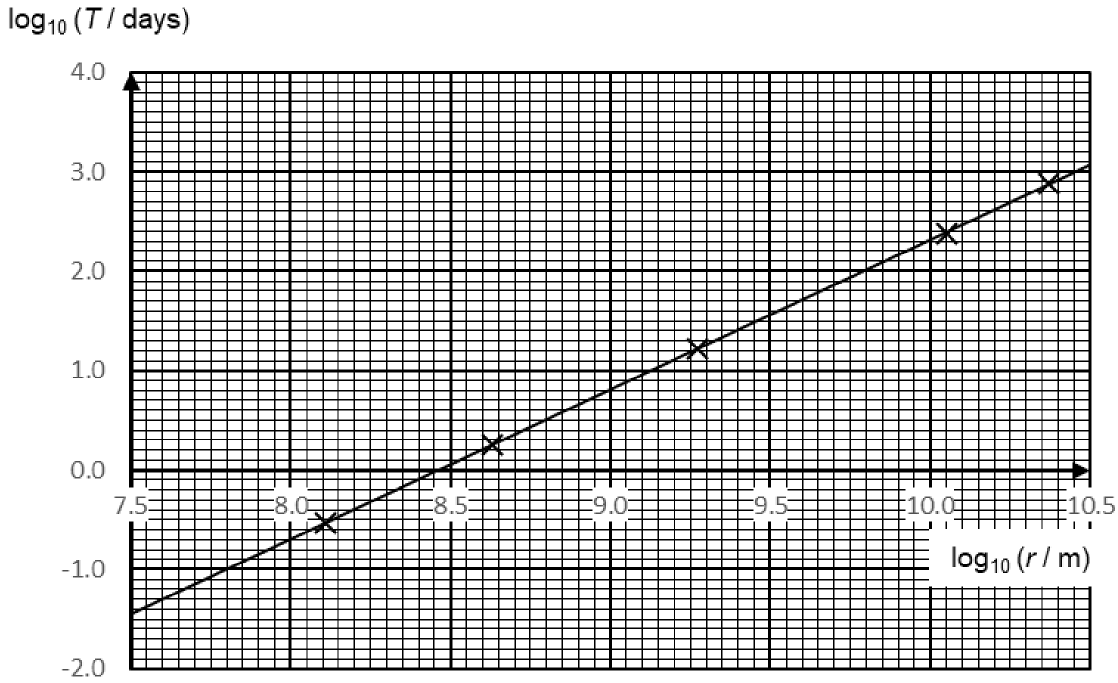

Fig. 6.1

Observations show that the moon Ganymede orbits Jupiter with a period of 7.16 Earth days. Use Fig. 6.1 to estimate the orbital radius of Ganymede.

orbital radius = ………………….. m [2]

(d) It is reported in the media that the moon Thebe is discovered to orbit Jupiter once every 16.2 hours at a height of 2.22×10^5 **km** above the surface of Jupiter.

Referring to Fig. 6.1, comment on the accuracy of this media report.

....

....

....

.... [2]

(e) Fig. 6.2 shows how the gravitational potential, Φ, vary due to the Earth at three orbits, A, B and C. These orbits could be occupied by a 53.2 kg satellite in circular orbit around the Earth, E, of radius 6.38×10^3 km.

orbit	Φ / MJ kg^{-1}	distance from surface / km
A	– 42.5	3000
B	– 47.6	2000
C	– 54.1	1000

Fig. 6.2

(i) Determine the change in gravitational potential energy (GPE) from orbit B to orbit A. Leave your answer in standard form.

change in GPE = ... J [2]

(ii) Using data from Fig. 6.2, show that the gravitational potential is inversely proportional to the radial distance. [1]

7 In a car, the power supply to two identical light bulbs R_1 and R_2 as shown in Fig. 7.1 consists of two power sources: a 12 V battery of internal resistance 0.20 Ω and a generator of 14 V connected in series with a variable resistor of resistance *R*. The resistance of each light bulb is 3.0 Ω.

