TAMPINES MERIDIAN JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATION

CANDIDATE NAME ( )

CIVICS GROUP

H2 PHYSICS 9749/02

Paper 2 Structured Questions **17 September 2025**

2 hours

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

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 or graphs.
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	/ 8
2	/ 9
3	/ 8
4	/ 8
5	/ 9
6	/ 8
7	/ 10
8	/ 20
Deduction	
Total	/ 80

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	=	$-\frac{GM}{r}$
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 A circuit is set up to measure the resistance of an unknown resistor X as shown in Fig. 1.1.

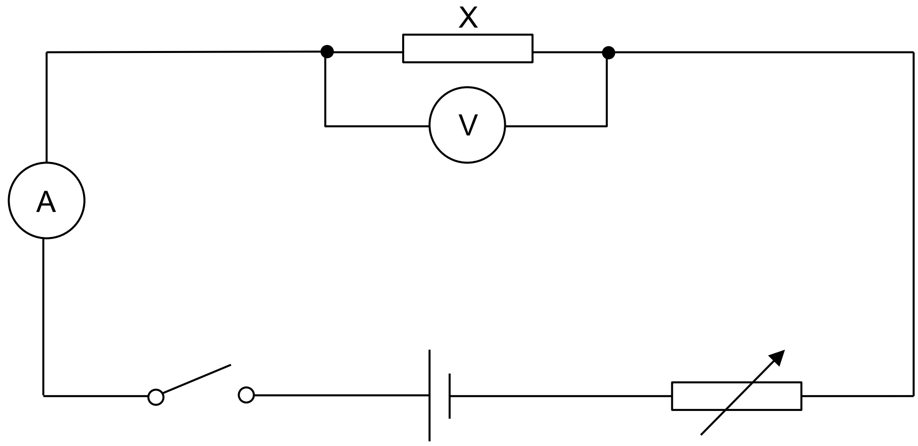

Fig. 1.1

(a) When the switch is closed, the average drift velocity v of electrons moving through a wire is given by the equation,

$$v = \frac{\mu F}{e}$$

where e is the charge on an electron,
F is a force acting on the electron, and
μ is a constant.

Determine the SI base units of μ.

SI base units = ………………………… [2]

(b) An analogue voltmeter is used to take measurements of the potential difference across X.
For these measurements, state one example of

(i) a systematic error,

.... [1]

(ii) a random error.

.... [1]

(c) The variable resistor is adjusted to give a new set of readings which, when repeated, give average values of potential difference V and current I of 3.00 ± 0.03 V and 4.9 ± 0.1 mA respectively.

(i) Show that the resistance of X is 612 Ω.

[1]

(ii) Determine the actual uncertainty in the value of resistance of X showed in **(i)**.

Hence state the value of resistance of X with its actual uncertainty to an appropriate number of significant figures.

resistance of X = ... ± .... Ω [2]

(d) When an experiment such as this is performed, it is common practice to adjust the variable resistor to obtain several sets of values of potential difference and current. These sets of values are then plotted on a graph from which the resistance of X may be deduced.
Discuss one advantage of this procedure compared with the determination of resistance of X from a single set of readings.

....

.... [1]

2 An object of mass 0.25 kg is launched with an initial speed, u, at an angle of 40° from the top of a cliff 100 m tall, as shown in Fig. 2.1.

