TAMPINES MERIDIAN JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATION

CANDIDATE NAME	( )
CIVICS GROUP	

H2 PHYSICS 9749/02

Paper 2 Structured Questions **14 September 2023**

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

Section B: Structured Questions

READ THESE INSTRUCTIONS FIRST

Write your name and Civics Group in the spaces at the top of the page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.
The use of an approved scientific calculator is expected, where appropriate.

Answer **all** questions.

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

For Examiners' Use	
1	/ 10
2	/ 10
3	/ 8
4	/ 10
5	/ 10
6	/ 12
7	/ 20
Deduction	
Total	/ 80

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$\left(1/\left(36\pi\right)\right) \times 10^{-9}$ 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	=	$-\frac{GM}{r}$
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	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm\, \omega\sqrt{x_o^{\,2} - x^2}$
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	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current / voltage	X	=	$x_o \sin \omega t$
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	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 At a training centre, a ski jumper takes off from a ramp. The end of the ramp is 1.0 m above the ground and is at an angle of 10° above horizontal as shown in Fig. 1.1. The ski jumper took 0.80 s, after leaving the ramp, to land on the ground. The air resistance is assumed to be negligible.

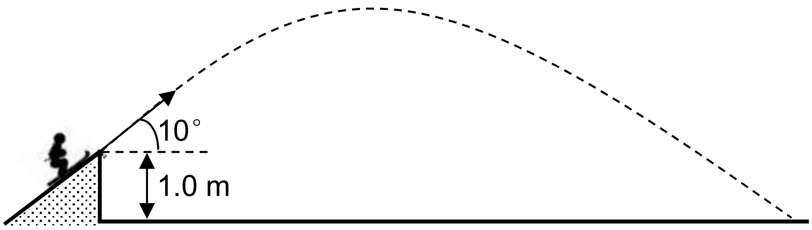

Fig. 1.1

(a) Show that magnitude of the vertical component of the velocity is 2.67 m s^{-1} when the ski jumper just leaves the ramp.

[1]

(b) Calculate the ski jumper's horizontal component of velocity as she leaves the ramp.

horizontal component of velocity = ………………… m s^{-1} [2]

(c) The measurement of time of flight 0.80 s was found to have an uncertainty of 0.08 s. In addition, a 5% uncertainty was found in the horizontal velocity in **(b)**.

Calculate the horizontal distance of the flight together with its uncertainty.

horizontal distance of flight = …………………± …………………. m [3]

(d) In real life, the effect of air resistance is not negligible.

(i) Explain the effect of air resistance on the vertical acceleration of the ski jumper from the moment she leaves the ramp until the highest point of the motion.

……………………………………………………………………………………….

……………………………………………………………………………………….

……………………………………………………………………………………….

……………………………………………………………………………………….

……………………………………………………………………………… [3]

(ii) It was observed that during the initial part of her flight, an Olympic ski jumper would lean forward in a V-shaped position, as shown in Fig. 1.2.

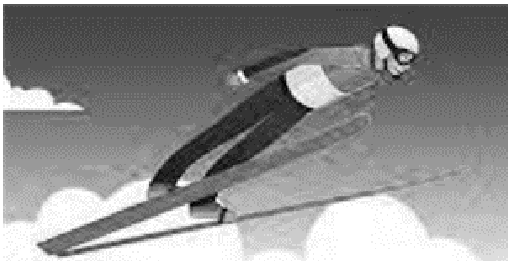

Fig. 1.2

Suggest why she could reach a further distance by adopting such posture.

……………………………………………………………………………………………..

…………………………………………………………………………………… [1]

2 **(a)** Fig. 2.1 shows a simplified model of a man lifting a suitcase. The spine can be treated as a rigid rod.

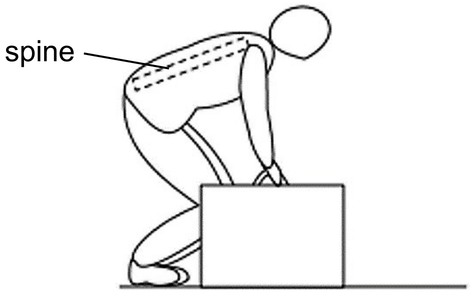

Fig. 2.1

When the suitcase is lifted, three forces *P*, *Q*, and *R* act on the spine which is in equilibrium. *P* is the force due to lifting the suitcase, *Q* is the force exerted by the muscles and *R* is the force acting on the base of the spine.