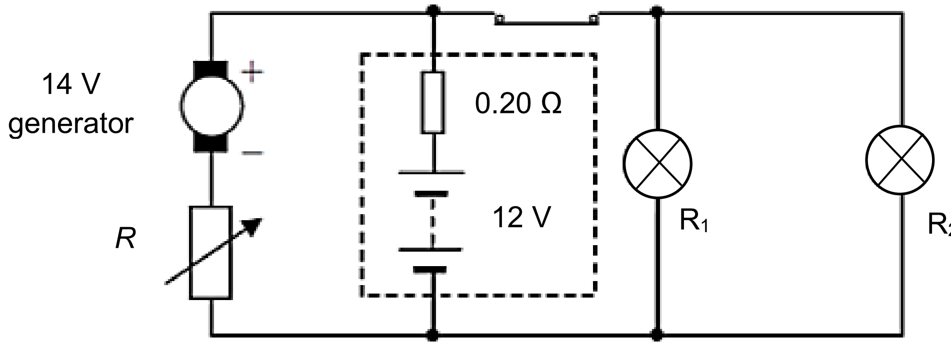

Fig. 7.1

(a) Resistance *R* is adjusted so that there is no current in the 12 V battery when the light bulbs are turned on.

Show that *R* = 0.25 Ω. Explain your working.

[2]

(b) A diode is connected to the circuit as shown in Fig. 7.2.

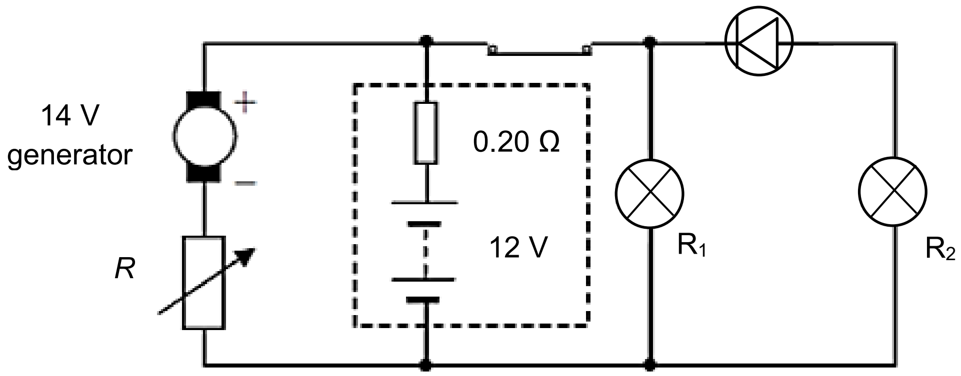

Fig. 7.2

Determine the value of *R* to maintain the current in the 12 V battery to be at zero ampere. Explain your working clearly.

R = ………………….. Ω [3]

(c) Suggest two advantages which the circuit, as shown in Fig. 7.1, has over a single power source.

....

....

....

.... [2]

8 **(a)** **(i)** A slow neutron and a uranium-235 nucleus undergo a fission process, which includes the formation of strontium-90 nucleus, ${}^{90}_{38}Sr$, summarised by the following equation.

$${}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{P}_{Q}X \rightarrow {}^{R}_{54}Xe + {}^{90}_{38}Sr + 3{}^{1}_{0}n + \text{energy}$$

State the numerical values of P, Q and R.

P = ...

Q = ...

R = ... [1]

(ii) In another fission process involving uranium-235,

$${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{148}_{57}La + {}^{85}_{35}Br + 3{}^{1}_{0}n$$

Given the following data, calculate the energy released in this process for one uranium nucleus.

mass of U-235 = 235.1 u
mass of neutron = 1.009 u
mass of La-148 = 148.0 u
mass of Br-85 = 84.9 u

energy = ... J [2]

(b) A strontium-90 nucleus emits a β^- particle and undergoes a *spontaneous and random* decay to yttrium (Y). The decay has a half-life of 28 years.

(i) State what is meant by

spontaneous: ....

....

random: ....

.... [2]

(ii) Write the nuclear transformation equation for the emission of the β^- particle. [1]

(iii) In a laboratory source of strontium-90, the number of atoms present in the year 2023 was 2.36×10^{13}.

