HWA CHONG INSTITUTION
JC2 Preliminary Examination
Higher 2

CANDIDATE NAME		**CT GROUP**	21S
CENTRE NUMBER		**INDEX NUMBER**	

PHYSICS **9749/02**

Paper 2 Structured Questions **13 September 2022**

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Centre Number, index number and name in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft 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.

The number of marks is given in brackets [ ] at the end of each question or part question.
You are reminded of the need for good English and clear presentation in your answers.

For Examiner's Use		
Paper 2		
1		11
2		8
3		10
4		8
5		10
6		11
7		22
Deductions		
Total		80

Data	Formulae	
speed of light in free space, $c = 3.00 \times 10^{8}$ m s^{-1}	uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
permeability of free space, $\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}	work done on / by a gas	$W = p\,\Delta V$
permittivity of free space, $\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1} $\approx (1/(36\pi)) \times 10^{-9}$ F m^{-1}	hydrostatic pressure	$p = \rho gh$
	gravitational potential	$\phi = -\frac{Gm}{r}$
elementary charge, $e = 1.60 \times 10^{-19}$ C	temperature	T/K = T/ °C + 273.15
	pressure of an ideal gas	$P = \frac{1}{3}\frac{Nm}{V} < c^2 >$
the Planck constant, $h = 6.63 \times 10^{-34}$ J s	mean kinetic energy of a molecule of an ideal gas	$E = \frac{3}{2}kT$
unified atomic mass constant, $u = 1.66 \times 10^{-27}$ kg	displacement of particle in s.h.m.	$x = x_o \sin \omega t$
rest mass of electron, $m_e = 9.11 \times 10^{-31}$ kg	velocity of particle in s.h.m.	$v = v_o \cos \omega t$ $= \pm \omega \sqrt{(x_o^2 - x^2)}$
rest mass of proton, $m_p = 1.67 \times 10^{-27}$ kg	electric current	$I = Anvq$
molar gas constant, $R = 8.31$ J K^{-1} mol^{-1}	resistors in series	$R = R_1 + R_2 + \ldots$
	resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
the Avogadro constant, $N_A = 6.02 \times 10^{23}$ mol^{-1}	electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
the Boltzmann constant, $k = 1.38 \times 10^{-23}$ J K^{-1}	alternating current / voltage	$x = x_o \sin \omega t$
gravitational constant, $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}	magnetic flux density due to a long straight wire	$B = \frac{\mu_o I}{2\pi d}$
acceleration of free fall, $g = 9.81$ m s^{-2}	magnetic flux density due to a flat circular coil	$B = \frac{\mu_o NI}{2r}$
	magnetic flux density due to a long solenoid	$B = \mu_o nI$
	radioactive decay	$x = x_o \exp(-\lambda t)$
	decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

1 **(a)** A student uses the following setup in Fig. 1.1 to find the spring constant k of a spring.

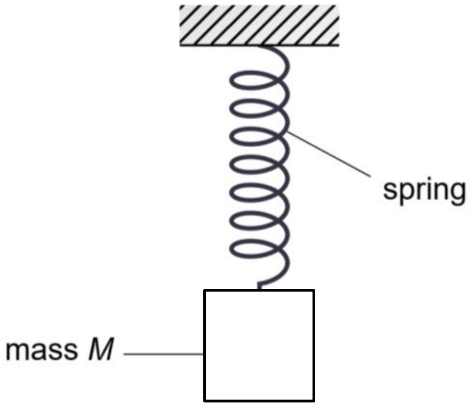

Fig. 1.1

The student obtained the following results from his experiment:

Length of spring when no mass is added: $L_1 = (1.3 \pm 0.1)$ cm

Length of spring when mass M is added: $L_2 = (3.7 \pm 0.2)$ cm

Mass of $M = (98.5 \pm 0.2)$ g

You may assume that the elastic limit of the spring has not been exceeded in his experiment.

(i) Show that the spring constant k of the spring is 40.3 N m^{-1}.

[2]

(ii) Calculate the actual uncertainty in k.

actual uncertainty in k = ... N m^{-1} [2]

(iii) State the value of k and its actual uncertainty to the appropriate precision.

k = (............................ ± ....) N m^{-1} [1]

(b) Fig. 1.2 shows a wooden cube P of volume V floating on the surface of a liquid with density ρ. 30% of the volume of the cube is above the surface of the liquid.

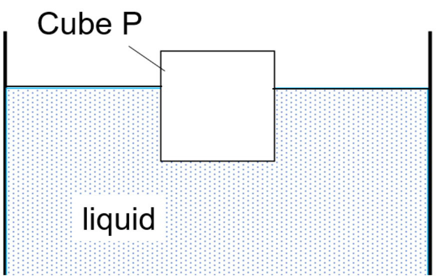

Fig. 1.2

The top face of cube P is now connected to a light string, which passes over a smooth pulley and supports an identical cube Q at its other end, which rests on a smooth inclined plane at an angle θ to the horizontal, as shown in Fig 1.3.

