Centre Number	Index Number	Name	Class
S3016			

RAFFLES INSTITUTION
2021 Preliminary Examination

PHYSICS **9749/03**
Higher 2 **September 2021**
Paper 3 Longer Structured Questions **2 hours**

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

READ THESE INSTRUCTIONS FIRST

Write your index number, name and class in the spaces at the top of this page.
Write in dark blue or black pen in the spaces provided in this booklet.
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 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		
Section A	1	/ 8
	2	/ 8
	3	/ 9
	4	/ 10
	5	/ 6
	6	/ 11
	7	/ 8
Section B	8 / 9	/ 20
Deduction		
Total		/ 80

This document consists of **22** printed pages.

[Turn over

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	=	ρgh
gravitational potential	ϕ	=	$-Gm/r$
temperature	T/K	=	$T/{}^\circ\mathrm{C} + 273.15$
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	=	$\frac{\mu_0 N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 n I$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

Answer **all** the questions from this Section in the spaces provided.

1 (a) A body has an initial velocity u and a constant acceleration a in the same direction. After time t, the body has moved a distance s and has a final velocity v. The motion can be summarised by the following equations

$$v = u + at$$

$$s = \frac{1}{2}(u+v)t$$

Using the above equations, derive an expression for v in terms of u, a and s.

[1]

(b) Fig. 1.1 shows a basketball player practicing a layup where the basketball of diameter 0.23 m is tossed vertically upwards close to the rim of the hoop into the hoop.

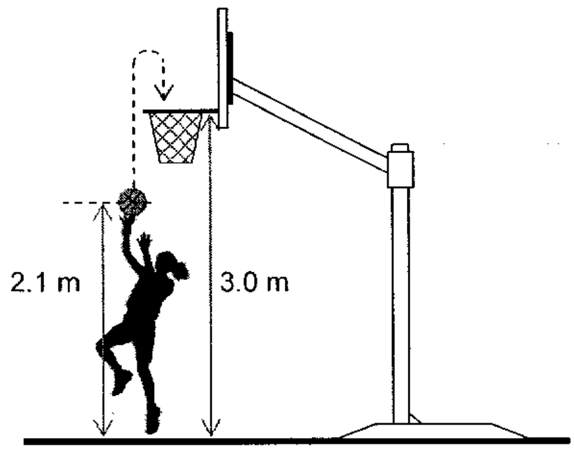


Fig. 1.1

Determine the minimum vertical velocity of release required in order for the basketball to enter the basket when it is thrown upwards from a height of 2.1 m.

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

(c) Fig. 1.2 shows another basketball player taking a jumpshot from the three-point line of a basketball court. He releases the basketball at an angle of 50° above the horizontal with speed u at line A at a height of 2.5 m above the ground. The hoop is at line B, 3.0 m above the ground and 6.7 m from line A.

The basketball takes 1.3 s to travel from line A to line B.

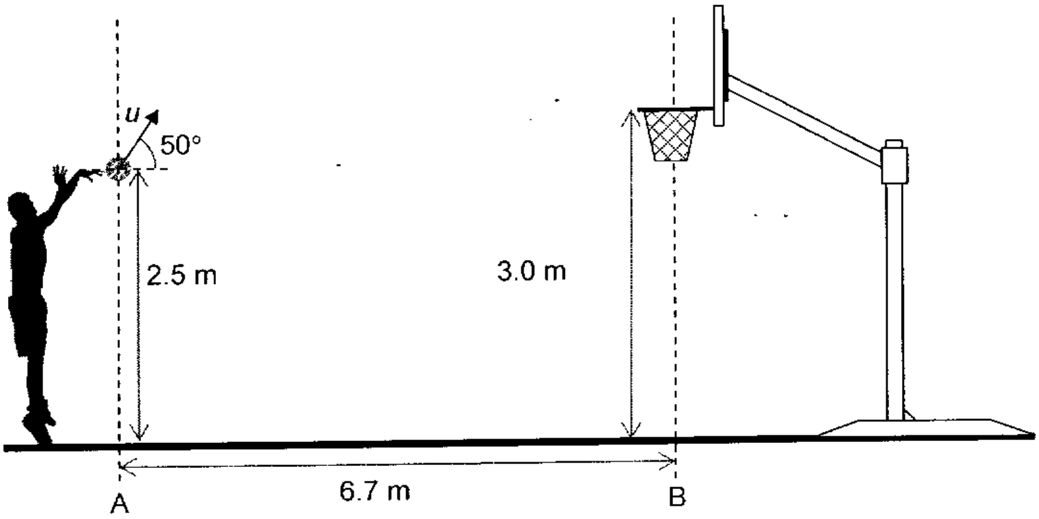


Fig. 1.2

(i) Show that the speed u is 8.0 m s^{-1}.

[1]

(ii) Hence, calculate the height of the basketball above the ground at line B.

height = ______________________ m [3]

2 **(a)** Explain why gravitational potential has a negative value.

....

....

....

.... [2]

(b) Fig. 2.1 shows the variation of the gravitational potential ϕ with distance d from the surface of a certain planet. Point P is at a distance of 1.0×10^7 m from the surface of the planet and point Q is on the surface of the planet.