Calculate the number of strontium atoms that will be present in the source in the year 2135 (112 years later).

number = ………………………………… [2]

Section B

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

9 A monatomic ideal gas in an expandable chamber is cooled from 50.0 °C to 10.0 °C at constant pressure 3.00×10^5 Pa. Total heat given out by the gas is 1.79×10^4 J.

(a) The specific heat capacity at constant pressure of the gas is 5190 J kg^{-1} K^{-1}. One mole of the gas has mass of 4.0 g.

Determine the number of gas atoms in the chamber.

number of gas atoms = ………………….. [3]

(b) **(i)** Define an ideal gas. Explain all symbols you may have used in your answer.

……………………………………………………………………………………

……………………………………………………………………………………

..………………………………………………………………………… [2]

(ii) Calculate the change in internal energy of the gas when it has been cooled. Explain your answer.

change in internal energy = ………………….. J [2]

(iii) Calculate the percentage change in root–mean–square speed of the gas when it has been cooled.

percentage change = …………………..% [2]

(c) **(i)** State the *first law of thermodynamics*.

……………………………………………………………………………………….

……………………………………………………………………………………….

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

(ii) Use the first law of thermodynamics, or otherwise, to determine the work done by the gas it has been cooled.

work done = ………………….. J [2]

(iii) Determine the heat given out by the gas if it is cooled from 50.0 °C to 10.0 °C at constant volume instead. Explain your working.

heat given out = ………………….. J [2]

(d) **(i)** Calculate the volume of the gas before and after the change in temperature, considering constant pressure.

volume before = ………………….. m^3

volume after = ………………….. m^3 [1]

(ii) Hence, sketch in Fig. 9.1 the pressure – volume graph of the gas as it is being cooled from 50.0 °C to 10.0 °C at constant pressure 3.00×10^5 Pa.

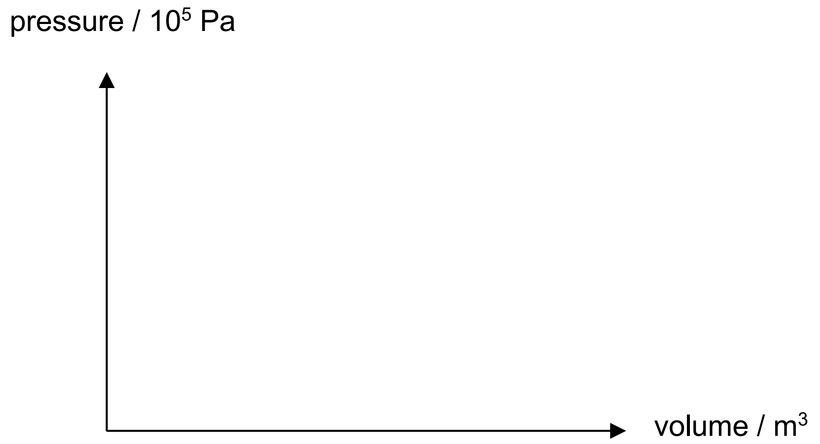

Fig. 9.1

[2]

(e) With reference to the heat given out, comment on the difference in your answer in **(c)(iii)**, if any, with the process when the gas is cooled at constant pressure.

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

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

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

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

…………………………………………………………………………………… [2]

10 **(a)** Fig. 10.1 shows a tuning fork made of a handle and two prongs. One of the tines of the tuning fork is knocked such that it vibrates with a frequency of 130 Hz.

The vibrations cause the neighbouring air molecules to vibrate such that a longitudinal progressive sound wave of the same frequency is formed. The positions of the air molecules around the tuning fork at a particular instant is also shown in Fig. 10.1.