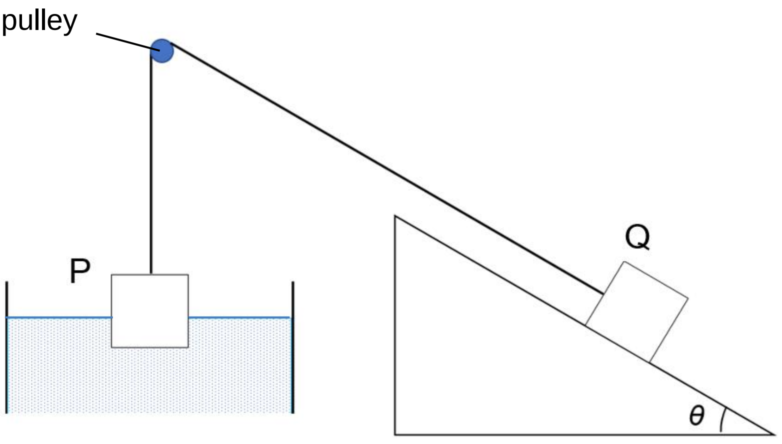

Fig. 1.3

At its new equilibrium position, 60% of the volume of Cube P is now above the surface of the liquid.

(i) On Fig. 1.4, label clearly all forces acting on Cube P when it is at its new equilibrium position.

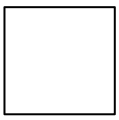

Fig. 1.4 [2]

(ii) State the expression for the weight W of cube P in terms of V and ρ.

[1]

(iii) Hence, show that the tension in the string is $\frac{3}{7}W$.

[2]

(iv) Determine the value of θ.

θ = ... ° [1]

[Total :11]

2 Jupiter has close to eighty moons, of which eight of them are in approximately circular orbits. Jupiter has a mass M_J, radius R_J and a Jupiter-day is approximately 0.417 Earth-days.

The orbital radii and periods of two of the moons of Jupiter are tabulated in Fig. 2.1. The orbital radii and the orbital periods of these moons are expressed in units of R_J and Earth-days respectively.

Name of Moon	**Orbital Radius / R_J**	**Orbital Period / Earth-days**
Amalthea	2.62	....
Thebe	3.18	0.676

Fig. 2.1

(a) **(i)** Show that the period T of a circular orbit around Jupiter, expressed in terms of the radius of the orbit R is given by

$$T = \sqrt{\frac{4\pi^2 R^3}{GM_J}}$$

[2]

(ii) Using the data provided in Fig 2.1, complete Fig. 2.1 with the orbital period for Amalthea. Show all working in the space below.

orbital period = ... Earth-days [2]

(b) **(i)** Determine an expression for the orbital speed *v* of a moon in terms of its orbital radius *R* and any other constants.

[1]

(ii) It is suggested that Jupiter's rings are formed from material ejected from the moons as the moons collide with meteorites.

Assuming no change in the speed of a moon, explain whether the moon can stay in orbit if it experiences a constant loss of mass.

....

.... [1]

(c) Using the data available for the moons of Jupiter, a graph of the orbital period was plotted against the orbital radius as shown in Fig 2.2.

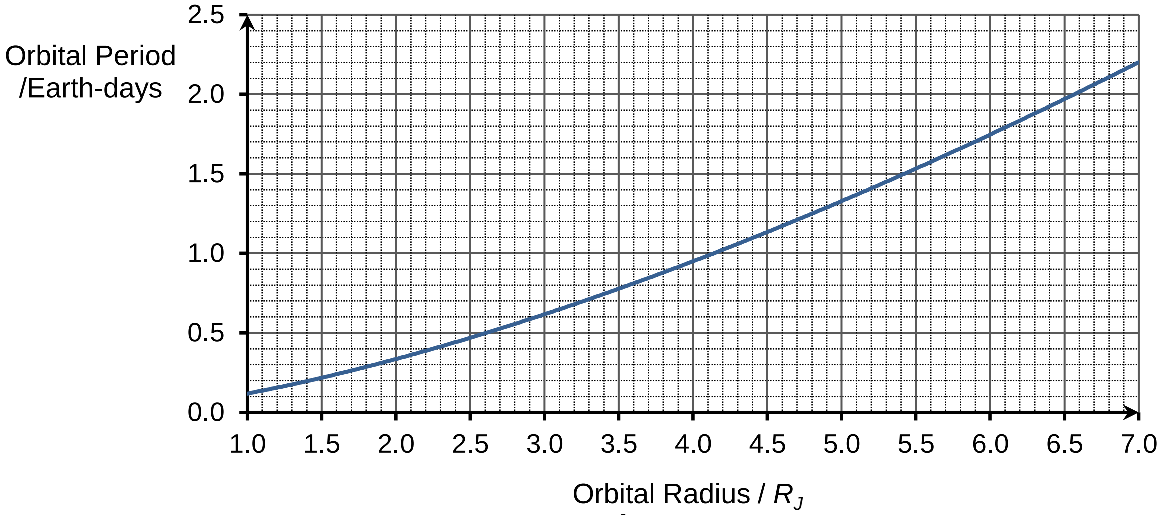

Fig. 2.2

(i) A satellite is moving in a "geostationary orbit" about Jupiter i.e. it is in an orbit above the same geographical spot on Jupiter. Using Fig. 2.2, estimate the radius of this "geostationary orbit".

radius = ... R_J [1]

(ii) Suggest a possible use for this "geostationary satellite" in **(c)(i)**.

....

.... [1]

[Total: 8]

3 A sound wave that is **propagating towards the left** is represented by the two graphs below.

Fig. 3.1 shows the variation with position along the wave of the displacement of the air particles from their equilibrium position at time t = 0. Fig. 3.2 shows the variation with time t of the displacement of an air particle from its equilibrium position.