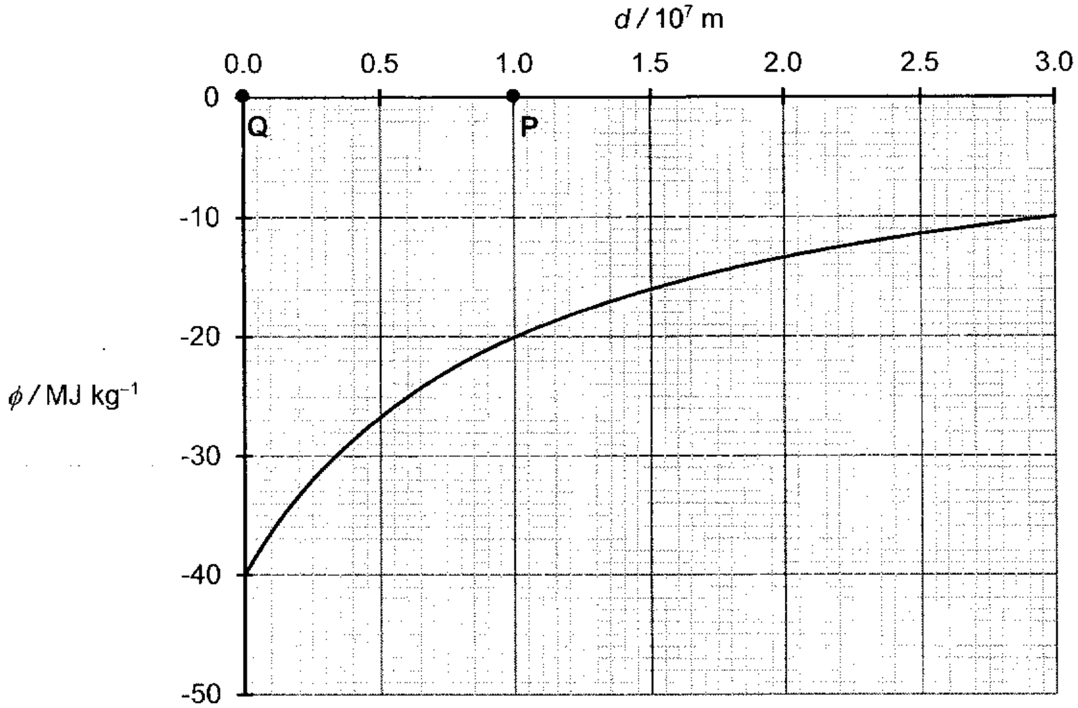


Fig. 2.1

(i) Determine the gravitational acceleration at point P.

gravitational acceleration = ... $m\ s^{-2}$ [2]

 [Turn over

(ii) Assuming that a 1.0 kg mass falls from point P toward point Q with the acceleration obtained in **(b)(i)** throughout the motion, calculate the increase in its kinetic energy.

increase in kinetic energy = ... J [2]

(iii) Indicate, using vertical double-head arrows, the parts of the graph that represent

1. your answer in **(b)(ii)**. Label this arrow **A**.
2. the actual increase in the kinetic energy of the 1.0 kg mass when the gravitational acceleration from P to Q is not constant. Label this arrow **B**.

[2]

3 **(a)** State how the temperature of an ideal gas is related to the energy of its molecules.

....

.... [1]

(b) An oven with volume 0.029 m^3 contains air at a pressure and temperature of 1.0×10^5 Pa and 27°C respectively. The mass of one mole of air is 0.030 kg. Assume that the air behaves as an ideal gas.

(i) Determine the root-mean-square speed of the air molecules in the oven.

root-mean-square speed = ... $m\ s^{-1}$ [2]

(ii) Calculate the number of moles of air molecules in the oven.

number of moles = ... [2]

(iii) The oven is heated to a temperature of 220°C.

Use your answer in **(a)** and the kinetic theory of gases to explain why the pressure of the air in the oven increases.

....

....

....

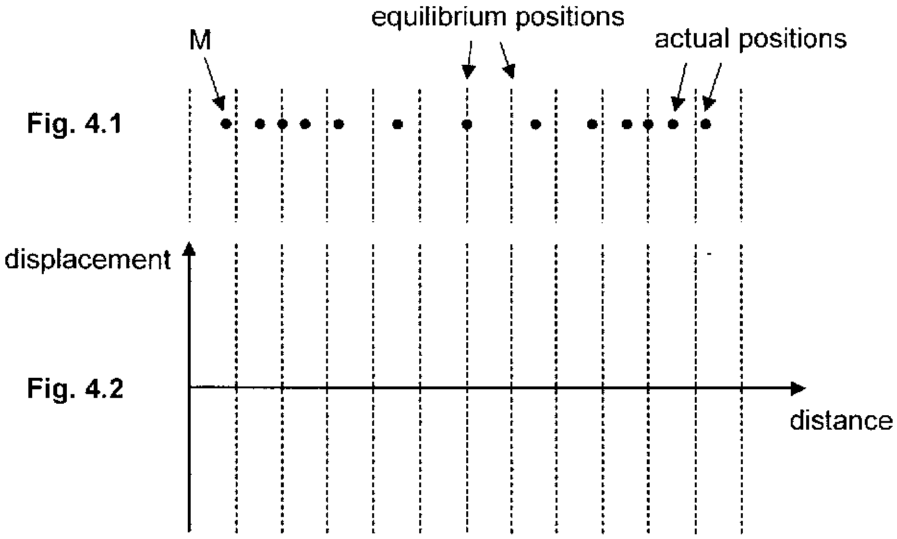
.... [2]

(iv) The oven door is opened.

Calculate the mass of air that must escape from the oven for the pressure in the oven to return to 1.0×10^5 Pa.

mass of air = ... kg [2]

4 **(a)** Fig. 4.1 shows the equilibrium and actual positions at an instant in time of a series of particles forming part of a stationary sound wave. Particle M is at its maximum displacement.



On Fig. 4.2,

(i) sketch the variation with distance of the displacement of the particles at the instant shown, taking motion to the right as positive. Label your sketch **P**.

[2]

(ii) sketch the variation with distance of the displacement of the particles at one-quarter of a period later. Label your sketch **Q**.

[1]

(iii) indicate the position of one displacement antinode with **A** and the position of one displacement node with **N**.