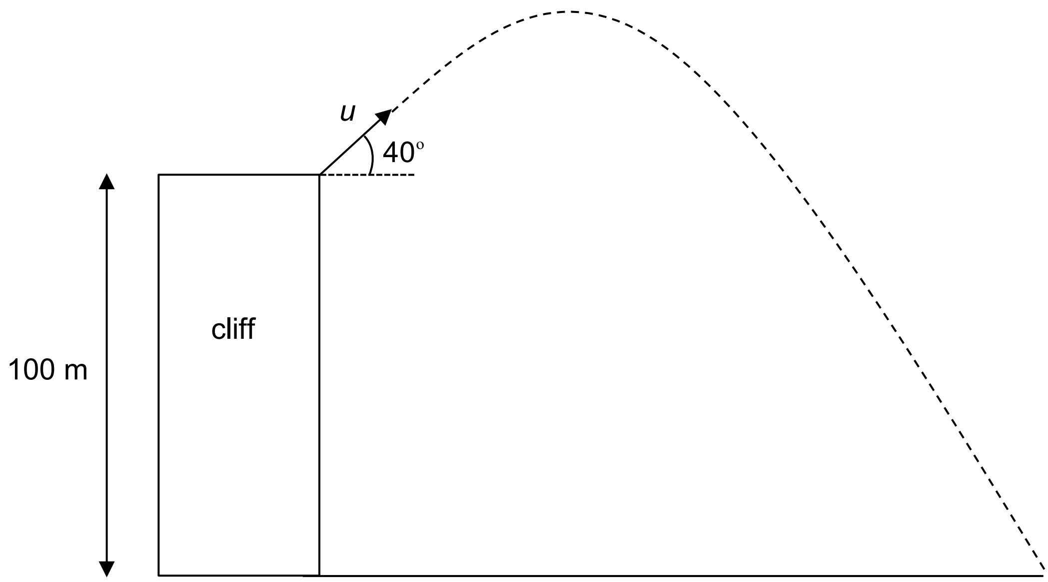

Fig 2.1

The minimum kinetic energy of the object during the trajectory is 12.5 J. Assume that air resistance is negligible.

(a) Explain why kinetic energy is minimum at the top of the trajectory.

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

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

(b) Show that u is 13 m s^{-1}.

[2]

(c) The object was in the air for a duration of time t before hitting the ground.

(i) Determine time t.

t = ……………………..… s [2]

(ii) Calculate the horizontal distance travelled by the object before hitting the ground.

horizontal distance = ………………………. m [1]

(iii) Determine the magnitude and direction of the velocity of the object just before it hits the ground.

magnitude of velocity = ……………………..… m s^{-1}

direction: ……………………….…..… [3]

3 An object of density ρ_o, and volume V_o, is placed in a fluid of density ρ_f, as shown in Fig 3.1. The acceleration of free fall is *g.*

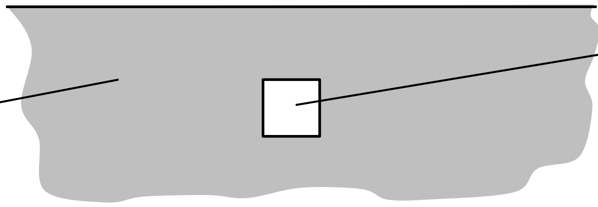

Fig. 3.1

(a) State the origin of upthrust.

....

.... [1]

(b) State an expression, in terms of ρ_o, V_o, ρ_f and g where appropriate, for

(i) weight of the object, W

.... [1]

(ii) upthrust acting on the object, U

.... [1]

(c) The object starts to sink from rest in the fluid.
With suitable working, show whether ρ_o is greater, lesser, or equal to ρ_f.

[2]

(d) The object sinks for a long time.

Describe and explain how the motion of the object changes until it reaches terminal velocity.

....

....

....

.... [3]

4 The “Round Up” is a hollow cylindrical ride with radius 8.0 m, as shown in Fig. 4.1. When it spins about its axis at sufficient angular speed, riders are pinned to the inner wall. The cylinder then tilts while spinning, creating the illusion of defying gravity as riders remain pinned to the wall.

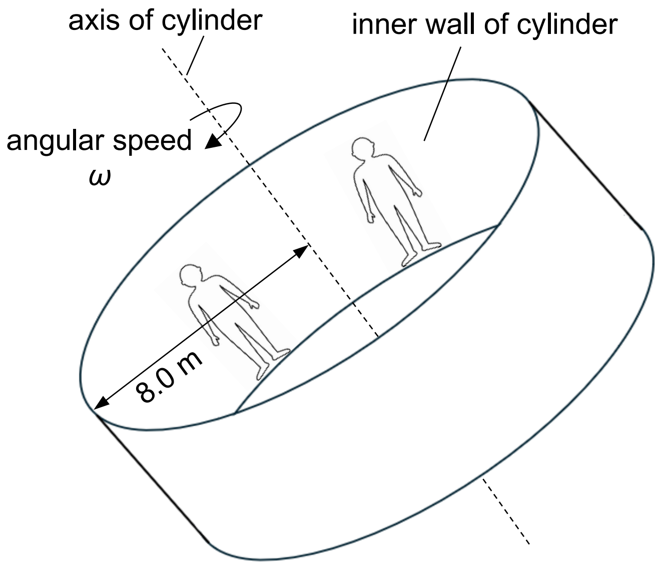

Fig 4.1

Fig. 4.2 shows the side view of the cylinder when it is tilted at an angle of 50° to the horizontal.