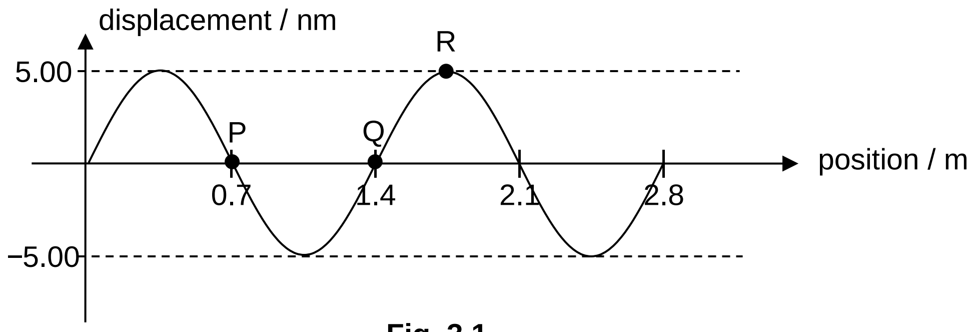

Fig. 3.1

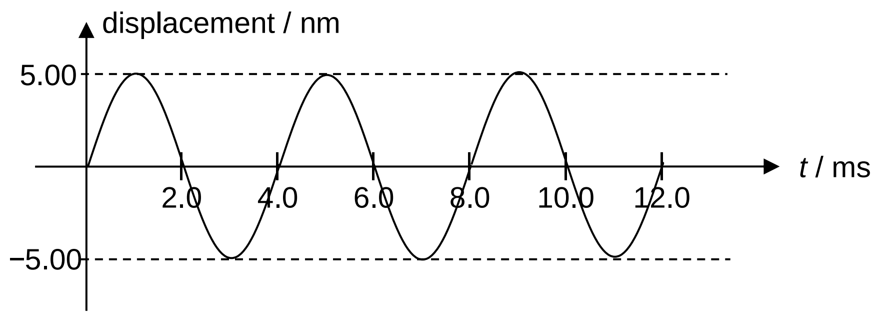

Fig. 3.2

(a) Calculate the speed of the sound wave.

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

(b) Fig. 3.1 shows three particles P, Q and R along the sound wave.
Taking rightwards to be positive, identify the particle that is

(i) instantaneously at rest at t = 0.

particle : .... [1]

(ii) at the centre of a rarefaction at t = 0.

particle : .... [1]

(iii) represented by Fig. 3.2.

particle : .... [1]

(c) Particle S is 0.70 m to the right of particle R.

(i) Determine the phase difference between particle S and R.

phase difference = ... [2]

(ii) Sketch in Fig. 3.1 the graph of the wave 1.0 ms later. Label the graph Y. [2]

(iii) Sketch in Fig. 3.2 the graph that corresponds to particle S. Label the graph Z. [1]

[Total: 10]

4 A thermistor is connected in series with a fixed resistor of 1.20 kΩ and a battery, as shown in Fig 4.1. The e.m.f. E of the battery is unknown and its internal resistance is negligible.

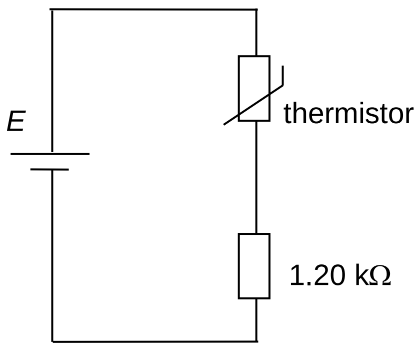

Fig. 4.1

The variation with temperature θ of the resistance R of the thermistor is shown in Fig. 4.2.