[1]

(b) The stationary wave in **(a)** is formed in a pipe of length 0.40 m that is closed at one end and open at the other. An incident sound wave of frequency 1060 Hz travels parallel to the axis of the pipe, and enters the pipe, as shown in Fig. 4.3.

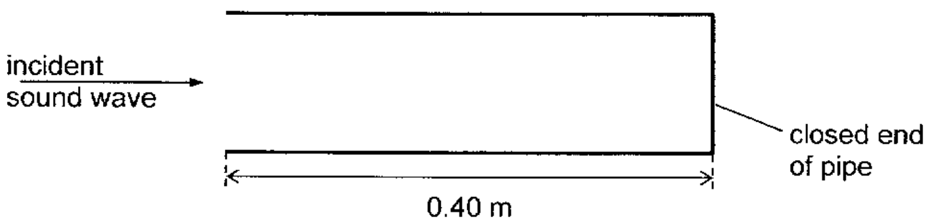


Fig. 4.3

(i) Explain the formation of the stationary (standing) wave in the pipe.

....

....

....

.... [2]

(ii) When a microphone is moved along the length of the pipe from the opening to the end, three maxima are detected.

Determine the wavelength of the sound.

wavelength = ... m [3]

(iii) Calculate the speed of the sound wave.

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

5 Fig. 5.1 shows a circuit that consists of a lamp, an ammeter, a voltmeter and a battery of unknown electromotive force (e.m.f.).

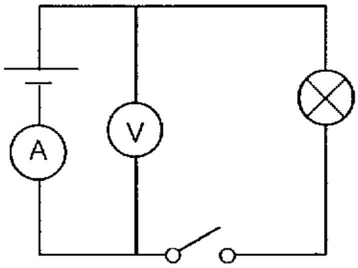


Fig. 5.1

When the switch is open, the ammeter and the voltmeter read 0 A and 3.00 V, respectively. When the switch is closed, the meters read 1.60 A and 2.20 V.

(a) State the e.m.f. of the battery.

e.m.f. = ... V [1]

(b) Determine the internal resistance of the battery.

internal resistance = ... Ω [2]

(c) **(i)** Calculate the power delivered to the lamp.

power = ... W [1]

(ii) Determine the efficiency of the power transfer of the battery.

efficiency = ... % [2]

 [Turn over

6 **(a)** Define magnetic flux density.

....

.... [1]

(b) Fig. 6.1 shows two parallel metal plates P and Q placed in a vacuum. P is connected to a positive potential and Q is connected to earth such that a uniform electric field of field strength 500 N C^{-1} is set up in the region between the plates.

A uniform magnetic field is also set up in the region between the plates.

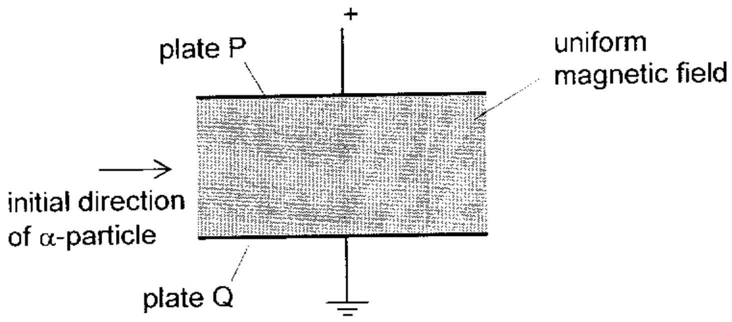


Fig. 6.1

An α-particle of charge +2e, mass 6.64×10^{-27} kg and kinetic energy 120 eV enters the region between the plates at right angles to the electric field. The α-particle travels through the region without any deflection.

(i) State and explain the direction of the magnetic field.

....

....

....

.... [2]

(ii) Show that the electric force on the α-particle is 1.6×10^{-16} N.

[1]

(iii) Calculate the speed of the α-particle.

speed = ... m s^{-1} [2]

(iv) Determine the flux density B of the magnetic field.

B = ... T [2]

(v) A proton travels along the same initial path with a kinetic energy of 120 eV. Describe and explain the initial deflection of the proton between the plates.

....

....

....

....

....

.... [3]

7 **(a)** An electron is moving with a kinetic energy of 4.96×10^{-24} J.

(i) Show that its momentum is 3.0×10^{-27} kg m s^{-1}.

[1]

(ii) Hence, determine the wavelength of ultraviolet light with the same momentum as that calculated in **(a) (i)**.

wavelength = ... m [2]

(b) A heated filament at one end of a fluorescent tube emits electrons through a process known as thermionic emission. These electrons are then accelerated by a potential difference applied between the two ends of the tube.

The accelerated electrons collide with the atoms of mercury vapour contained within the tube as shown in Fig. 7.1 to emit UV light.

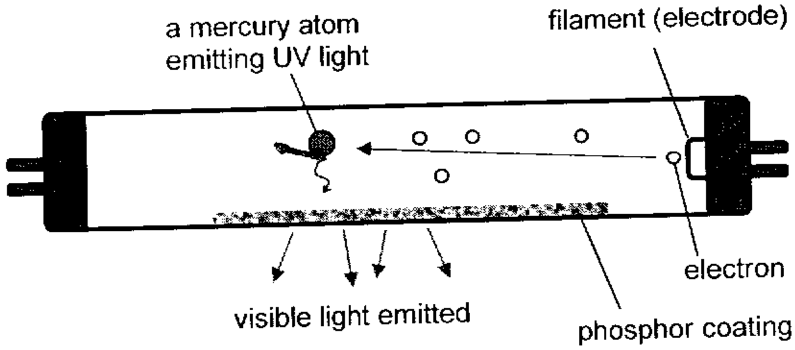


Fig. 7.1

Some of the energy levels of a mercury atom are represented in Fig. 7.2.

