Name: ______________________________ Class: ______________

JURONG PIONEER JUNIOR COLLEGE

JC2 Preliminary Examination 2023

PHYSICS **9749/02**

Higher 2 **29 August 2023**

Paper 2 Structured Questions **2 hours**

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

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/ 9
2	/ 9
3	/ 11
4	/ 9
5	/ 10
6	/ 10
7	/ 22
Total	/ 80

This document consists of **23** printed pages and **1** blank page.

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$= (1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ 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	$\phi = -\frac{GM}{r}$
temperature	$T / \text{K} = T / {}^\circ\text{C} + 273.15$
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	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 **(a)** **(i)** Magnetic flux density B generated by a magnet may be found by determining the magnetic flux ϕ passing normally through an area A according to the expression

$$\phi = BA$$

In one experiment, ϕ and A were determined to be (50 ± 5) μWb and $(4.00 \pm 0.01) \times 10^{-4}$ m^2 respectively.

Determine the value of B along with its associated uncertainty.

B = ……………….. ± .... T [3]

(ii) Explain why the value of B cannot be more precisely determined even if the precision in the instrument used to measure A is improved.

....

.... [1]

(b) A non-uniform bar AB makes an angle of 60° with a horizontal surface, as shown in Fig. 1.1.

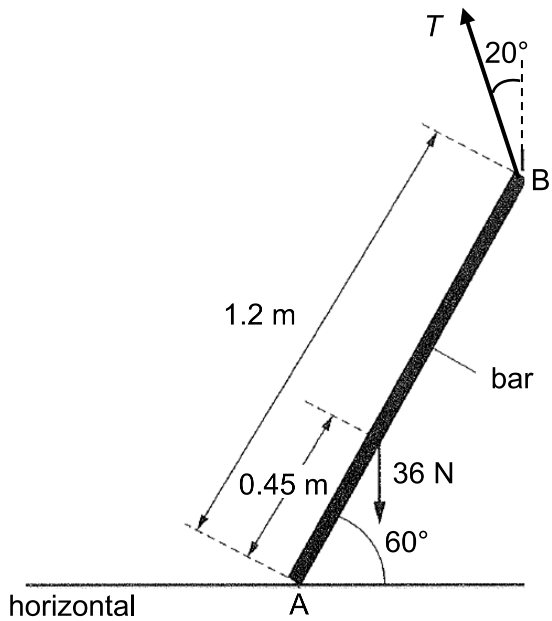

Fig. 1.1

The bar is hinged as A and is supported by a light string at B. The string is inclined at an angle of 20° to the vertical. The bar has a length of 1.2 m and a weight of 36 N. The centre of gravity of the bar is 0.45 m from A.

(i) Show that the magnitude of the tension *T* in the string is 8.8 N.

[2]

(ii) A force *F* acts on the bar at A.

Calculate the magnitude of *F*.

F = ... N [3]

2 As part of a physics lesson demonstration, a student stands between a sound speaker and a wall, such that he is 1.10 m from the speaker and 0.30 m from the wall as shown in Fig. 2.1. The speaker emits a sound wave of a single wavelength of 0.40 m. The sound wave hits the wall perpendicularly and is reflected back.

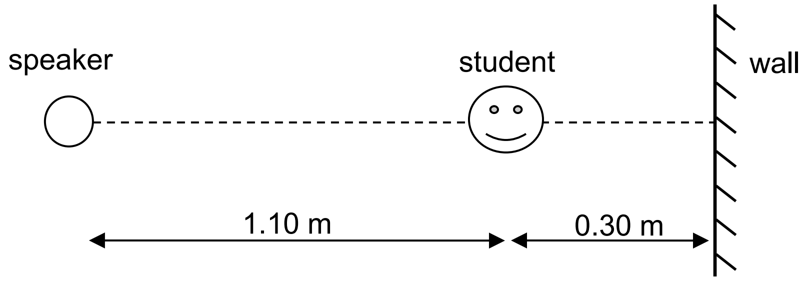

Fig. 2.1

The reflection at the wall causes the wave to undergo a phase change of π rad.

(a) Calculate the phase difference between the waves that come directly from the speaker and the one that is reflected back from the wall, when they meet at the student's location. Leave your answer in multiples of π.

phase difference = ... rad [3]

(b) The sound wave is emitted uniformly in all directions by the speaker. When the wave reaches the student directly from the speaker, it has an amplitude of 1.2×10^{-8} m.