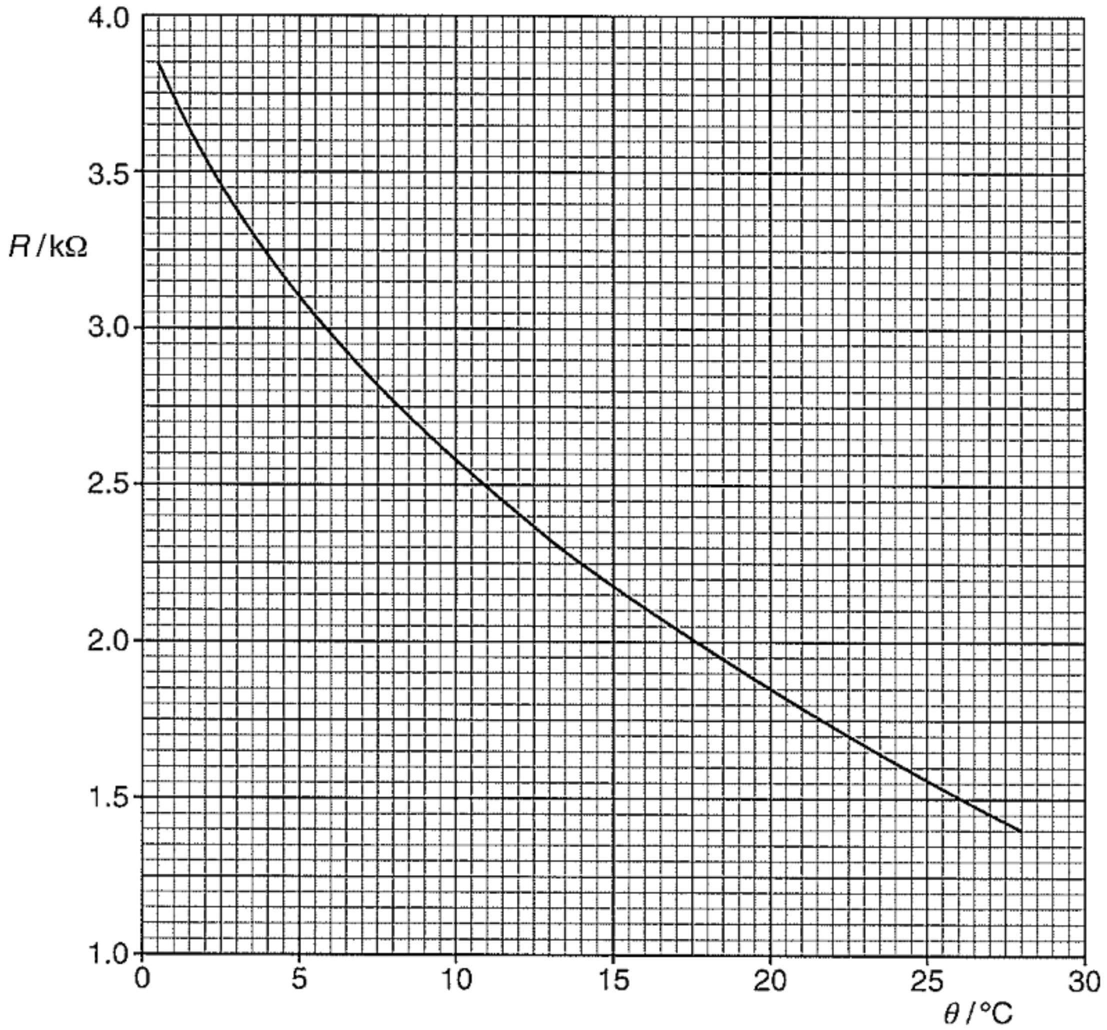

Fig. 4.2

The thermistor is immersed in a liquid maintained at a constant temperature of 5.0 ^oC. The energy delivered by the battery is 11.3 J for a duration of 10.0 min.

(a) **(i)** Determine the power delivered by the battery.

power = ... W [2]

(ii) Hence, determine the e.m.f. *E* of the battery.

E = ... V [3]

(b) The thermistor is removed and immersed in another liquid maintained at a constant temperature of 17.5 ^oC. The fixed resistor is replaced with another fixed resistor with a different resistance.

If the battery delivers the same power as before, determine the resistance of the fixed resistor.

resistance = ... Ω [3]

[Total: 8]

5 **(a)** Explain why a charge moving perpendicular to a magnetic field will follow a *uniform circular* path.

....

....

....

....

....

.... [2]

(b) An electron (e_1) enters a uniform magnetic field of flux density 7.5 mT with a speed of 8.5×10^7 m s^{-1}. The magnetic field only exists within a square **MNOP** measuring 5.0 cm x 5.0 cm, as shown in Fig. 5.1 below.

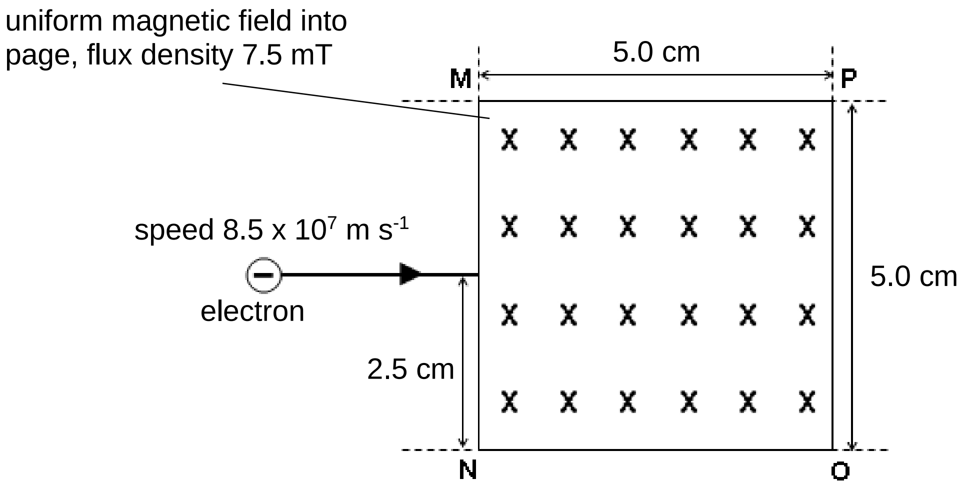

Fig. 5.1

(i) Calculate the radius of the path taken by the electron in the magnetic field.

radius = ... cm [2]

(ii) With reference to your answer in **(b)(i),** on Fig. 5.1, sketch the path of this electron as it passes through, and beyond the region of the magnetic field. [3]

(iii) Show that the period T (i.e. time to complete a circular path) of the motion of the electron when it is in the magnetic field is independent of its speed v and radius r of the path of the electron.

[1]

(iv) Another electron (e_2) moving with a **different** speed approaches the magnetic field along the same path as e_1. e_2 exits the field from side **MN**.

Hence, with reference to **(b)(iii),** explain which electron (i.e. e_1 or e_2), spends a longer time in the magnetic field.

....

....

....

....

....

....[2]

[Total: 10]

6 **(a)** Explain what is meant by the *activity* of a radioactive source.

....

....

.... [1]

(b) A sample of pure $^{235}_{92}U$ has a mass of 2.40 x 10^{-6} g has an activity of 0.1919 Bq.