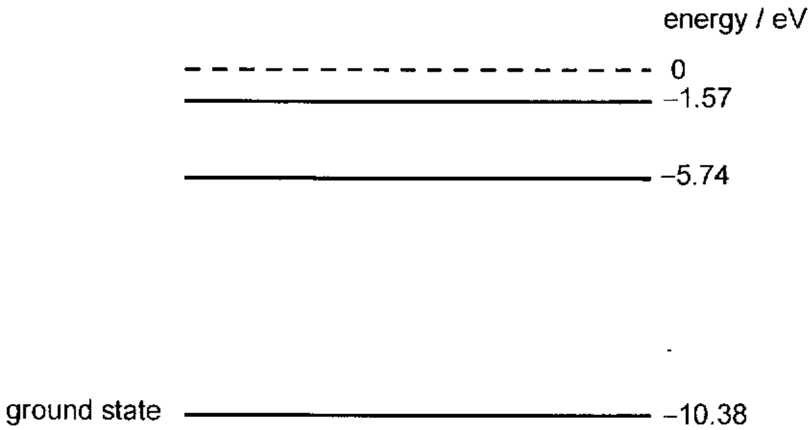


Fig. 7.2 (not to scale)

(i) Explain why the energy of each energy level is negative.

....

.... [1]

(ii) In one particular interaction, an electron with kinetic energy 9.0 eV collides with a mercury atom at ground state.

Use Fig. 7.2 to determine the longest wavelength of UV radiation that can be emitted due to this interaction.

wavelength = ... m [3]

(iii) The UV photons emitted by the mercury atoms strike the phosphor coating on the inside of the fluorescent tube. The phosphor absorbs the UV photons and emits visible light by "fluorescence". Some amount of infrared radiation is also emitted.

Fig. 7.3 shows three energy levels E_1, E_2 and E_3 of an atom in the phosphor that are involved in the absorption of UV and emission of infrared and visible light.

On Fig. 7.3, draw arrows to indicate the following transitions:
(1) absorption of a UV photon
(2) emission of an infrared photon
(3) emission of a red light photon

Label the transitions clearly.

Fig. 7.3

[1]

Section B

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

8 **(a)** Define simple harmonic motion.

....

....

....

.... [2]

(b) Fig. 8.1 shows a U-tube containing a liquid that was initially at rest. The U-tube has a uniform cross-sectional area A. The density of the liquid is ρ and the total length of the liquid is L.

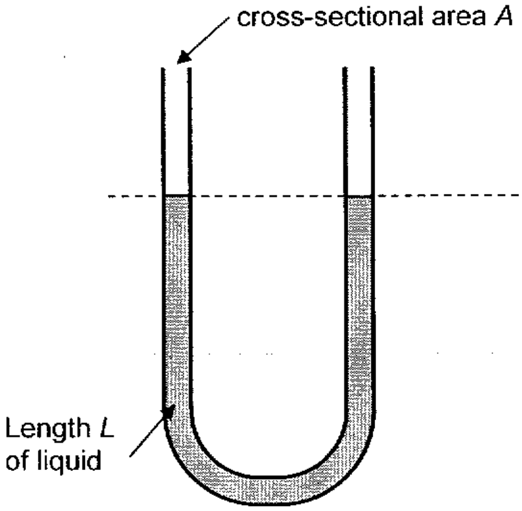


Fig. 8.1

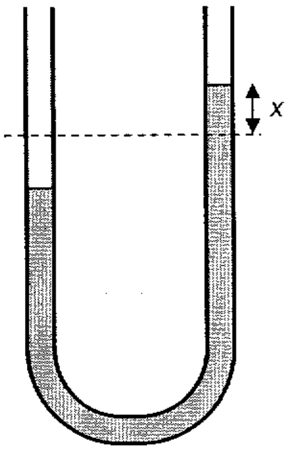


Fig. 8.2

Due to a small disturbance, the liquid level on the right limb is displaced upwards by a distance x as shown in Fig. 8.2. The difference in the liquid levels between the two limbs will produce a pressure difference and this in turn will cause a restoring force to act on the length of liquid to accelerate it back towards its equilibrium position.

(i) In terms of A, L and ρ, write down the expression for the total mass M of the liquid.

[1]

(ii) Derive the expression for the magnitude of the restoring force F acting on the liquid in terms of ρ, g and x and A.

[2]

(iii) Using the relationship

$$F = Ma$$

where a is the acceleration of the liquid, and your answers in parts **(i)** and **(ii)**, show that the liquid will oscillate with simple harmonic motion after it is disturbed from its equilibrium state. You may assume that viscous forces in the liquid are negligible.

[3]

(iv) Hence, show that the angular frequency of the oscillations is $\omega = \sqrt{\frac{2g}{L}}$.

[1]

(c) The liquid shown in Fig. 8.2 has a length L of 0.92 m, mass M of 1.2 kg and an initial displacement of 0.080 m.

(i) Calculate the angular frequency ω.

ω = ... rad s^{-1} [1]

(ii) Determine the period T of the oscillations.

T = ... s [1]

(iii) Determine the maximum kinetic energy $E_{K,max}$ of the oscillating liquid.

$E_{K,max}$ = ... J [2]

(d) Viscous forces in the liquid in **(c)** are assumed to be negligible. In practice, there will be damping due to small viscous forces in the liquid.

(i) Explain what is meant by damping.

....

.... [1]

(ii) On the axes in Fig. 8.3, sketch the variation with time t of the displacement x of the liquid in **(c)** for the first two cycles of oscillations.

Assume that the period of oscillations is unaffected by the viscous forces.