Fig. 2.2 shows the directions and points of action of only *P* and *Q*.

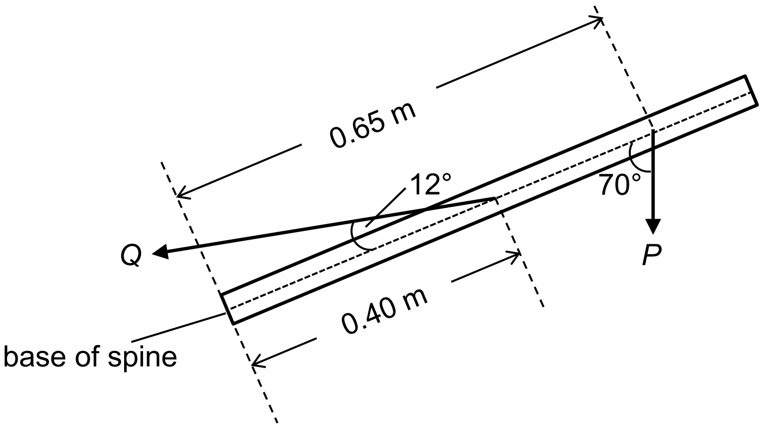

Fig. 2.2

(i) State the conditions required for a body to be in equilibrium.

....

....

....

.... [2]

(ii) Force R acts at the base of the spine.

On Fig. 2.3, draw an arrow to represent the direction of force R.

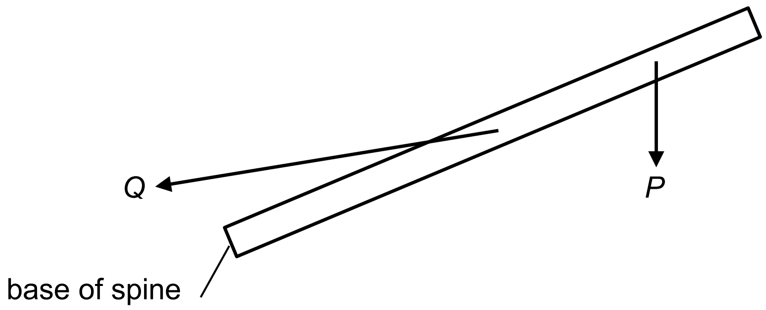

Fig. 2.3

[1]

(iii) Calculate the ratio of $\dfrac{Q}{P}$.

$\dfrac{Q}{P}$ = ... [2]

(b) The suitcase of mass 11 kg is tied to a light rope that is passed over a pulley as shown in Fig. 2.4. When the man applies a force of 30 N on the rope, the suitcase accelerates horizontally across a rough floor. The frictional force between the suitcase and the rough floor is 8.5 N.

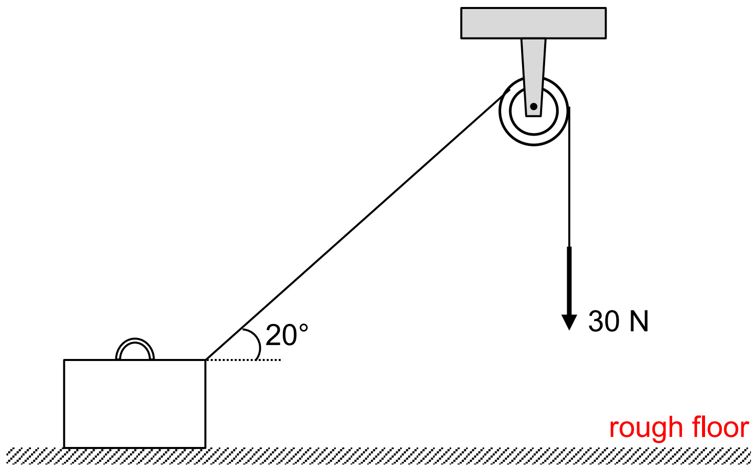

Fig. 2.4

(i) Determine the normal contact force acting on the suitcase.

normal contact force = ……………………… N [2]

(ii) State Newton's second law of motion.