(i) Determine the number of radioactive nuclei in this sample.

number of radioactive nuclei = ... [2]

(ii) Hence, calculate the decay constant of $^{235}_{92}U$.

decay constant = ... s^{-1} [2]

BLANK PAGE

[Question continues next page.]

(c) The nuclide Potassium-42 $\left({}^{42}_{19}\mathrm{K}\right)$ undergoes radioactive decay to become Calcium-42 $\left({}^{42}_{20}\mathrm{Ca}\right)$. A fresh sample of radioactive material contains N_o nuclei of Potassium-42 and no Calcium-42 at time t = 0. Fig. 6.2 shows the variation with time t of the ratio of the number N of nuclei of Potassium-42 to its original number N_o.

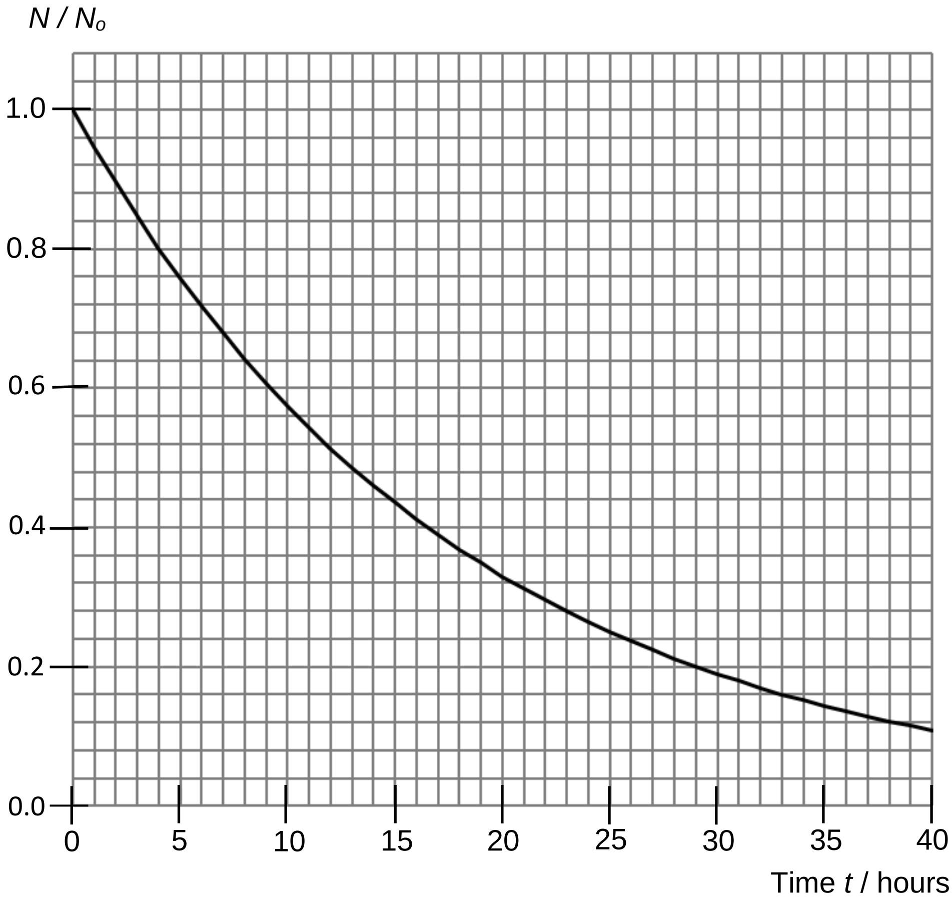

Fig. 6.2

(i) State the particles emitted in the radioactive decay of Potassium-42.

....[1]

(ii) Use Fig 6.2 to estimate the half-life of Potassium-42 in hours.

half-life = ...h [1]

(iii) Calcium-42 is stable. On Fig. 6.2, sketch a graph to show the variation with time t of the number of Calcium-42 atoms in the sample. [2]

(iv) Using Fig. 6.2, or otherwise, determine the age of the radioactive sample when the ratio $\dfrac{\text{Number of Calcium-42 atoms}}{\text{Number of Potassium-42 atoms}}$ is equal to 4.0.

age = ...h [2]

[Total: 11]

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

Forces in Flight

Thrust, drag, lift, and weight are the four forces that act upon all aircraft in flight. Understanding how these forces work and knowing how to control them are essential to flight.

Lift is the upward force on the aircraft acting perpendicular to the wing. While an aircraft's weight is concentrated at the centre of gravity (CG), the lift occurs at the centre of pressure (CP). In the design of aircraft, the CG is fixed forward of the CP as shown in Fig. 7.1 in order to retain flight equilibrium. The tailplane of the aircraft helps to maintain the stability of the aircraft. It consists of a horizontal stabiliser with a fixed wing section and an elevator which could be adjusted to produce a vertical force acting on the rear of the aircraft's body. The vertical stabilizer consists of a rudder which could be maneuvered to produce a force to adjust the sideway movements of the aircraft.