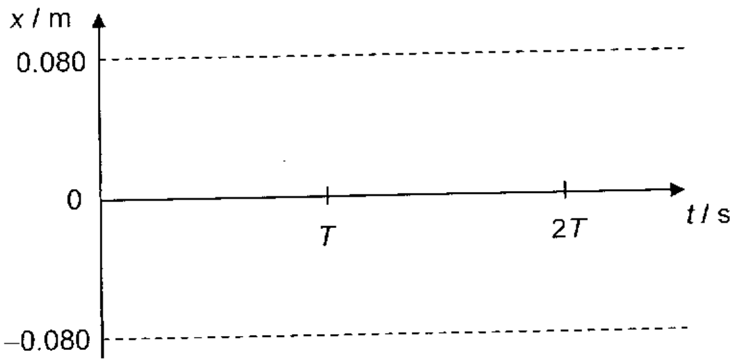


Fig. 8.3 [2]

(iii) On the axes in Fig. 8.4, sketch the corresponding variation with time t of the kinetic energy of the liquid for the first two cycles of oscillation.

You need not label any numerical values on your graph.

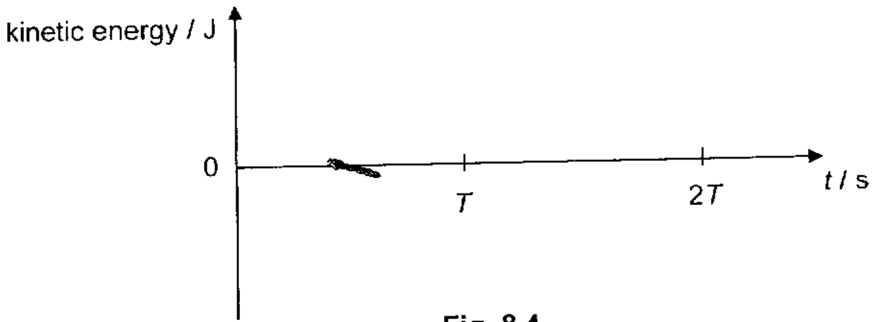


Fig. 8.4 [2]

(e) Damping is important in some applications. State one such application and explain why damping is important.

....

....

....

.... [2]

[Total: 20]

9 (a) The Sun is a star that comprises mainly of hydrogen nuclei (protons). It derives its large radiative power from nuclear fusion. The nuclear reactions responsible for energy generation in the Sun, collectively known as the proton-proton chain reactions, are listed as follows:

I. ${}^{1}_{1}\text{H} + {}^{1}_{1}\text{H} \rightarrow {}^{2}_{1}\text{H} + {}^{0}_{1}e +$ other radiations

II. ${}^{2}_{1}\text{H} + {}^{1}_{1}\text{H} \rightarrow {}^{3}_{2}\text{He} +$ energy

III. ${}^{3}_{2}\text{He} + {}^{3}_{2}\text{He} \rightarrow {}^{4}_{2}\text{He} + n\ {}^{A}_{1}\text{Y} +$ energy

where ${}^{0}_{1}e$ denotes a positron. A positron is a particle with the same mass as an electron but having a charge of $+e$.

(i) For reaction III, identify the number n and name the particle Y

n = ... [1]

Y = ... [1]

(ii) Deuterons (${}^{2}_{1}\text{H}$) are produced in reaction I. Suggest a reason why reactions II and III are observed in the formation of helium-4 instead of the following one:

$${}^{2}_{1}\text{H} + {}^{2}_{1}\text{H} \rightarrow {}^{4}_{2}\text{He} + \text{ energy}$$

.... [1]

(iii) Reactions I to III can be combined into one overall reaction:

$$4\,{}^{1}_{1}\text{H} \rightarrow {}^{4}_{2}\text{He} + 2\,{}^{0}_{1}e + \text{ energy}$$

It is given that

mass of proton:	1.007276 u
mass of alpha particle:	4.001506 u
mass of positron:	0.000585 u

where u is the atomic mass unit.

Calculate the amount of energy released in one such reaction.

energy = ... J [3]

(b) The Earth is at a distance of 1.5×10^{11} m away from the Sun. The maximum intensity of sunlight at the Earth's surface can reach as high as 1400 W m^{-2} at normal incidence.

(i) Use the above information to determine the amount of energy generated by the Sun in one second.

energy generated per second = ... W [2]

(ii) Hence, determine

1. the number of nuclear reactions described in **(a)(iii)** that occur in the Sun every second.

reactions per second = ... [1]

2. the time taken for the Sun to be depleted of hydrogen, assuming that the total mass of the hydrogen in the Sun is now 2.0×10^{30} kg and the rate of nuclear reactions remain constant until all the hydrogen is depleted.

time taken = ... s [2]

(c) Apart from electromagnetic radiation, the Sun also showers the Earth with a large number of protons with very high kinetic energy. When these protons collide with the atoms in the atmosphere, they produce neutrons which in turn react with nitrogen in the air to form carbon-14:

$${}^{14}_{7}N + {}^{1}_{0}n \rightarrow {}^{14}_{6}C + {}^{1}_{1}H$$

Carbon-14 is radioactive with a half-life of 5730 years. In atmospheric carbon dioxide, about 1 out of 10^{12} carbon atoms are carbon-14. During photosynthesis, green plants take in carbon dioxide and convert them into carbon compounds. Because the mixing of carbon-14 with carbon-12 is efficient, all living things have the same ratio of carbon-14 to carbon-12.

(i) Define *half-life*.

.... [1]

(ii) Carbon-14 decays spontaneously into nitrogen-14. Write down the equation for this reaction.

[1]

(iii) The radioactivity of a 33.3 g piece of charcoal, assumed to be pure carbon, found from the remains of an ancient campfire is measured to be 0.4 counts per second. This value was derived from a measurement of 240 decays over 10 minutes.