(i) Calculate the amplitude of the wave that reaches the student after reflection from the wall. State an assumption made in your calculation.

amplitude = ... m [2]

Assumption: ....

.... [1]

(ii) Hence calculate the amplitude of the resultant wave experienced by the student.

amplitude = ... m [1]

(c) The intensity of the sound wave that reaches the student directly from the speaker is 1.0×10^{-6} W m^{-2}.

Calculate the intensity of the resultant wave that reaches him.

intensity = ... W m^{-2} [2]

3 Fig. 3.1 shows lines joining points at the same potential in and around a pair of parallel, charged metal plates. The plates have a separation of 2.5 cm.

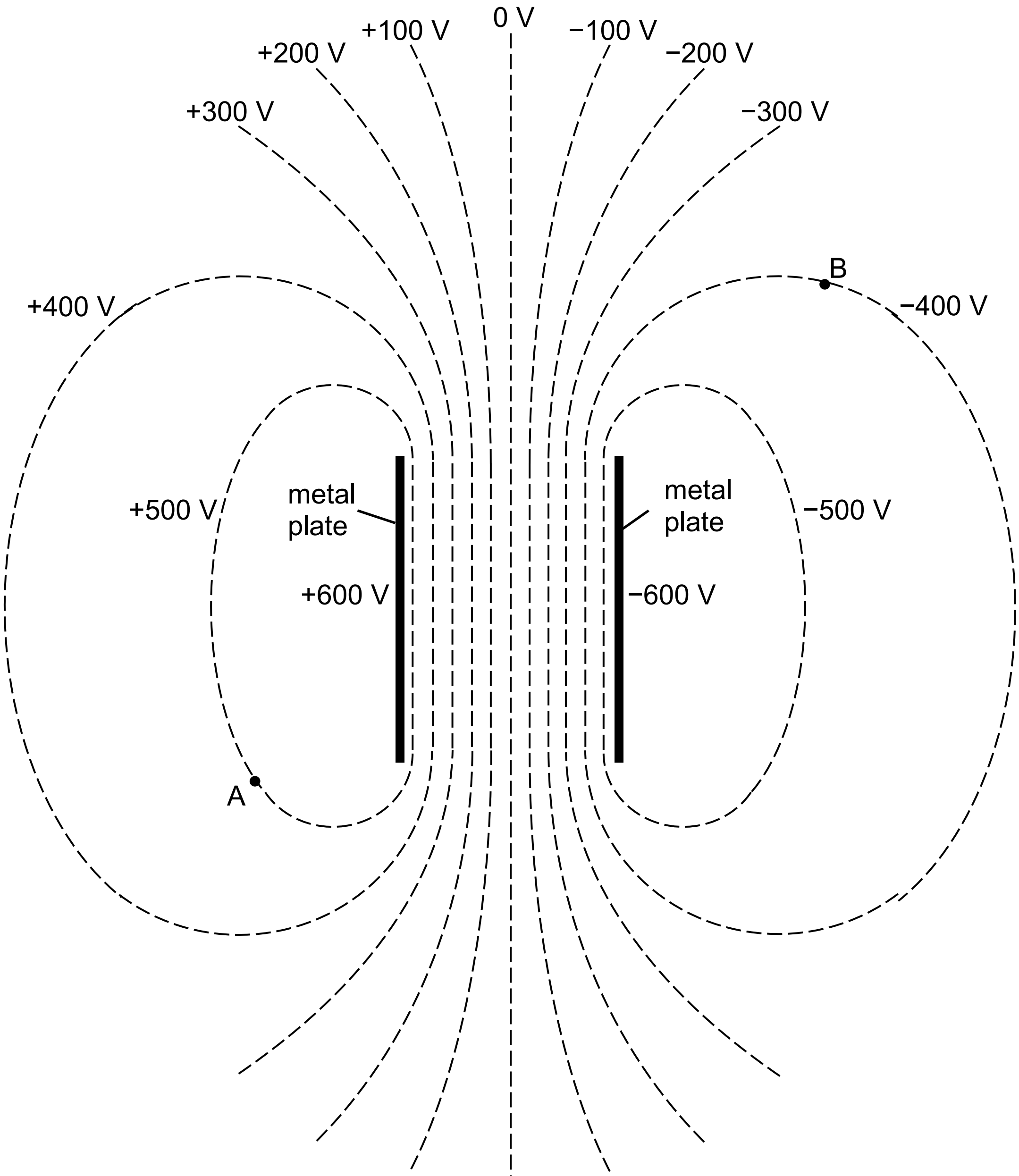

Fig. 3.1

(a) (i) State the relation between electric field strength E and potential V.