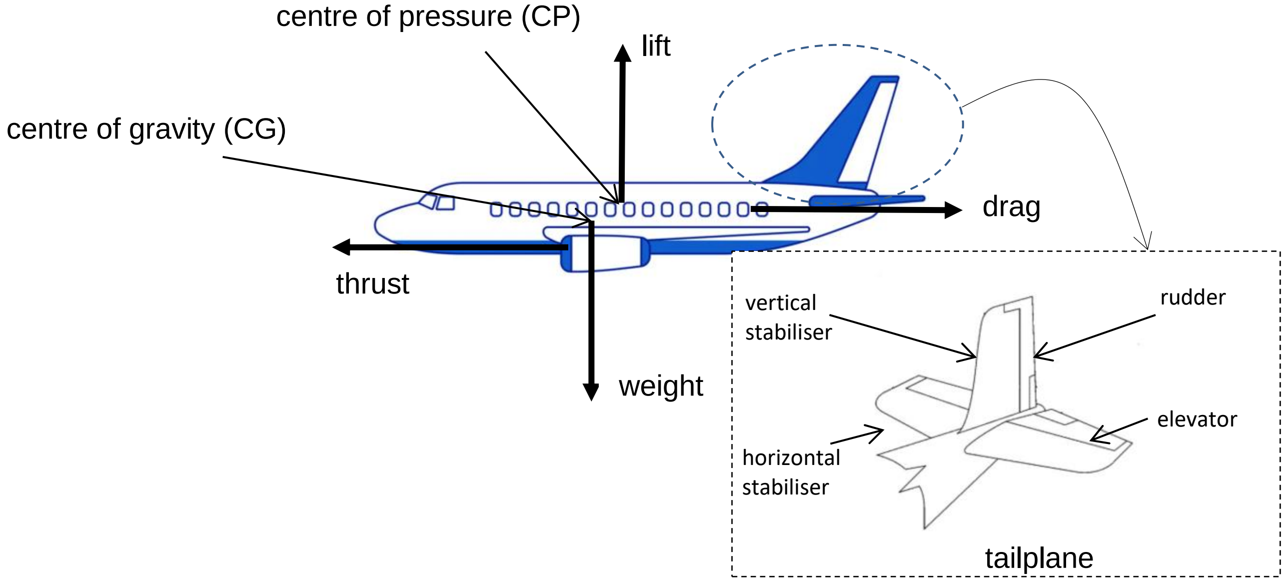

Fig. 7.1

The thrust is the forward force provided by a propulsion system of the plane – often the jet engines in a modern aircraft. A jet engine works by sucking air in the front, compressing it and then mixing and combusting the air with fuel before pushing it out at a much higher speed and higher pressure. Fig. 7.2 is a typical jet engine.

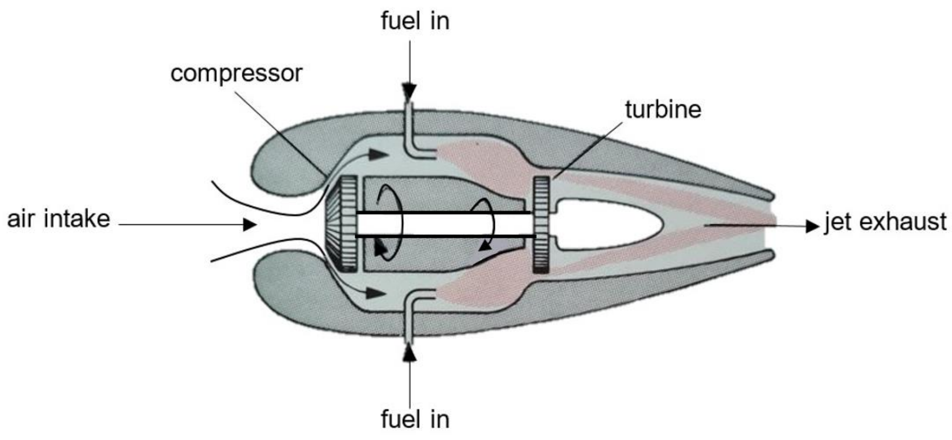

Fig. 7.2

Most of the lift of the aircraft is usually generated at the wings. The cross-section of the wings of the aircraft has a very special shape called an *aerofoil*. (Fig. 7.3(a)) The aerofoil looks like a teardrop that deflects the airflow downwards, increasing the velocity of the airflow on top and decreasing the velocity at the bottom. This effect produces a pressure difference between the top and the bottom of the wings which produces a net upward force known as the lift. By tilting the aerofoil at different angles with respect to the velocity of the air that flows through it, the lift force can also vary. This angle which the aerofoil makes with the velocity of the air that flows through it is known as the *angle of attack* α. (Fig. 7.3(b))

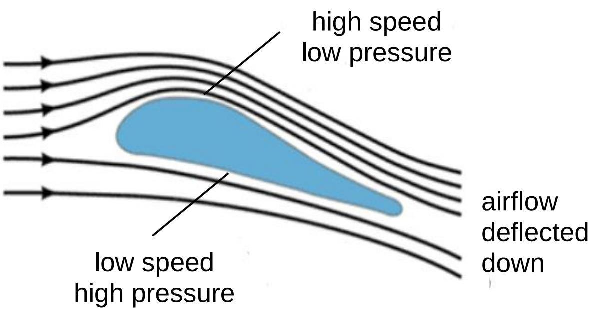

Fig. 7.3(a)

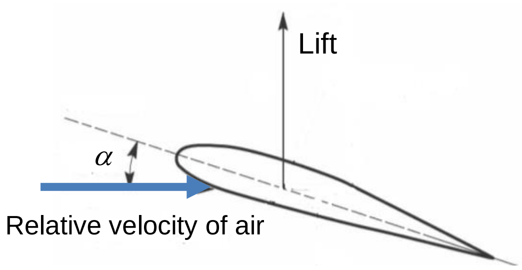

Fig. 7.3(b)

Although a lift force is generated by the wing when it moves through the air, due to the viscosity of air, a drag force is also generated as an inevitable product of the lift. Apart from the wings, all other parts of an aircraft's airframe also generate a drag force which acts in opposite direction to the flight.