1. Explain why, for this piece of charcoal, it is a good experimental practice to measure the number of decays over 10 minutes rather than 1 minute or 1 second.

.... [2]

2. In living wood, 1 out of 10^{12} carbon atoms are carbon-14.
Show that the number of carbon atoms in this piece of charcoal is about 1.67×10^{24}. Hence estimate the age of this piece of charcoal.

age = ... years [5]

[Total: 20]

2021 Raffles Institution Preliminary Examinations – H2 Physics
Paper 3 – Suggested Solutions

1 (a) $t = \dfrac{v-u}{a}$

Sub into the 2nd equation

$$s = \frac{1}{2}(u+v)\left(\frac{v-u}{a}\right) = \frac{(v+u)(v-u)}{2a}$$

$$2as = v^2 - u^2$$

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

(b) Displacement required $= 3.0 + \dfrac{0.23}{2} - 2.1 = 1.015$ m

Minimum speed of release required means that velocity at 1.015 m is zero.

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

$$0 = u^2 + 2(-9.81)(1.015)$$

$$u = 4.46 \text{ m s}^{-1}$$

OR,

using conservation of energy

Loss in kinetic energy = Gain in GPE

$$\frac{1}{2}mu_y^2 - 0 = mgh_f - mgh_i$$

$$\frac{1}{2}u_y^2 = g(h_f - h_i) = gs_y$$

$$u_y^2 = \sqrt{2(9.81)(1.015)}$$

$$u_y = 4.46 \text{ m s}^{-1}$$

(c) (i) Horizontally

$$s_x = u_x t = ut\cos\theta$$

$$6.7 = u(1.3)\cos 50^\circ$$

$$u = \frac{6.7}{1.3\cos 50^\circ} = 8.02 \text{ m s}^{-1}$$

(ii) Vertically

$$s_y = u_y t + \frac{1}{2}a_y t^2 = ut\sin 50^\circ + \frac{1}{2}(-9.81)(1.3)^2$$

$$= 8.0\sin 50^\circ \times 1.3 + \frac{1}{2}(-9.81)(1.3)^2$$

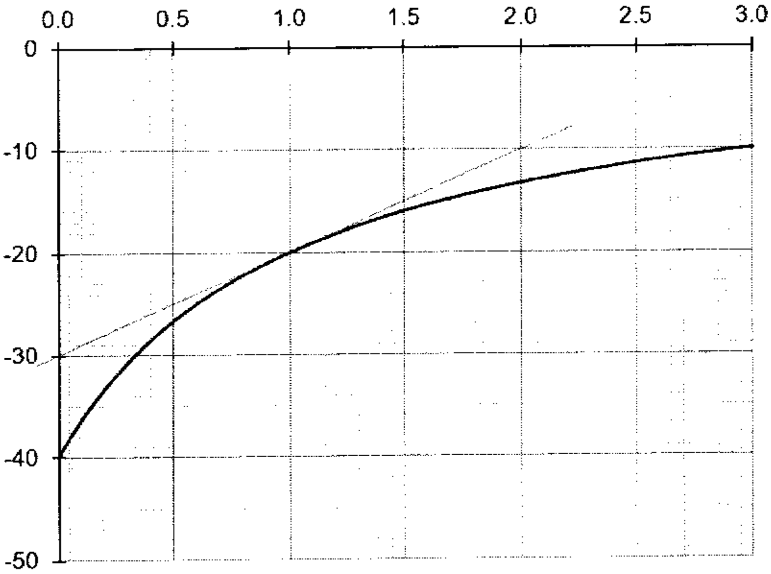
$$= -0.3226 \text{ m}$$

height = 2.5 – 0.3226 = 2.18 m

2 (a) Gravitational potential (or potential energy) at infinity is zero.

Since gravitational force is attractive in nature, to bring a mass from infinity to a point in the gravitational field, the direction of the external force is opposite to the direction of displacement of the mass. This results in negative work done by the external force

(b) **(i)**



acceleration = gradient

$$= \frac{\left[-10-(-30)\right]\times 10^{6}}{(2.00-0.00)\times 10^{7}}$$

$$= 1.00 \text{ m s}^{-2}$$

(ii) Since acceleration is assumed to be constant,

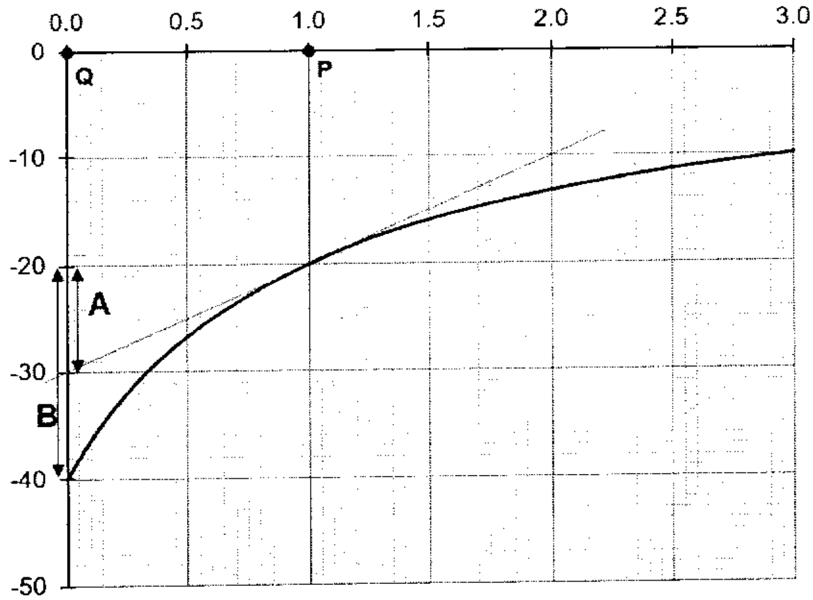
$$v^2 - u^2 = 2as$$

$$\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = mas$$

$$= 1.0 \times 1.00 \times 1.0 \times 10^{7}$$

$$= 1.00 \times 10^{7} \text{ J}$$

(iii)



3 **(a)** The thermodynamic temperature of an ideal gas is proportional to the mean kinetic energy of the molecules of the gas.