....

.... [1]

(ii) By reference to Fig. 3.1, suggest why the electric field between the plates is uniform.

....

.... [1]

(iii) Determine the value of the electric field strength between the plates.

electric field strength = ... $N C^{-1}$ [2]

(b) On Fig. 3.1, draw six lines to represent the electric field between the plates. [2]

(c) A particle moves from point A to point B. As a result, there is a loss in potential but the particle gains electric potential energy of 1.44×10^{-16} J.

(i) Calculate the charge of the particle.

charge = ... C [2]

(ii) Suggest a particle that might have this value of charge.

.... [1]

(iii) Hence, calculate the speed of the particle at B, given that its initial speed at A is 3.5×10^{7} m s^{-1}.

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

4 **(a)** A resistor of resistance of 8.4 kΩ and a LDR (light dependent resistor) are connected in series, as shown in Fig. 4.1. The resistance of the LDR when light is shone on it is 400 Ω.

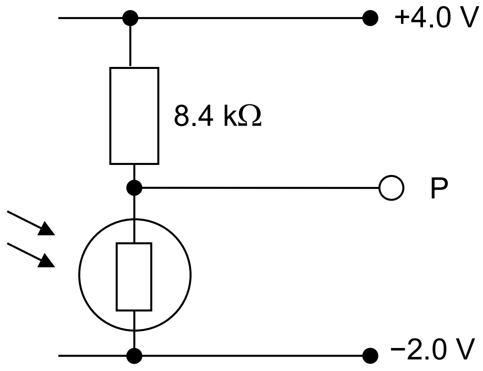

Fig. 4.1

(i) Calculate the potential at point P when light is shone on the LDR.

potential = ……………..………… V [2]

(ii) An alarm is now connected in parallel with the LDR in Fig. 4.1 and a laser beam is directed continuously at the LDR in a simple burglar alarm system. When a burglar blocks the laser that is shining on the LDR, the alarm is triggered. Assume that the resistance of the alarm is very large.

Explain how the LDR is used to trigger the alarm in such a system.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(b) A circuit is set up as shown in Fig. 4.2. The potentiometer wire XY has a resistance of 1.6 Ω and is 1.00 m long. The movable contact J can be connected to any point along wire XY.

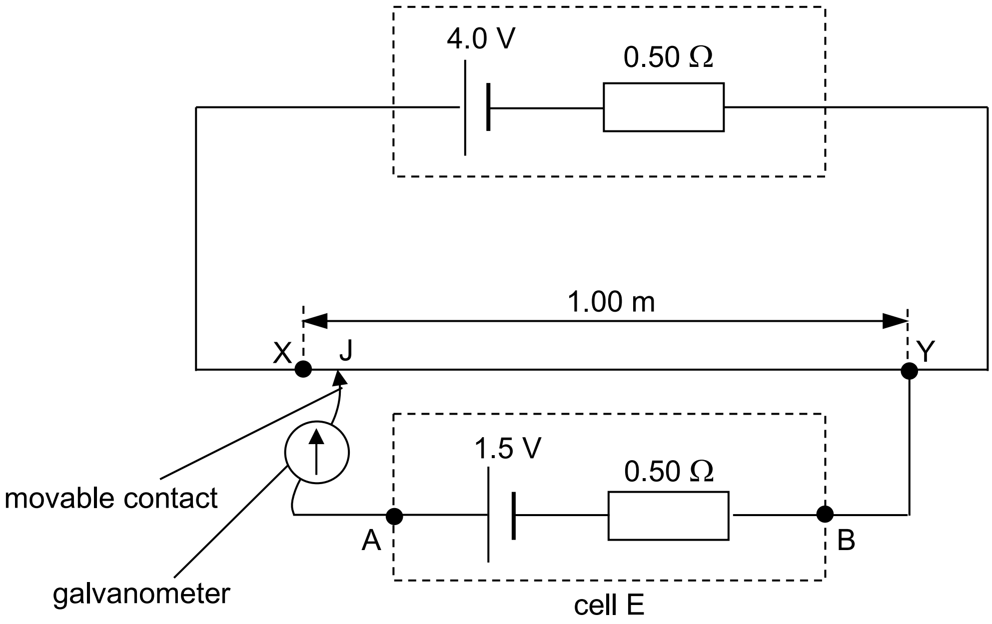

Fig. 4.2

(i) Determine the distance of the contact J from Y, such that there is no deflection in the galvanometer.

distance = ……………..………… m [2]

(ii) A 1.5 Ω resistor is then connected across points A and B.