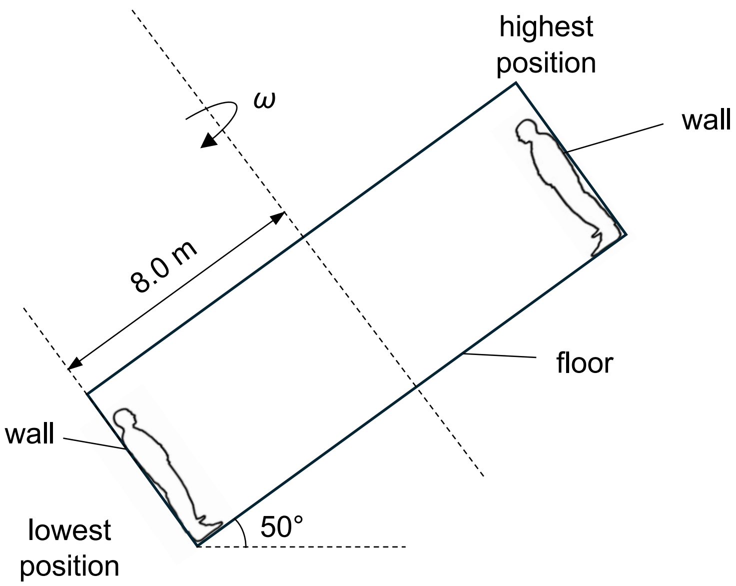

Fig 4.2

The cylinder is rotating at a constant angular speed ω that is sufficient for a rider of mass 65 kg to be just in contact with the wall at the highest position.

At the highest and lowest positions shown, the rider experiences no friction from the wall and floor of the cylinder.

(a) By considering the forces acting on the rider at the highest position, show that ω is 0.97 rad s^{-1}. Explain your working.

[2]

(b) Calculate the magnitude of normal contact force exerted by the wall of the cylinder on the rider at the lowest position.

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

(c) Calculate the gain in gravitational potential energy when the rider is moved from the lowest position to the highest position.

gain in potential energy = ………………… J [2]

(d) Hence, calculate the average power required to bring the rider from the lowest position to the highest position.

average power = ………………… W [2]

5 A pendulum consists of a sphere suspended from a fixed point by an inelastic light string. When the sphere is set in motion, it oscillates with simple harmonic motion. At its lowest position, it has kinetic energy of 0.86 J and momentum of 0.72 N s.

(a) Define *simple harmonic motion*.

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

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

(b) Show that the mass of the sphere is 0.30 kg.

[2]

(c) The simple pendulum is now placed in front of a screen. A vertical rod is fixed near the rim of a horizontal turntable which is rotating at a frequency of 0.55 Hz. A horizontal beam of light casts a shadow of the rod onto the screen in front of which the simple pendulum is suspended, as shown in Fig. 5.1. The shadow of the rod also oscillates with simple harmonic motion.

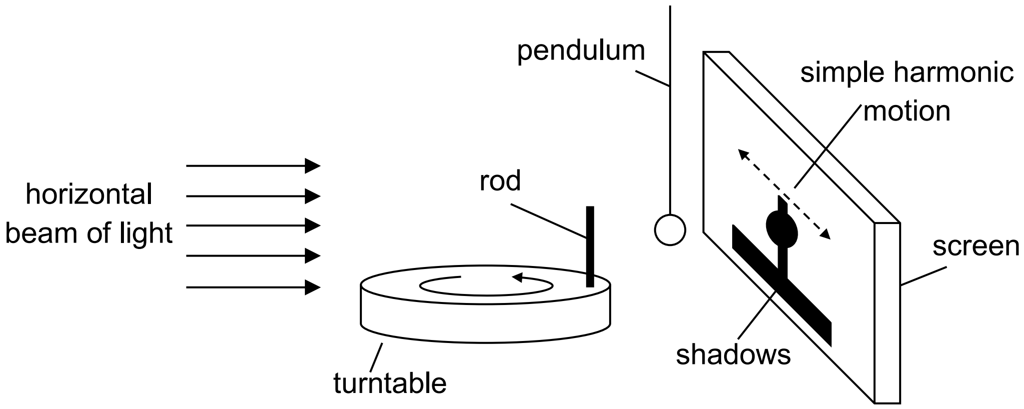

Fig. 5.1

(i) The period T of a pendulum is related to its length L by the expression $T = 2\pi\sqrt{\frac{L}{g}}$, where g is the acceleration of free fall.