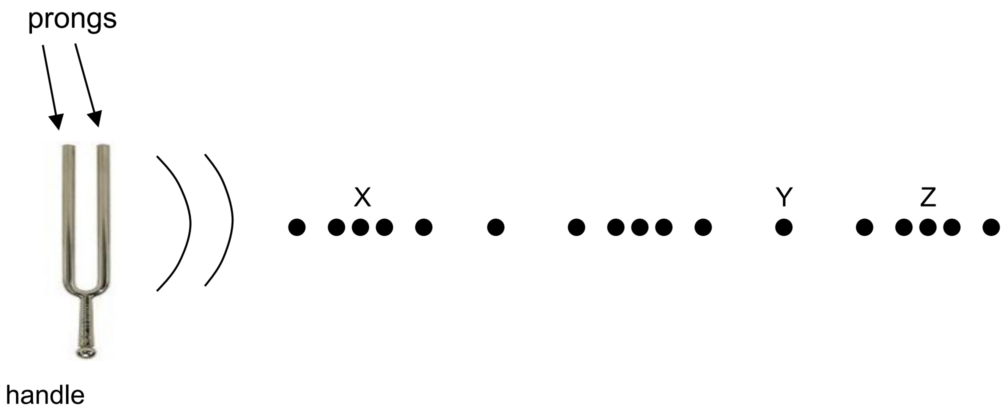

Fig. 10.1

(i) State what is meant by *longitudinal progressive sound wave*.

…………………………………………………………………………………...

…………………………………………………………………………………...

………………………………………………………………………………… [2]

(ii) By considering the movement of air molecules, state and explain the pressure experienced by the air molecule at Y, at the instant shown in Fig. 10.1.

…………………………………………………………………………………...

…………………………………………………………………………………...

…………………………………………………………………………………...

………………………………………………………………………………… [2]

(iii) Given that the distance between X and Z is 5.1 m, calculate the speed of the longitudinal wave between X and Z.

speed of wave = …………….. m s^{-1} [2]

(iv) State the phase angle of Y with respect to X.

phase angle = …………………. rad [1]

(b) The longitudinal waves created by the tuning fork in **(a)** can be assumed to have a power of 0.82 W and is equally radiated in all directions. A microphone with effective circular cross sectional area of radius 2.5 cm is placed 4.8 m away from the tuning fork as shown in Fig. 10.2 (not to scale).

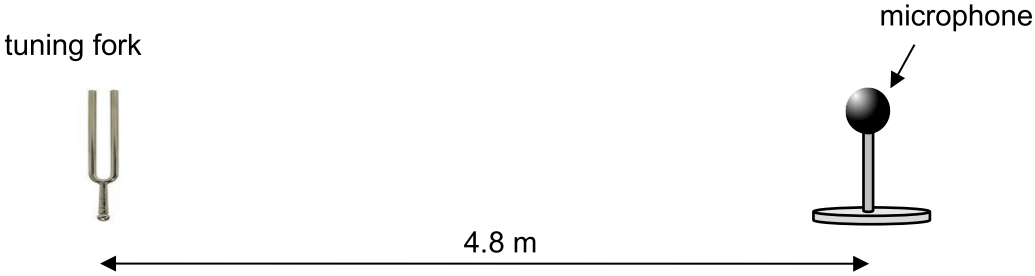

Fig. 10.2

(i) Estimate the power received by the microphone.

power = …………………. W [3]

(ii) Fig. 10.2 shows the position of microphone at time t = 0 s. The microphone moves at constant speed of 0.40 m s^{-1} directly away from the turning fork for until t = 2.0 s.

Sketch a graph on the axes given in Fig. 10.3 of how power P received by the microphone varies with t. Label your graph clearly.