……………………………………………………………………………………...……

……………………………………………………………………………………..…

……………………………………………………………………………….… [1]

(iii) Determine the horizontal acceleration of the suitcase.

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

3 **(a)** Define *angular velocity*.

....

.... [1]

(b) Fig. 3.1 shows the setup for a stunt performance.

The stuntman, of mass 65 kg, steps off the platform from rest. He falls freely and catches a handle bar at position X, where the rope is horizontal. He then moves in a circular path until position Y at the bottom of the circle.

The rope attached to the handle bar is light and inextensible.

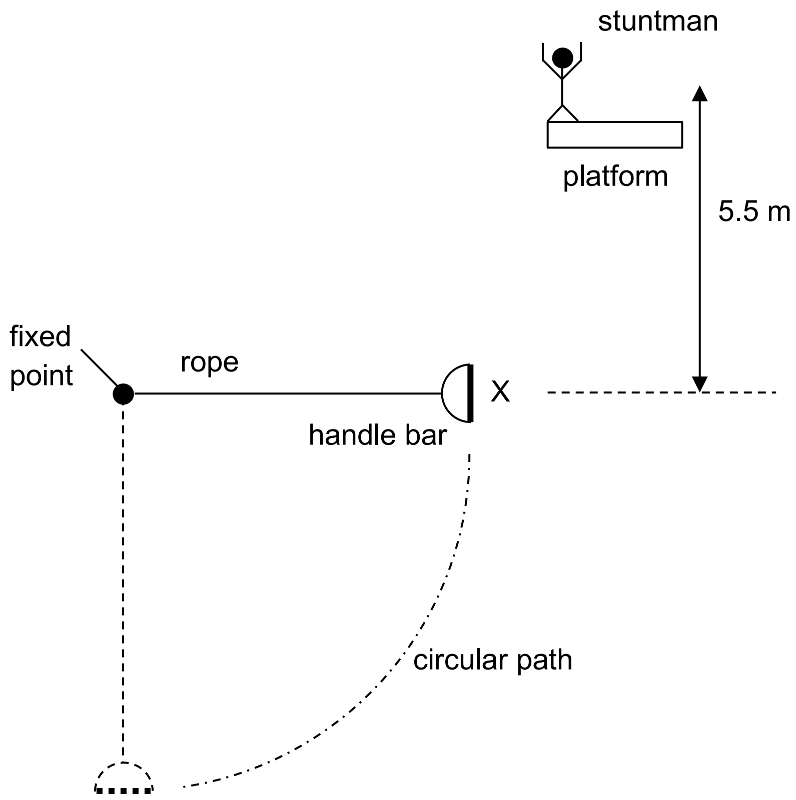

Fig. 3.1

The centre of mass of the stuntman is at a position 5.5 m above X. The radius of his circular path is 4.5 m.

(i) Show that the speed of the stuntman is 14 m s^{-1} when he reaches position Y.

[2]

(ii) Calculate the angular velocity of the stuntman at Y.

angular velocity = ………………………….. rad s^{-1} [1]

(iii) Calculate the tension in the rope at position Y. Explain your answer.

tension = ………………………… N [3]

(iv) The stuntman releases himself from the handle bar just after passing Y.

Describe his subsequent path after the release.

………………………………………………………………………………………

……………………………………………………………………………….. [1]

4 **(a)** Two resistors X and Y are connected to a power supply of e.m.f. of 8.0 V with negligible internal resistance. The circuit is earthed at point B between the two resistors as shown in Fig. 4.1.

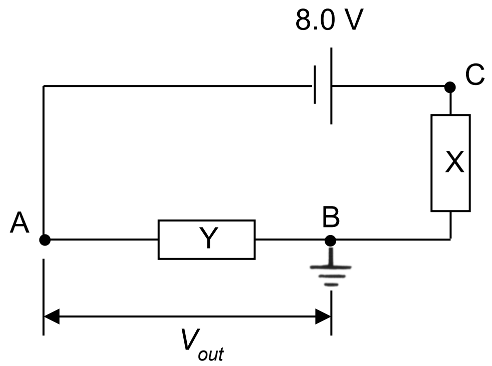

Fig. 4.1

The resistance of Y is 80 Ω.

The current in X is 40 mA.

The potential difference across Y is V_{out}.