The pendulum is now set in motion, and it is observed that the shadows of the rod and the pendulum sphere move in phase on the screen.

Calculate the length of the pendulum, L.

L = ... m [2]

(ii) The pendulum is then held stationary and set in motion again. Now it is observed that shadow of the sphere passes the equilibrium position 0.50 s later than the shadow of the rod.

Calculate the phase difference between their motions.

phase difference = ... rad [1]

(d) The pendulum is next placed in water and set into motion. Fig. 5.2 shows the variation of displacement from its equilibrium position, *x* of the pendulum with time, *t*, for the first half oscillation.

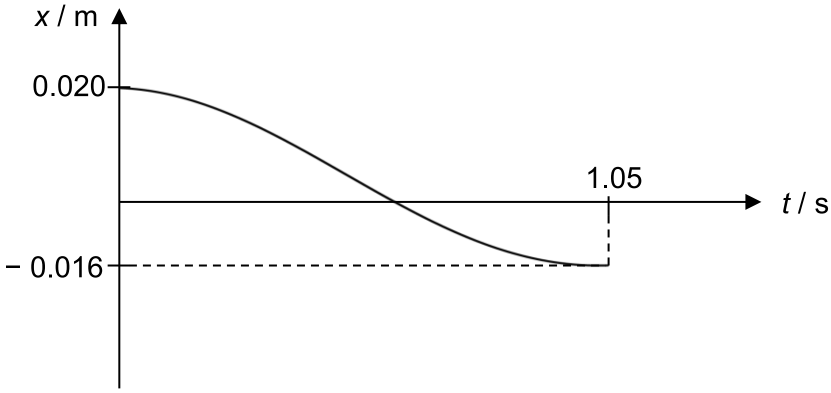

Fig. 5.2

(i) Explain why the maximum negative displacement of the pendulum is not equal to its maximum positive displacement.

…………………………………………………………………………………………...

……………………………………………………………………………………. [1]

(ii) Determine the decrease in energy of the oscillation for the first half of the oscillation.

decrease in energy = ……………………….. J [2]

6 A battery of e.m.f. 6.0 V and internal resistance of 0.70 Ω is connected to 4 different components as shown in Fig. 6.1.

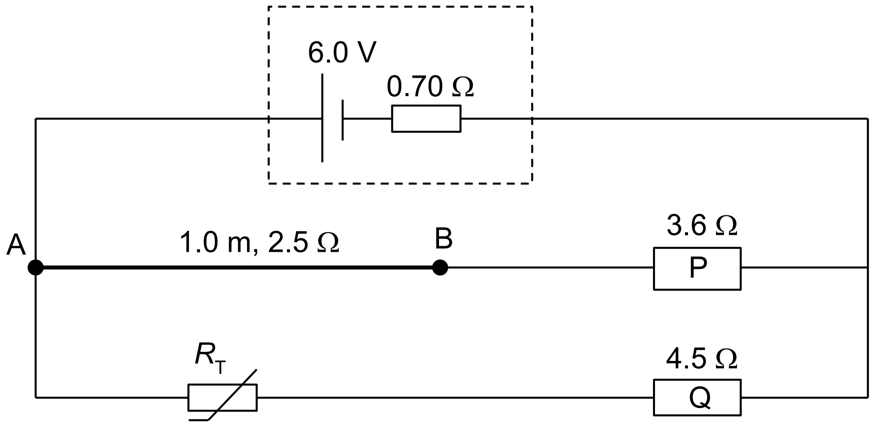

Fig. 6.1

Wire AB is a uniform resistance wire of length 1.0 m and resistance 2.5 Ω.
P and Q are fixed resistors of resistances 3.6 Ω and 4.5 Ω respectively.
R_T is a thermistor, and the variation with temperature θ of its resistance is shown in Fig. 6.2.