Determine the distance of the contact J from Y, such that there is no deflection in the galvanometer.

distance = …………….…………. m [3]

5 Fig. 5.1 shows an electron passing an earthed vertical plate P_1 with negligible speed and accelerates horizontally towards vertical plate P_2 which is at a potential 200 V.

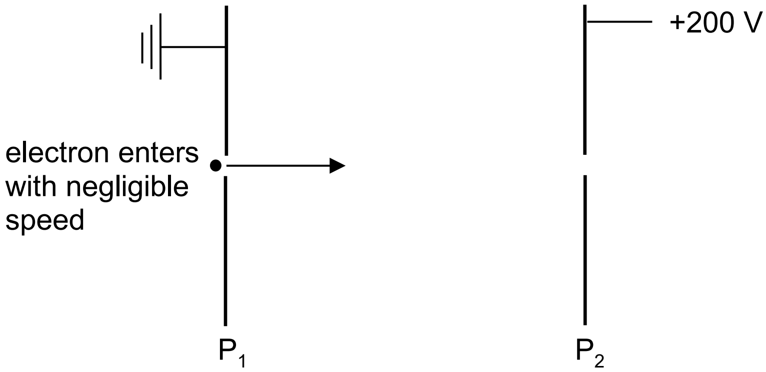

Fig. 5.1

(a) Show that the speed of the electron when it reaches plate P_2 is 8.38×10^6 m s^{-1}.

[2]

(b) After emerging from plate P_2, the electron enters a region of uniform magnetic field of flux density B, directed into the plane of the paper as shown in Fig. 5.2.

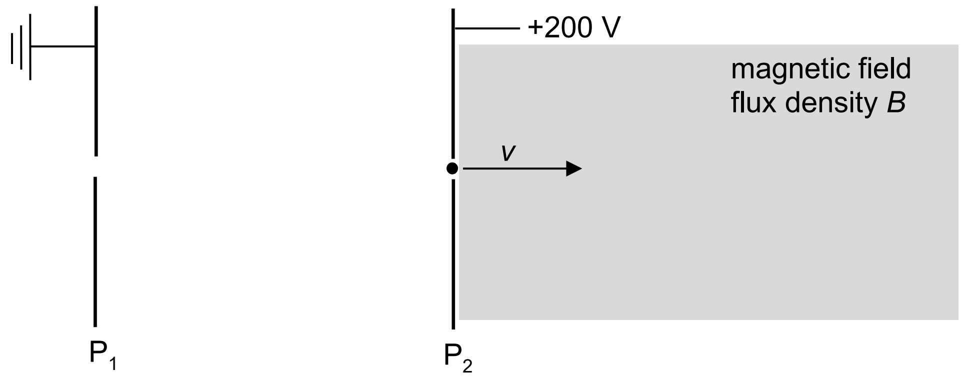

Fig. 5.2

(i) On Fig. 5.2, draw a solid line to represent a possible path of the electron. [1]

(ii) The electron moves in a path with a radius of curvature of 2.8 cm.

Calculate the magnitude of the magnetic flux density B.

B = ... T [2]

(c) The direction of the magnetic field is now changed such that it is at an angle of 30° below the horizontal, as shown in Fig. 5.3.