(i) Determine the potential at point A.

potential at point A = ………………… V [2]

(ii) Calculate the resistance of resistor X.

resistance = ………………… Ω [2]

(b) An NTC thermistor is now connected across resistor Y as shown in Fig. 4.2.

The resistance of the thermistor is 100 Ω when it is at room temperature.

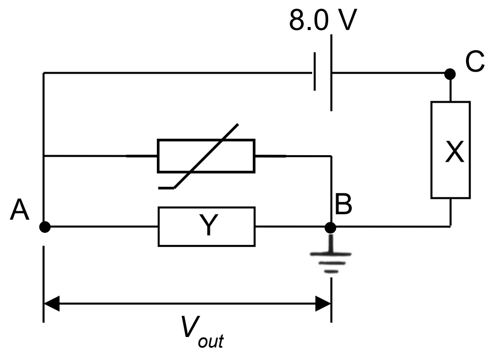

Fig. 4.2

(i) Calculate V_{out} at room temperature.

V_{out} = ………………… V [3]

(ii) State and explain whether a fan should be connected across AB or BC so that it turns on when the temperature gets hotter.

……………………………………………………………………………………………..

……………………………………………………………………………………………..

……………………………………………………………………………………………..

……………………………………………………………………………………………..

…………………………………………………………………………………… [3]

5 Fig. 5.1 shows the view along the axis of a solenoid. The solenoid is 0.30 m in length and has 50 turns. It has a current of 2.0 A flowing through it.

An electron located at the centre of the solenoid is moving to the right.

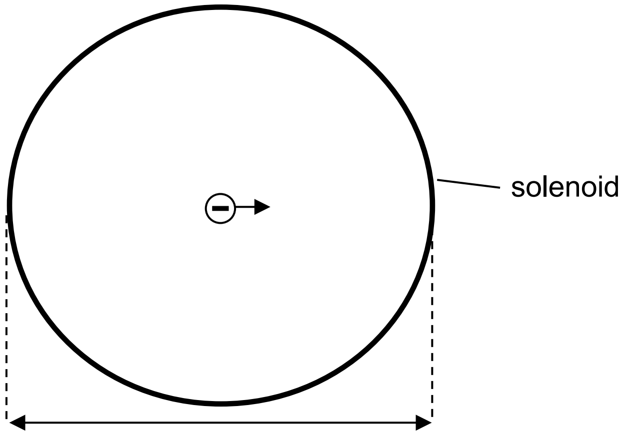

Fig. 5.1

(a) **(i)** State what is meant by *magnetic flux density*.

……………………………………………………………………………………………..

……………………………………………………………………………………………..

…………………………………………………………………………………… [1]

(ii) Indicate on Fig. 5.1, the direction of current flowing through the solenoid for the electron to experience a downward force.

[1]

(iii) Calculate the magnetic flux density B at centre of solenoid.

magnetic flux density = …………………….. T [1]

(iv) Hence, determine the magnetic force acting on the electron if it is moving with a speed of 10 m s^{-1}.

force = …………………….. N [2]

(v) Explain why the force experienced by the electron due to the magnetic force does not change the speed of the electron.

…………………………………………………………………………………………..

…………………………………………………………………………………………..

……………………………………………………………………………………… [2]

(b) A uniform electric field is now applied in the region of magnetic field within the solenoid so that the electron can move to the right undeflected.

(i) Calculate the magnitude of the electric field strength *E*.

electric field strength = ……………… V m^{-1} [2]

(ii) Indicate on Fig. 5.1 with an arrow, the direction of the electric field. [1]

6 **(a)** The three most common types of radioactive decay are *α, β* and γ.

State in Fig. 6.1 the changes to the number of protons and of neutrons that occur within the nuclei after they undergo each type of decay.

type of decay	number of protons	number of neutrons
α		
β		
γ		

Fig. 6.1

[3]

(b) To illustrate the effect of a magnetic field on the paths of *α, β* and γ radiations when travelling in a vacuum, a student drew the following diagram as shown in Fig. 6.2.