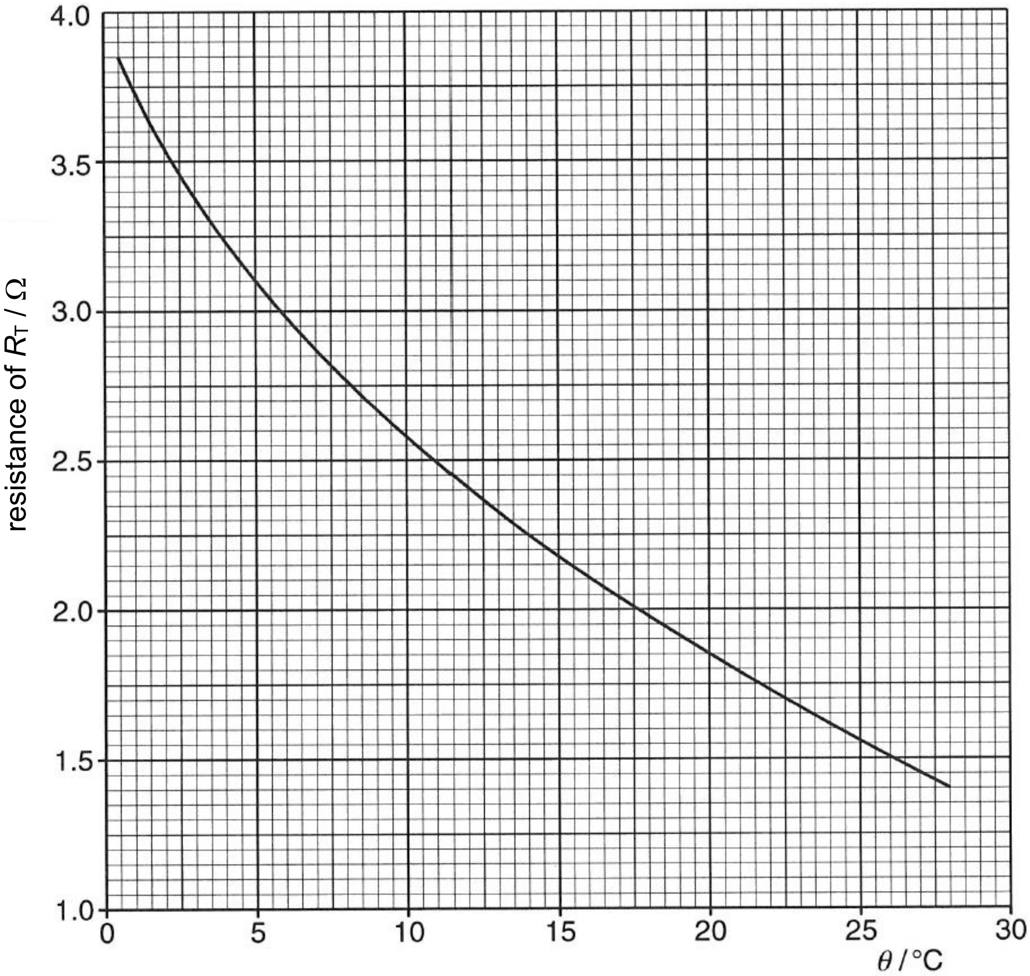

Fig. 6.2

The temperature of the thermistor is maintained at 20 °C.

(a) Using Fig. 6.2, determine the resistance of R_T.

resistance = …………………… Ω [1]

(b) Show that the terminal potential difference across the battery is 4.9 V.

[2]

(c) Determine the current flowing through the thermistor.

current = …………………… A [2]

(d) Hence, or otherwise, determine the potential difference across the thermistor.

potential difference = …………………… V [1]

(e) A galvanometer is now connected to point C on wire AB, and point D between the thermistor and Q, as shown in Fig. 6.3.