Both the lift (L) and the drag (D) forces depend on factors such as the shape of the aerofoil, angle of attack and the relative velocity between the air and the aircraft. These factors are taken into consideration in the following *Lift* and *Drag Equations* used by pilots to determine L and D :

Lift Equation : $L = \frac{1}{2}C_L \rho v^2 S$ and Drag Equation: $D = \frac{1}{2}C_D \rho v^2 S$

where ρ is the density of the air, v is the relative speed between the aircraft and the wind and S the effective surface area of the wings. C_L and C_D are dimensionless constants known as the *lift coefficient* and the *drag coefficient* respectively. A dimensionless constant is one in which its unit is equal to one. Both C_L and C_D are dependent on the shape of the aerofoil and the angle of attack.

(a) An aircraft travels in a straight, level flight with a constant velocity as shown in Fig. 7.1. The total weight of the aircraft is 1.5×10^6 N, and the engines give it a forward thrust of 0.60×10^6 N.

(i) Determine the value of the lift and the drag.

lift = ... N

drag = ... N [2]

(ii) The horizontal separation of the lines of action of lift and weight is 0.75 m. Determine the vertical separation of the lines of action of thrust and drag.

vertical separation = ... m [2]

(iii) Due to the design of the aircraft, when the CG is forward of the CP, there is a natural tendency for the nose of the aircraft to tilt downwards when in flight.

Suggest how the tail stabiliser assists in maintaining the equilibrium of the plane.

....

....

....

....

.... [2]

(b) A simplified model of a jet engine of an aircraft is shown in Fig. 7.4.

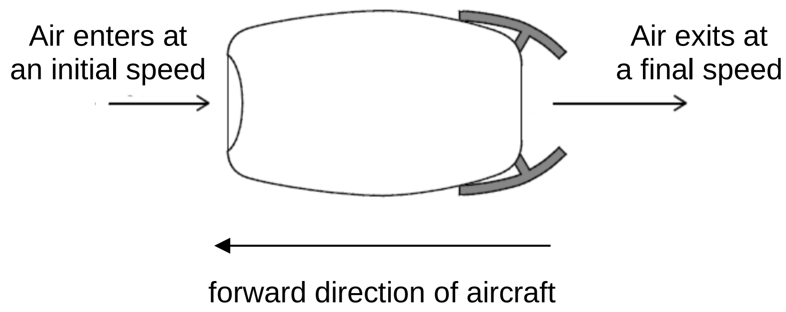

Fig. 7.4

(i) By using Newton's Laws of Motion, explain how the air is able to exert a forward thrust on the engine.

....

....

....

....

....

.... [2]

(ii) For a particular flight, the mass flow rate of the air that enters the jet engine is 210 kg s^{-1} and this mass of air increases speed by 580 m s^{-1} as it passes through the engine.

Calculate the thrust provided by the air on this jet engine.

thrust = ... N [2]

(iii) In reality, the actual thrust on the engine is different from the value calculated in **(ii)**. Suggest a possible physics related reason for the difference.

....

....[1]

(c) An aircraft has a mass of 2.85×10^5 kg and each wing has an area of 360 m^2. During level flight, the pressure on the lower wing surface is 7.00×10^4 Pa. Determine the pressure on the upper wing surface.

pressure = ...Pa [2]

(d) **(i)** Show that the coefficient of lift C_L is a dimensionless quantity.

[2]

(ii) To make a turn in flight, an aircraft often needs to do a tilt as shown in Fig. 7.5. Explain why the aircraft needs to tilt and increase in speed if it wishes to maintain the same altitude as before while making the turn.

Fig. 7.5

....

....

....

....

....

....[2]

BLANK PAGE

[Question continues next page.]

(e) Both C_L and C_D are normally experimentally determined using a wind tunnel. Fig. 7.6 depicts the graphs of C_L and C_D with against the angle of attack α for a particular aerofoil wing; C_L is on the left axis and C_D is on the right axis. From these graph, the ratio of C_L to C_D can be found. This ratio is equal to the lift to drag ratio (L/D) which gives an indication of the efficiency of the performance of the plane in flight. A graph of some of the data showing the variation of L/D with α is shown in Fig. 7.7.