(b) **(i)**

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

$$\frac{1}{2}\times\frac{0.030}{6.02\times10^{23}}\times\langle c^2\rangle = \frac{3}{2}\times1.38\times10^{-23}\times(27+273.15)$$

$$c = 499 \text{ m s}^{-1}$$

(ii)

$$PV = nRT$$

$$1.0\times10^5\times0.029 = n\times8.31\times(27+273.15)$$

$$n = 1.16$$

(iii) The root-mean-square speed of the molecules increases with temperature.

Since the volume of the oven remains the same, there is an increase in the number of collisions per unit time of the molecules and the walls of the oven, causing an increase in pressure.
Or
For each collision between a molecule and the wall of the oven, there is a greater change in momentum of the molecule. This leads to a greater force exerted on the wall and an increase in pressure.

(iv)

$$PV = nRT$$

$$1.0\times10^5\times0.029 = n_2\times8.31\times(220+273.15)$$

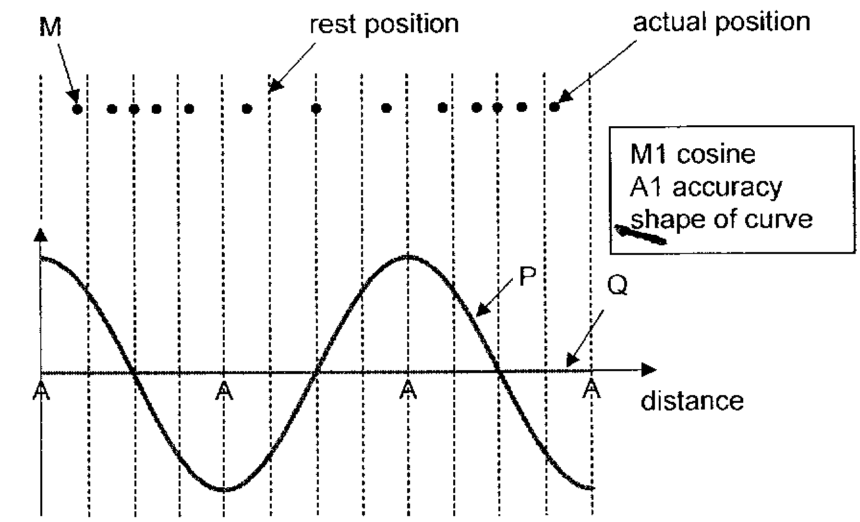
$$n_2 = 0.7076$$

mass of air $= (1.163 - 0.7076)\times0.030 = 1.37\times10^{-2}$ kg

4 **(a)** **(i), (ii) & (iii)**

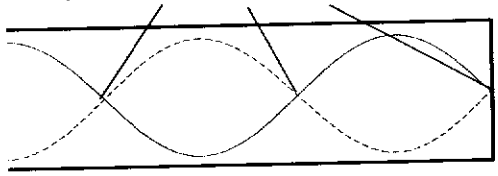
Fig. 4.1

Fig. 4.2



(b) **(i)** The incident wave reflects off the wall of the pipe at the end, producing a wave of the same amplitude, wavelength and frequency travelling in the opposite direction. The reflected wave interferes with subsequent incident wave, to produce nodes and antinodes at different positions of the pipe, depending on the path difference between the two waves.

(ii)



The positions of maxima correspond to pressure antinodes (displacement nodes). As shown in the picture above, three positions of maxima imply that the length of the pipe is equal to 5/4 wavelengths.

$$\frac{5}{4}\lambda = 0.40 \Rightarrow \lambda = 0.32 \text{ m}$$

(iii) $v = f\lambda = 1060 \times 0.32 = 339 \text{ m s}^{-1}$

5 (a) e.m.f. = 3.0 V.

(b) $V_T = E - Ir$

$2.20 = 3.00 - 1.60 \times r$

$r = \frac{3.00 - 2.20}{1.60} = 0.50\ \Omega$

(c) (i) power $= IV = 1.60 \times 2.20 = 3.52$ W

(ii) $\text{efficiency} = \frac{\text{power delivered to lamp}}{\text{total power}} = \frac{IV}{IE} = \frac{V}{E}$

$= \frac{2.20}{3.00}$

$= 73.3\%$

6 (a) The magnetic flux density of a magnetic field is numerically equal to the force per unit length acting on a long straight conductor carrying a unit current at right angles to the magnetic field.

(b) (i) Since the α-particle is positively charged, electric force is acting downwards.

The magnetic force acting on the α-particle must be upwards for it to be traveling undeflected. By Fleming's Left hand rule, the magnetic field is pointing into the page.

(ii) $F = qE = (2)(1.60 \times 10^{-19})(500) = 1.60 \times 10^{-16}$ N

(iii)

$$KE = \frac{1}{2}mv^2$$

$$120 \times 1.60 \times 10^{-19} = \frac{1}{2}(6.64 \times 10^{-27})v^2$$

$$v = 7.60 \times 10^4 \text{ m s}^{-1}$$

(iv) $qE = Bqv$

$E = Bv$

$500 = B(7.60 \times 10^4)$

$B = 6.58 \times 10^{-3}$ T

(v) Since the mass of the proton is smaller than that of the α-particle, the velocity of the proton will be greater than that of the α-particle.
Both forces are proportional to charge. However, the magnetic force is also proportional to velocity. The magnetic force acting on the proton is greater than electric force.
Proton deflects upwards towards plate P.