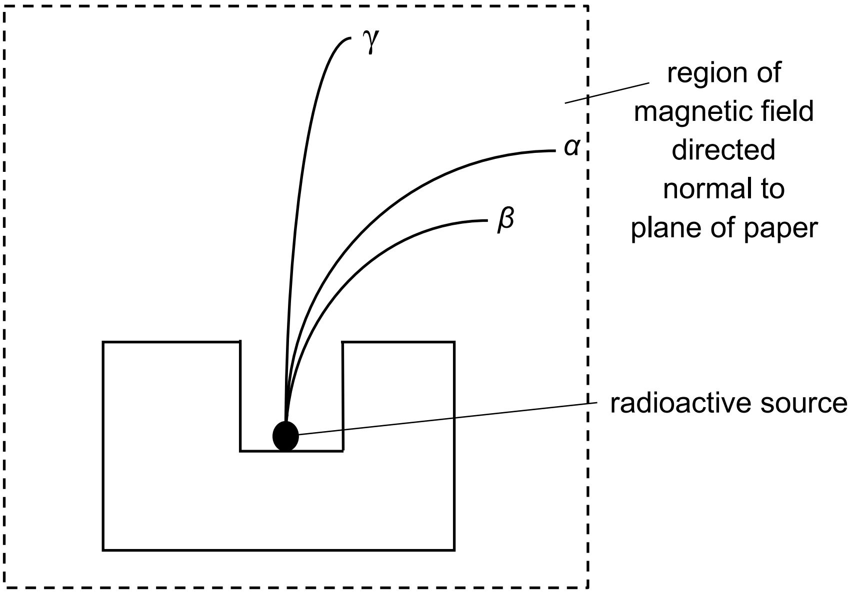

Fig. 6.2

State and explain two errors in the student's illustration.

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……

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………………………………………………………………………………………………… [4]

(c) Cobalt-60 is a radioactive nuclide. It has a mass of 59.9338 u.

Fig. 6.3 shows the products from the radioactive decay of cobalt-60 and their respective masses.

decay product	mass / u
nickel-60	59.9308
β	5.4348×10^{-4}
γ	-

Fig. 6.3

(i) Describe the energy changes which take place for the radioactive decay of a cobalt-60 nucleus. You need to refer to the different forms of energy involved.

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

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

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

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

(ii) Calculate, in MeV, the energy released during the decay. Leave your answer in two decimal places.

energy = ………………… MeV [3]

7 Read the passage below and answer the questions that follow.

As scientists and engineers work to reduce noise pollution from aircraft, a thorough understanding of the Physics of sound is necessary.

Speed of sound

Sound is produced by vibrating objects, and it can be transmitted through solids, liquids, or gases. As it propagates through different mediums, it travels at different speeds as shown in Fig. 7.1.

	solid steel	sea water	air
speed of sound at 30° C	5200 m s^{-1}	1500 m s^{-1}	350 m s^{-1}

Fig. 7.1

The speed of sound is also dependent on temperature. For example, as the temperature of air increases, the speed of sound in air increases. For air at sea level, the expected speed of sound *v,* in m s^{-1}, is related to the temperature of the air *T* by the following equation:

$$v = 331\sqrt{\frac{T}{T_0}}$$

where T_0 is the temperature, in Kelvin, at which ice melts.

Intensity of sound

An isotropic sound source emits sound wave equally in all directions. The relative "loudness" of sound is often expressed in the unit decibel.

The decibel (dB) expresses the relative intensity of a sound. The difference in intensity I of the sound with respect to a reference intensity I_{ref} is given by the following equation:

$$\text{Difference in sound level (in decibel)} = 10\lg\frac{I}{I_{ref}} \text{ dB}$$

As sound is usually measured using microphones, which respond proportionally to the varying sound pressures, the difference in sound level (in decibel) can also be expressed in terms of the pressure amplitudes *p* of the sound with respect to a reference pressure amplitude p_{ref}. This is given by the following equation:

$$\text{Difference in sound level (in decibel)} = 20\lg\frac{p}{p_{ref}} \text{ dB}$$

The faintest sound that a typical human ear can detect has an intensity of 1.0 pW m^{-2}. This is taken as standard reference level, and a sound at this intensity is at 0 dB.

Sonic boom

When an aircraft travels at supersonic speed of greater than the speed of sound, the effect of noise pollution becomes an issue. As it exceeds the speed of sound, it creates shockwaves that propagate as sonic booms. These sonic booms can be heard as loud, explosive noises.