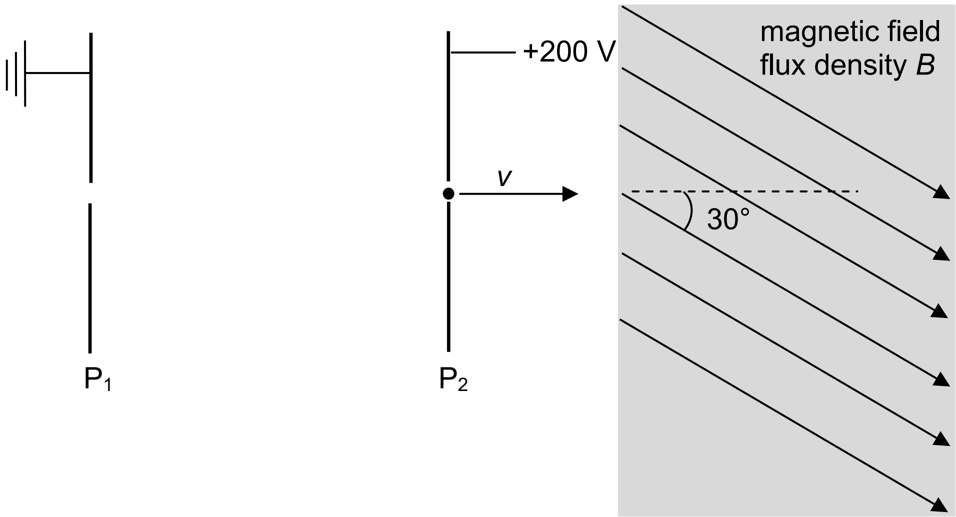

Fig. 5.3

(i) By considering the components of the velocity parallel to the magnetic field and at right-angle to the magnetic field, describe and explain qualitatively the motion of the electron in the field.

....

....

....

....

....

.... [3]

(ii) Calculate the radius of curvature of this new path.

radius = ... m [2]

6 **(a)** Fig. 6.1 shows the energy levels of sodium gas.

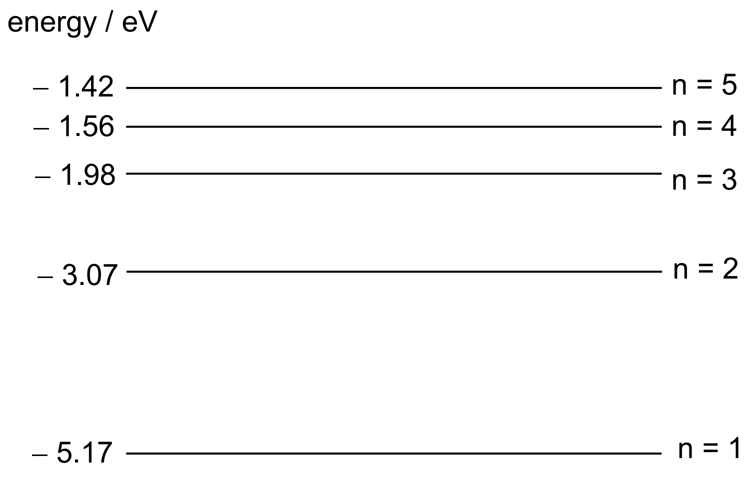

Fig. 6.1

The cool sodium gas at low pressure is bombarded by incoming electrons with kinetic energy of 3.70 eV.

(i) On Fig. 6.1, draw arrows to show all the possible de-excitation transitions that will be observed if all the sodium atoms are at ground state initially. [2]

(ii) Fig. 6.2 shows the emission line due to the transition from n = 2 to n = 1.

On Fig. 6.2, sketch the positions of all the other possible emission lines observed.

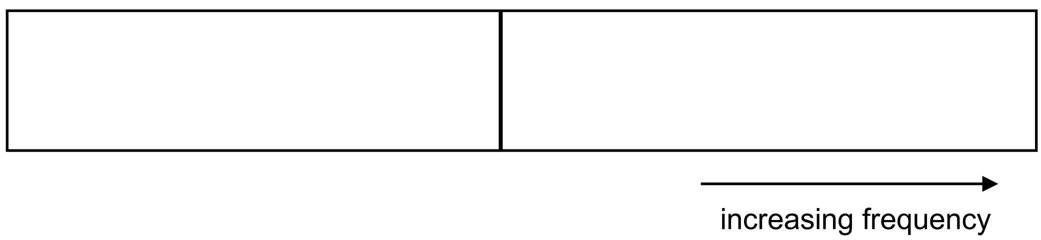

Fig. 6.2

[2]

(iii) The cool sodium gas is now bombarded by incoming photons of energy of 3.70 eV instead.

State and explain the number of emission lines observed, if any.

....

.... [1]

(b) Fig. 6.3 shows the variation against wavelength of the relative intensity of emitted X-rays radiation from an X-ray tube. In the evacuated X-ray tube, electrons emitted at the cathode are accelerated from rest using an accelerating voltage to hit a target made of a metal at the anode and produce X-rays as a result.