7 (a) (i) p of electron $= \sqrt{2mE_k}$

$= \sqrt{2(9.11 \times 10^{-31})(4.96 \times 10^{-24})}$

$= 3.0 \times 10^{-27}$ kg m s^{-1}

(ii) de Broglie wavelength

$\lambda = \dfrac{h}{p}$

$= \dfrac{6.63 \times 10^{-34}}{3.0 \times 10^{-27}}$

$= 2.2 \times 10^{-7}$ m

(b) (i) An electron in an energy level is bound to the nucleus (or atom) by the attractive Coulomb force. The total energy of such a bound system is negative.

(ii) 9.0 eV electron has sufficient energy to excite mercury atom from ground state to energy level of –1.57 eV (because –1.57 – (–10.38) = 8.81 eV).

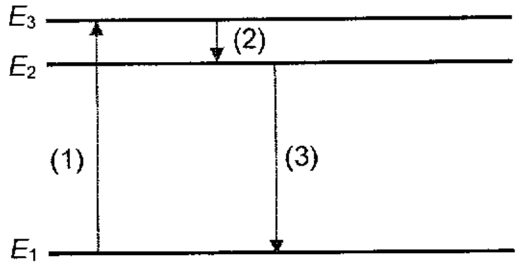
As atom de-excites from –1.57 to –5.74 eV, a photon is emitted.

$\dfrac{hc}{\lambda} = [-1.57 - (-5.74)] \times (1.6 \times 10^{-19})$

$\lambda = \dfrac{(6.63 \times 10^{-34})(3.00 \times 10^{8})}{6.672 \times 10^{-19}}$

$\lambda = 2.98 \times 10^{-7}$ m

(iii)



8 **(a)** Simple harmonic motion is defined as the motion of a particle (or body) about a fixed point such that its acceleration is proportional to its displacement from the fixed point and is always directed towards the point.

(b) **(i)** $M = AL\rho$

(ii) $\Delta p = h\rho g = 2x\rho g$

$$\Delta p = \frac{F}{A} \quad \Rightarrow \quad F = (\Delta p)A = 2xA\rho g$$

(iii) Since F is the restoring force, (F acts in the opposite direction to x)

$F = -2\,xA\rho g$

$F = Ma$ where a is the acceleration

$$\therefore -2xA\rho g = AL\rho \cdot a$$

$$\therefore a = \frac{-2xA\rho g}{AL\rho} = \frac{-2gx}{L}$$

$\therefore a \propto -x$, since $\frac{2g}{L}$ is a constant

Hence the motion is s.h.m.

(iv) Since $a = -\omega^2 x$ and $a = -\frac{2gx}{L}$

$$\therefore \omega^2 = \frac{2g}{L} \Rightarrow \omega = \sqrt{\frac{2g}{L}}$$

(c) **(i)** $$\omega = \sqrt{\frac{2g}{L}} = \sqrt{\frac{2 \times 9.81}{0.92}} = 4.62 \text{ rad s}^{-1}$$

(ii) $$T = \frac{2\pi}{\omega} = \frac{2\pi}{4.618} = 1.36 \text{ s}$$

(iii) $$E_{K,\max} = \frac{1}{2}Mv_{\max}^2 = \frac{1}{2}M\omega^2 x_0^2$$

$$= \frac{1}{2}(1.2)(4.618)^2(0.080)^2$$

$$= 0.0819 \text{ J}$$

(d) **(i)** Damping refers to the loss of energy in an oscillatory system (due to the presence of dissipative forces).

(ii)

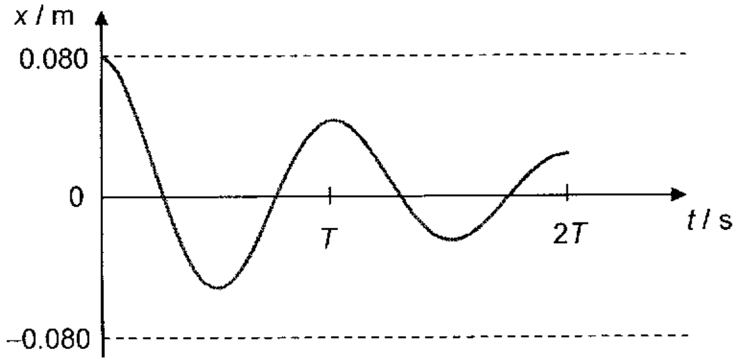


Fig. 8.3

(iii)

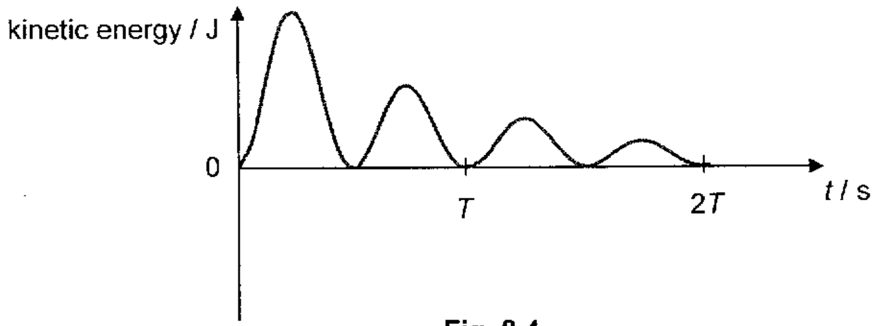


Fig. 8.4

(e) Car suspension,
to reduce motion sickness of passengers
OR damping of oscillation of pointer in analogue meters, to allow readings to be taken more quickly
OR door closer, to close door without door slamming or swinging.
OR mass dampers in buildings