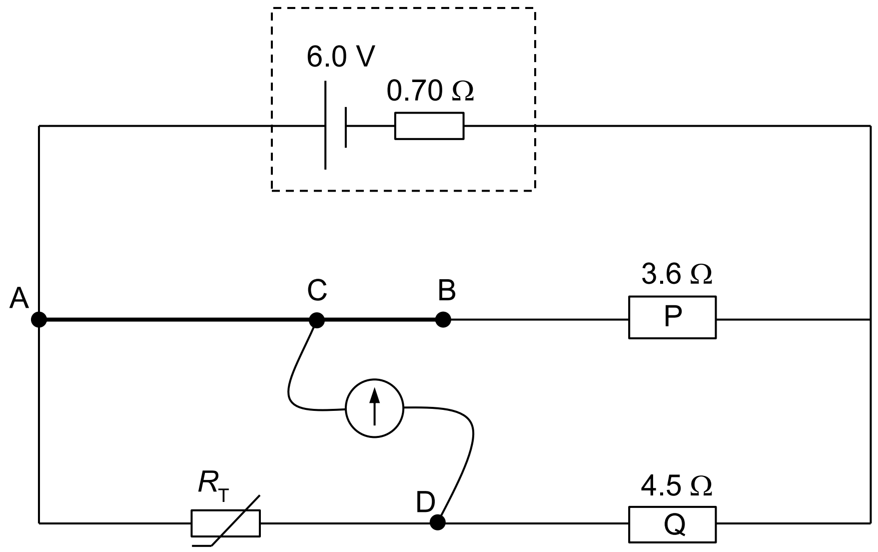

Fig. 6.3

Determine the length of wire between points A and C, such that the reading on the galvanometer is zero.

length of AC = ………………… m [2]

7 **(a)** The masses of some nuclei are shown in Fig. 7.1.

	mass / u
proton ($^{1}_{1}p$)	1.007
neutron ($^{1}_{0}n$)	1.009
lanthanum-141 ($^{141}_{57}La$) nucleus	140.911

Fig. 7.1

(i) Determine the number of neutrons in the lanthanum-141 nucleus.

number of neutrons = ……………………… [1]

(ii) Use data from Fig. 7.1 to show that the binding energy of a nucleus of lanthanum-141 is 1162 MeV.

[3]

(iii) A plutonium-239 ($^{239}_{94}Pu$) nucleus has binding energy of 1807 MeV.

By comparing the binding energy per nucleon of lanthanum-141 and plutonium-239, state and explain whether lanthanum-141 or plutonium-239 is more likely to undergo nuclear fission.

……………………………………………………………………………………………..

……………………………………………………………………………………………..

…………………………………………………………………………………… [3]

(b) Lanthanum-141 ($^{141}_{57}\text{La}$) undergoes radioactive decay to form cerium-141 ($^{141}_{58}\text{Ce}$) and a particle X. Particle X deflects as it moves through a magnetic field.

The decay can be represented by the equation

$$^{141}_{57}\text{La} \rightarrow {}^{141}_{58}\text{Ce} + \text{X}$$

(i) State what particle X is.

.... [1]

(ii) According to conservation laws of energy and momentum, when lanthanum-141 nuclide of fixed initial energy undergoes decay, the emitted particle X should have a specific energy value. However, experimental observations show that particle X are emitted with a range of energies from different lanthanum-141 nuclides.

Explain the experimental observations.

....

....

.... [2]

8 In 1814, Joseph von Fraunhofer studied the light from the Sun. He made a crucial discovery when he observed dark lines on a continuous spectrum of white light, known as the solar absorption spectrum, shown in Fig. 8.1. These lines, now known as Fraunhofer lines, were later found to be absorption lines caused by elements in the Sun's outer gas layers.

The thickness of the lines shows the amount of absorption that happens for a particular wavelength. Thicker lines indicate a higher amount of absorption by the gases in the outer gas layers.

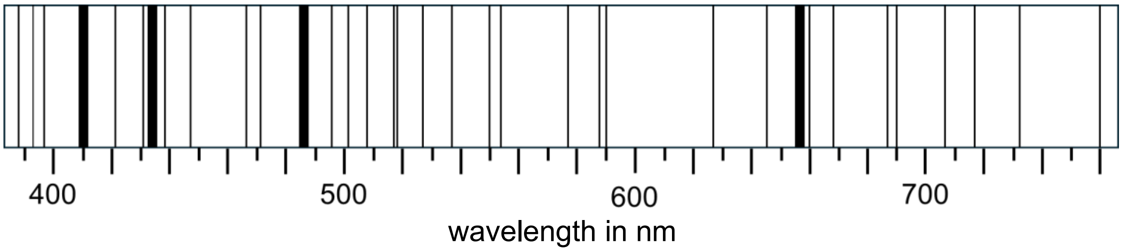

Fig 8.1: Solar absorption spectrum

By the early 20th century, scientists had established that each element produces a unique line spectrum when excited. This occurs because electrons in atoms can only occupy specific energy levels, and when they transit between these levels, they emit or absorb light of precise wavelengths, known as an emission or absorption spectrum. This principle has enabled astronomers to determine the chemical composition of distant celestial objects, such as the Sun, simply by analysing the light they emit. The emission spectrum for hydrogen and helium are shown in Fig. 8.2 and Fig 8.3 respectively.