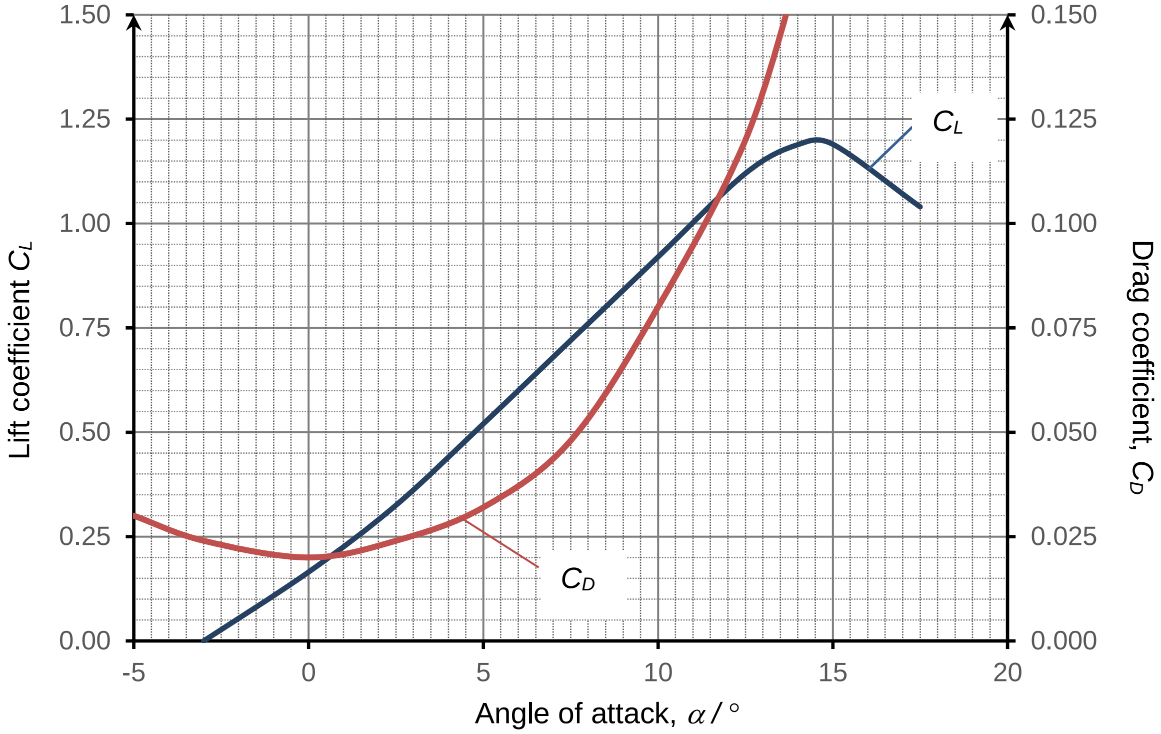

Fig. 7.6

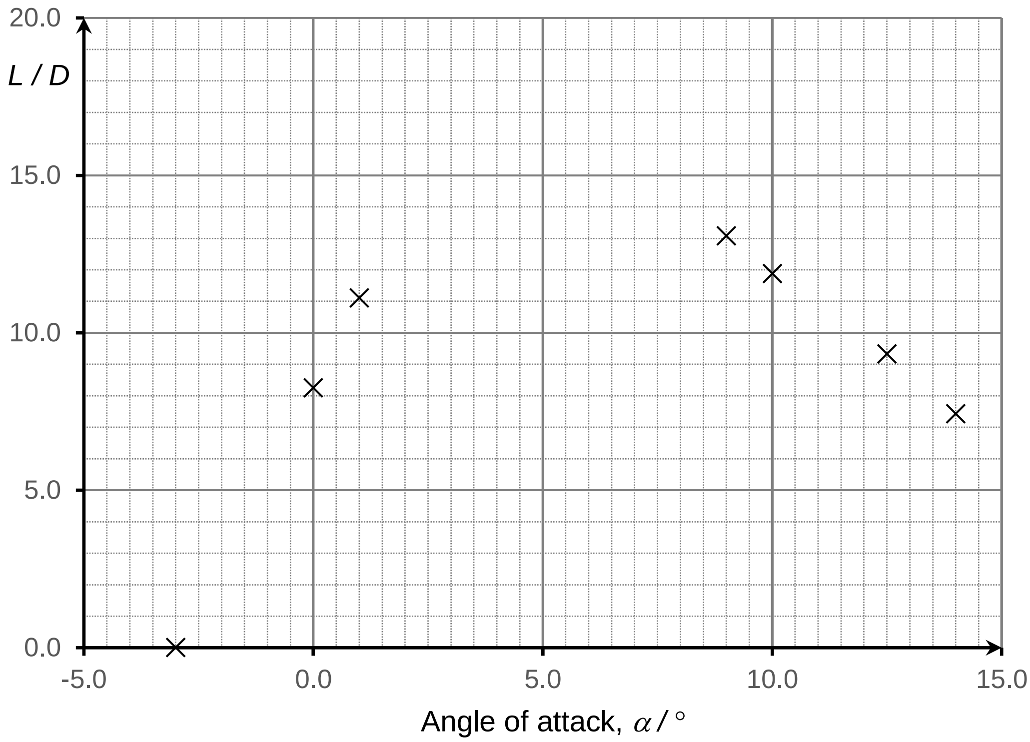

Fig. 7.7

(i) Using the *Lift* and *Drag Equations*, show that the ratio of C_L to C_D is equal to the lift to drag ratio *L/D*.

[1]

(ii) In most phases of flight, the generation of lift is a distinct benefit, while the generation of drag is a distinct disadvantage. When the aircraft is at level flight, the wing is said to be working most efficiently when the lift to drag ratio is a maximum. Suggest why this is so.

....

....

....

....[1]

(iii) For most conventional aerofoil wing, this greatest efficiency in **(e)(ii)** is achieved at an angle of attack at 4°.

1. Using Fig. 7.6, determine the lift to drag ratio at this angle of attack for the aerofoil.

L/D = ... [1]

2. Plot this point on Fig. 7.7 and sketch the best fit curve. [2]

[Total : 22 marks]

Acknowledgements:
1. Fig. 7.1. Source : (https://www.vectorstock.com/royalty-free-vector/aeroplane-side-view-vector-23448245)
2. Fig. 7.2. Source : (https://www.basicairdata.eu/knowledge-center/measurement/in-flight-angle-of-attack-usage/)
3. Key Reference 1 : Principles of Flight for PPL and Beyond, v. 5. Oxford Aviation Academy.

End of paper