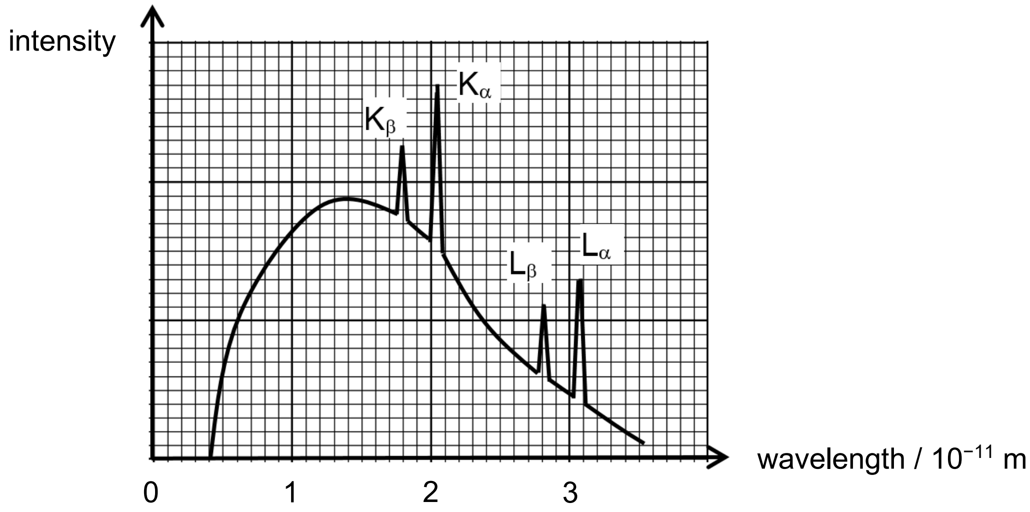

Fig. 6.3

(i) Explain why the X-ray tube is evacuated.

....

.... [1]

(ii) Explain what is meant by a *photon*.

....

.... [1]

(iii) Determine the maximum energy of the X-ray photons emitted.

energy = ... J [2]

(iv) Hence, show that the accelerating voltage required to accelerate the electrons in the tube is 310 kV.

[1]

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

Modern aircrafts operated by airlines use jet engines. A jet engine is a type of reaction engine, drawing in air and discharging a fast-moving jet of heated exhaust gas (air mixed with jet fuel) that generates thrust by jet propulsion.

Fig. 7.1 shows an engine designed for modern passenger aircraft that draws in a maximum mass of air of 1300 kg per second. The diameter of the engine intake fan is 3.0 m. The air drawn into the engine is compressed, or "squeezed", and then in the combustion chamber, it is heated to a very high temperature. Finally, the engine blows the heated exhaust gas back out of its nozzle producing thrust.

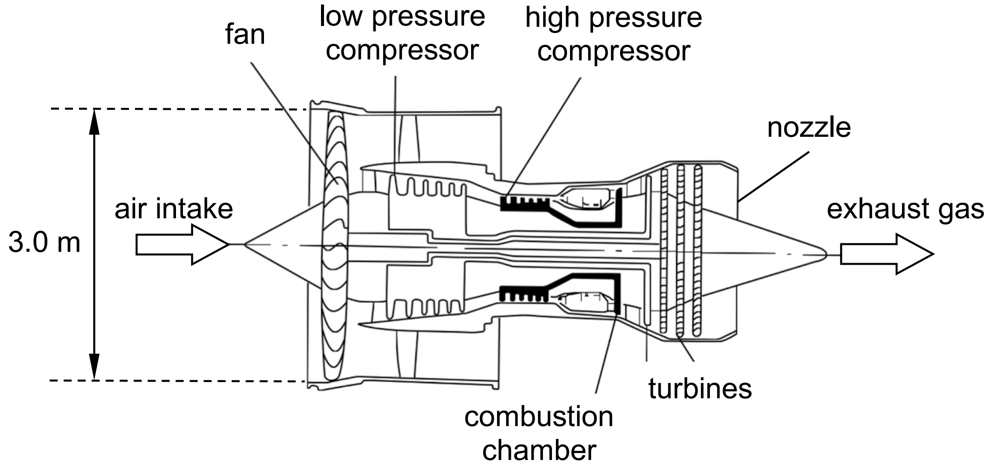

Fig. 7.1

The thrust F produced by such an engine is given by the expression

$$F = \left(m_{\text{air}} + m_{\text{fuel}}\right)v_{\text{exhaust}} - m_{\text{air}}v_{\text{in}}$$

where m_{air} is the mass of air intake per second, m_{fuel} is the mass of fuel consumed per second, v_{in} is the velocity of air intake, and v_{exhaust} is the velocity of exhaust gas.