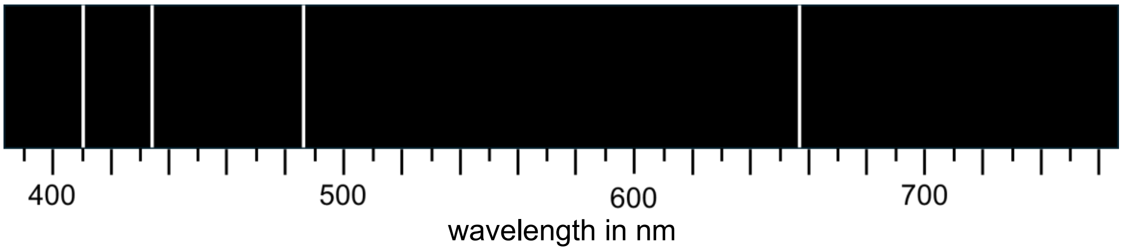

Fig 8.2: Hydrogen emission spectrum

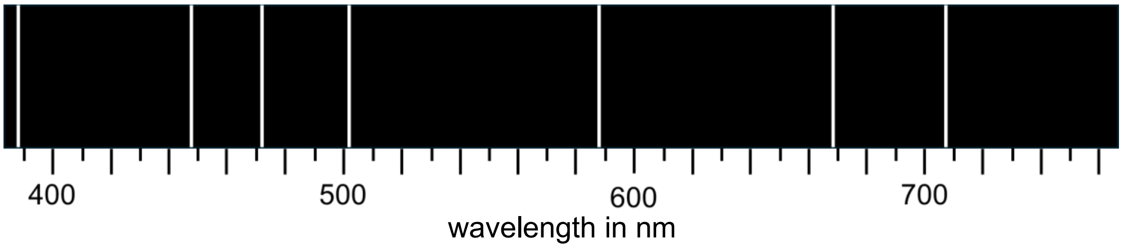

Fig 8.3: Helium emission spectrum

In 1929, Edwin Hubble made a groundbreaking observation while studying the line spectra of distant galaxies at Mount Wilson Observatory. He noticed that the spectral lines from these galaxies were systematically shifted towards longer wavelengths compared to the same spectral lines measured from a stationary source such as a hydrogen lamp in the laboratory. For instance, the hydrogen absorption spectrum from a distant galaxy J1030 is shown in Fig. 8.4.

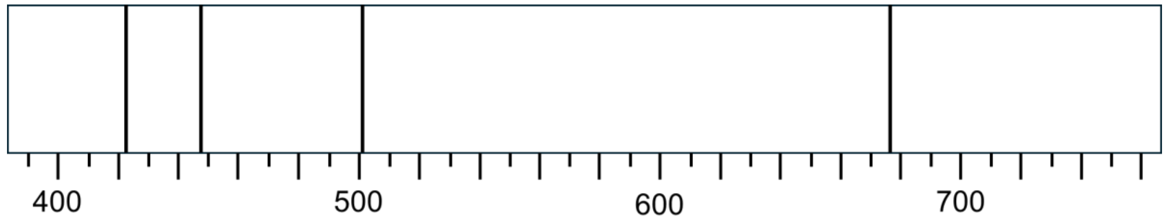

Fig. 8.4: Hydrogen absorption spectrum from galaxy J1030

This can be explained by the Doppler effect. The effect, first described by Christian Doppler in 1842, explains how light waves change wavelength when their source moves relative to an observer. When a light source moves away from an observer, the wavelength increases. Conversely, when the source moves towards the observer, the wavelength decreases. This effect is quantified in the equation

$$z = \frac{\lambda_{\text{moving}} - \lambda_o}{\lambda_o} = \frac{v}{c}$$

where z is a quantity known as "red-shift",
λ_{moving} represents the wavelength from the moving light source,
λ_o represents the wavelength from a stationary source,
v is the speed of the moving source, and
c is the speed of light.

This discovery led to one of the most important methods in cosmology: using the wavelength of emitted light from a galaxy to determine if it is stationary or moving relative to Earth.

(a) The Sun is modelled to have a hot dense core, surrounded by an outer layer of cooler gases. Explain how Fig. 8.1 supports this model.

....

....

....

.... [2]

(b) Using Fig. 8.1, Fig. 8.2 and Fig. 8.3, compare whether there is more hydrogen or helium in the gas layer. Explain your answer.

....

....