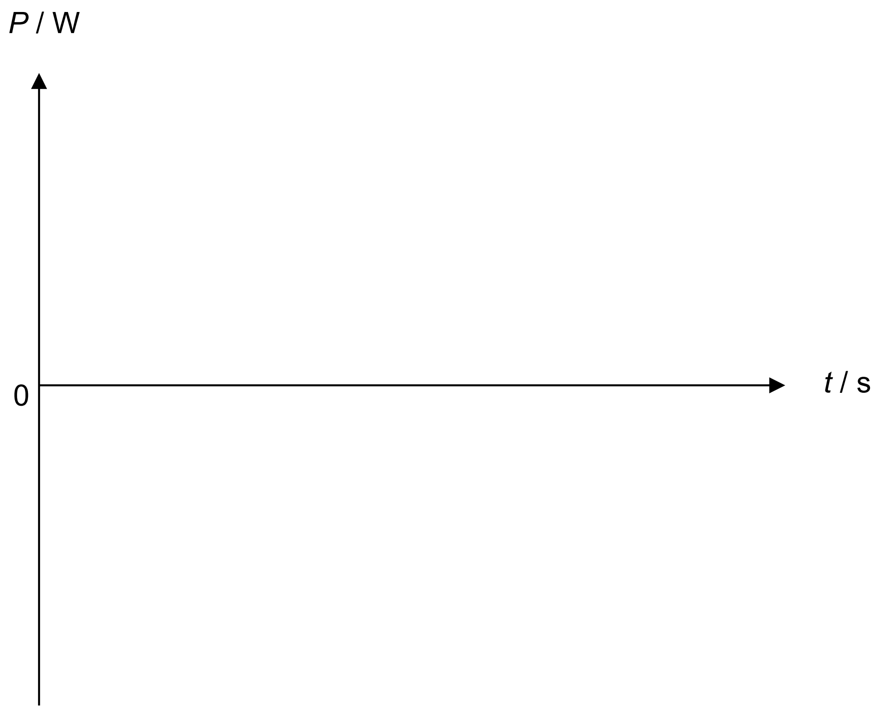

Fig. 10.3

[3]

(c) A new tuning fork and microphone in **(b)** are now placed in the setup as shown in Fig. 10.3. The tuning fork is now vibrating at a new frequency *f*. The sound waves generated by the tuning fork arrive at microphone via two different paths, APB and AQB. The left-tube is fixed in position, while the right-tube consists of a sliding-section. Both the left-tube and right-tube are made of metal.

At position B, the sound waves from the two paths interfere.

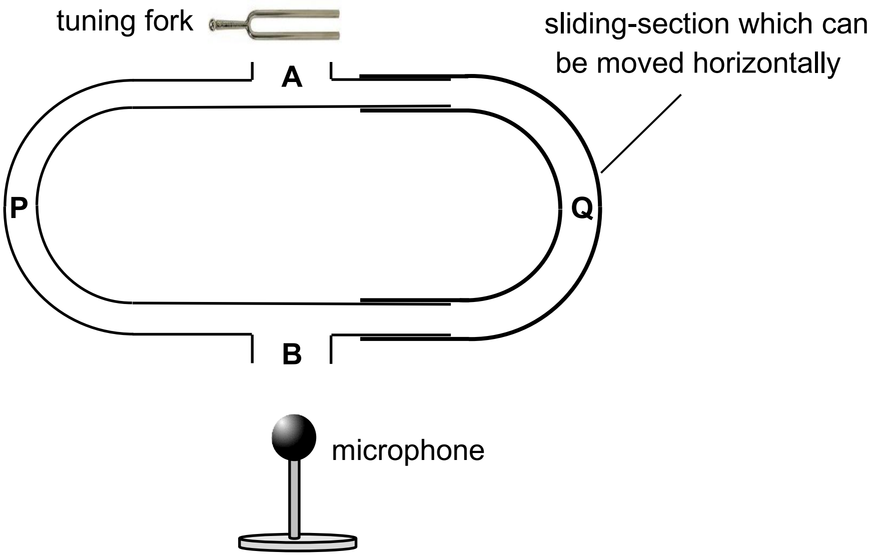

Fig. 10.3

Initially, the lengths of path APB and AQB are equal. The sliding-section is then pulled out horizontally by 0.20m, and the loudness at B changes from one maximum to subsequent maximum.

(i) Determine the path difference between the two waves after the sliding-section is pulled out.

path difference = …………………. m [1]

(ii) Assuming the speed of wave in the pipe is 320 m s^{-1}, calculate *f*.

f = …………………. Hz [2]

(iii) Explain why a standing wave is set up in the tube in Fig. 10.3.

…………………………………………………………………………………….

…………………………………………………………………………………….

…………………………………………………………………………………….

…………………………………………………………………………………….

…………………………………………………………………………… [2]

(iv) The tuning fork is now replaced by a microwave emitter.

A. Suggest one possible change to the setup in Fig. 10.3 to detect interferences at B.

……………………………………………………………………………..

……………………………………………………………………………..

…………………………………………………………………… [1]

B. Hence explain for the difference between the signal detected after the change and the original signal detected in Fig. 10.3.

……………………………………………………………………………..

……………………………………………………………………………..

…………………………………………………………………… [1]

End of Paper