One example of an aircraft capable of such speed is the Concorde. It is the world first supersonic passenger-carrying commercial aircraft that could fly at Mach 1.78, or 1.78 times the speed of sound. Regulations permitted the Concorde to cruise at supersonic speeds only over the ocean at its designated cruising altitude.

The X-59, a cutting-edge experimental aircraft, cruises at Mach 1.4 without producing the loud sonic boom typical of supersonic flights like the Concorde. This capability could open up new flight routes currently restricted.

(a) Sound is transmitted as a wave from the source.

(i) State and explain if sound can be polarised.

…………………………………………………………………………………………..

………………………………………………………………………………… [2]

(ii) Fig. 7.1 shows that the speed of sound is faster in solid steel than in air.

Suggest why.

…………………………………………………………………………………………..

………………………………………………………………………………… [1]

(iii) State the relationship between the intensity of sound I and the distance r from an isotropic sound source.

………………………………………………………………………………… [1]

(iv) Fig. 7.2 shows the cross-section of a human ear. The eardrum is a sensitive organ that can be damaged if the force on it is too large.

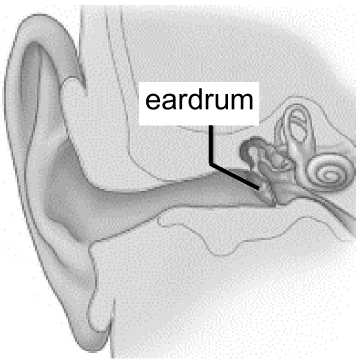

Fig. 7.2

When sound waves enter the ear, it vibrates the eardrum which converts the sound to electrical signal that is sent to the brain. The faintest sound that a typical human ear can detect at 0 dB has a pressure amplitude of 20 μPa.

1. Determine the intensity and pressure amplitude of a sound at 120 dB.

intensity = ………………… W m^{-2}

pressure amplitude = ….…………………. Pa [2]

2. Estimate the area of a typical eardrum.

area = …………………… m^2 [1]

3. Hence estimate the maximum force on a human eardrum at 120 dB.

maximum force = …………………… N [2]

(b) The Concorde cruises at an altitude of 18 km above sea level. At this height, sound travels at 295 m s^{-1}.

(i) Suggest why the Concorde was only permitted to cruise at supersonic speed when it was flying over the ocean.

…………………………………………………………………………………………

……………………………………………………………………………………… [1]

(ii) Suggest why the Concorde cruises at an altitude of 18 km above sea level.

…………………………………………………………………………………………

……………………………………………………………………………………… [1]

(iii) Calculate the cruising speed of the X-59 when it cruises at the same height as the Concorde.

speed = ………………… m s^{-1} [2]

(c) An experiment was conducted to measure the speed of sound through air. Fig. 7.3 shows the setup. A speaker is placed near the opening of a burette that is initially filled with water.

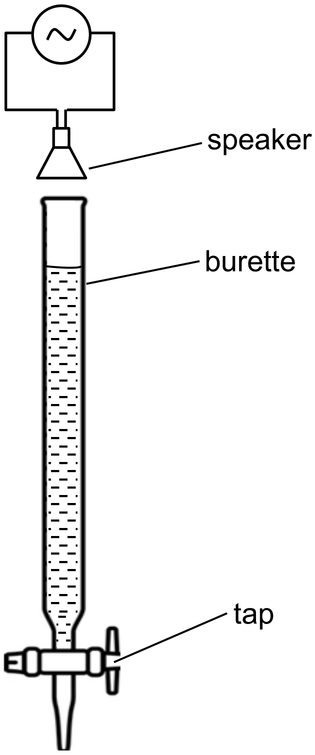

Fig. 7.3

The speaker, connected to a sinusoidal signal generator, emits a continuous sound with a frequency of 480 Hz. Water flows out of the burette when the tap at the base is opened.

As the water drains out, a series of loud and soft sounds are heard. Successive loud sounds are heard when the water level is at 54 cm and 91 cm from the opening of burette.

(i) State the phenomenon occurring when a loud sound is heard.

.... [1]

(ii) Determine the wavelength of the sound measured.

wavelength = ... m [2]

(iii) Hence calculate the speed of sound measured.

speed = ………………… m s^{-1} [2]

(iv) The experiment was conducted at a temperature of 22 °C.

Calculate the expected speed of sound at this temperature. Show your working clearly.

speed = ………………… m s^{-1} [2]