.... [2]

(c) Using Fig. 8.1, Fig. 8.2 and Fig. 8.3, state and explain whether only hydrogen and helium are present in the outer gas layer of the Sun.

....

....

.... [2]

(d) **(i)** Show that the highest frequency of light in the hydrogen emission spectrum is 7.3×10^{14} Hz.

[1]

(ii) Calculate the energy of the photon in **d(i)**.

energy = ... J [2]

(e) A distant galaxy GN-Z11 is found to be moving away from Earth and is a moving light source.

Fig. 8.5 compares certain wavelengths of the line spectra of hydrogen obtained from a stationary source on Earth and GN-Z11. Some values of *z* and *v* are also included.

Hydrogen spectral wavelengths from GN-Z11 / nm	Hydrogen spectral wavelengths from stationary source on Earth / nm	z	v / m s^{-1}
676	656	0.0305	9.15×10^6
500	485		

Fig 8.5

(i) Complete the table in Fig. 8.5. [2]

(ii) Suggest why the shift in wavelengths is called "red shift".

....

.... [1]

(iii) The hydrogen spectral wavelengths from another galaxy, the Andromeda Galaxy, were instead discovered to be shorter than the wavelengths from a stationary source on Earth.

State what this implies about the motion of the Andromeda Galaxy relative to Earth.

....

.... [1]

(f) Fig. 8.6 below shows the z values of four galaxies, and their distance from Earth d.

Galaxy	z	d / million light-years
Perseus	0.018	250
NGC 4889	0.022	308
Coma	0.023	321
Hercules Cluster	0.037	500

Fig. 8.6

(i) One *light-year* is defined as the distance travelled by light in one year. Express one light-year in metres.

one light-year = ... m [1]

(ii) Using the data in Fig 8.6, describe qualitatively the relationship between the distance of a galaxy and the speed with which it is moving away from Earth.

....

.... [1]

(iii) Fig. 8.7 shows the variation of z with distance d.

Plot the data for the Hercules Cluster on Fig 8.7.

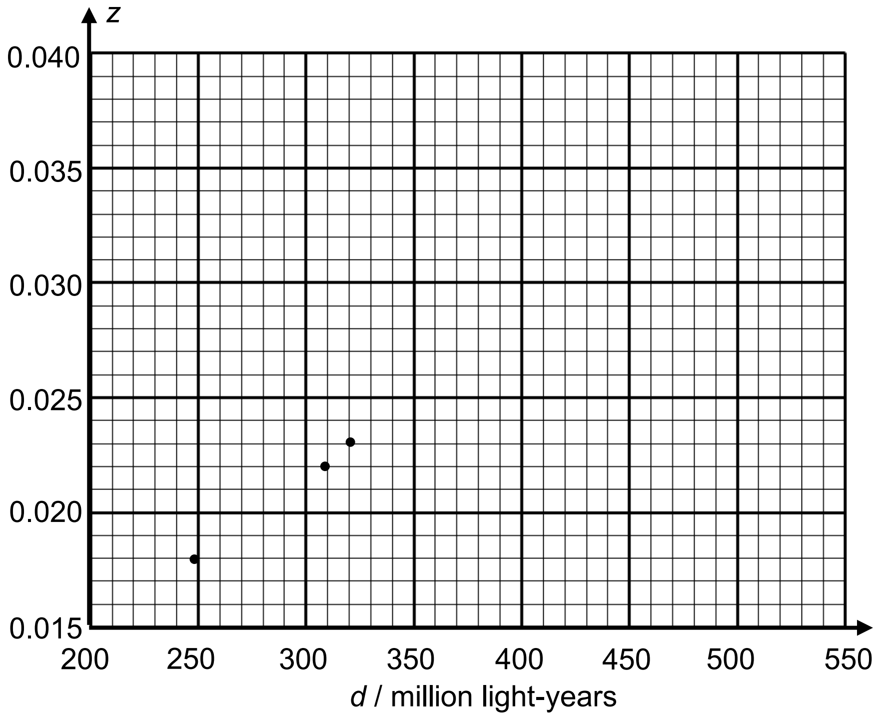

Fig. 8.7

[1]

(iv) Add a line of best fit in Fig. 8.7. [1]

(v) z is related to d by the equation

$$z = \frac{H_o d}{c}$$

where H_o is the Hubble constant and c is the speed of light.

Using the line of best fit in **(iv)**, determine H_o.

H_o =………………………… s^{-1} [3]

End of Paper

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