Table 7.1 show data for the engine operating during take-off.

Table 7.1

m_{air}	1300 kg s^{-1}
m_{fuel}	17 kg s^{-1}
v_{exhaust}	410 m s^{-1}

A modern passenger aircraft is fitted with two such engines. When operating at maximum thrust, the aircraft with the maximum take-off weight (MTOW) of 2.75×10^6 N is accelerated from rest to an airspeed that provides sufficient lift to be airborne in 45 s.

At take off, the aircraft performs a rotation to point its nose upwards for take off as shown in Fig. 7.2. This is accomplished with the aid of its rear horizontal stabilisers as shown in Fig. 7.3.

Fig. 7.2

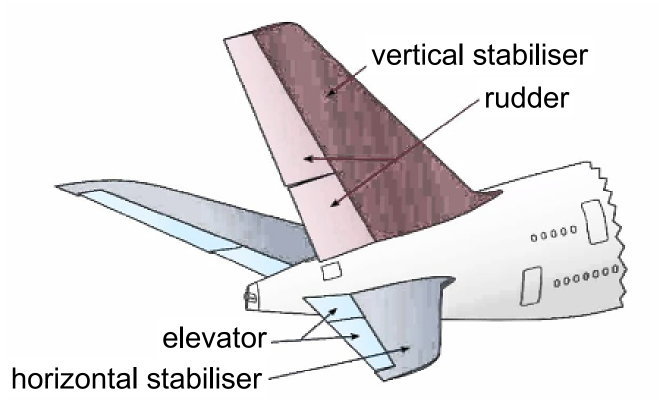

Fig. 7.3

The energy density of jet fuel is 42 MJ kg^{-1}.

Aviation accounts for about 2.5% of global carbon dioxide emissions, so transitioning the sector away from its dependence on fossil fuels to clean electric power is seen as a priority. While battery-powered electric aircraft is far from being able to replace the large passenger aircraft used on long-haul routes, they may be able to take on city-to-city hops of several hundred kilometres.

The electrical energy onboard aircrafts is stored in lithium-ion batteries. When fully charged, the battery has a specific energy of 0.260 kW h kg^{-1}.

(a) **(i)** The density of air is 1.2 kg m^{-3}.

Show that the velocity of air intake of the engine is 150 m s^{-1}.

[2]

(ii) Calculate the maximum thrust F.

F = ... kN [2]

(iii) Determine the maximum acceleration of the aircraft.

maximum acceleration = ... m s^{-2} [2]

(b) A cross-section of the rear horizontal stabiliser on the aircraft during rotation for take off is shown in Fig. 7.4.

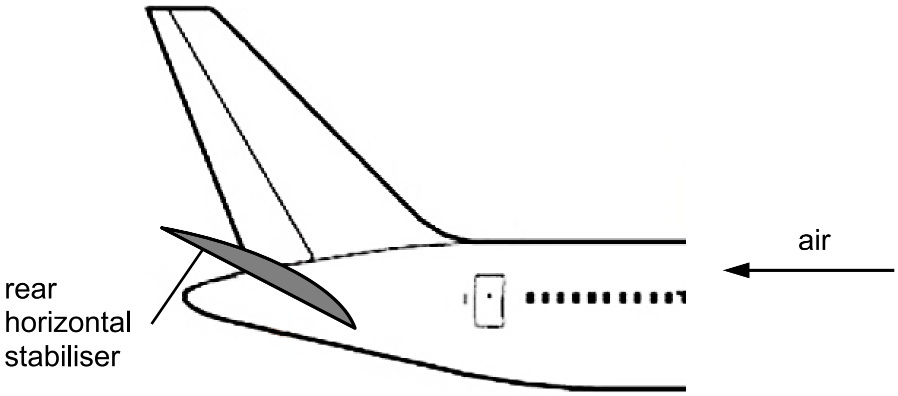

Fig. 7.4

The stabiliser deflects air when the aircraft is moving along the runway.

Explain, by reference to the change in momentum of the air, why this air flow causes the aircraft to rotate for take off.

....

....

....

....

....

.... [2]

(c) Some of the forces acting on the aircraft while accelerating from rest are shown in Fig. 7.5.

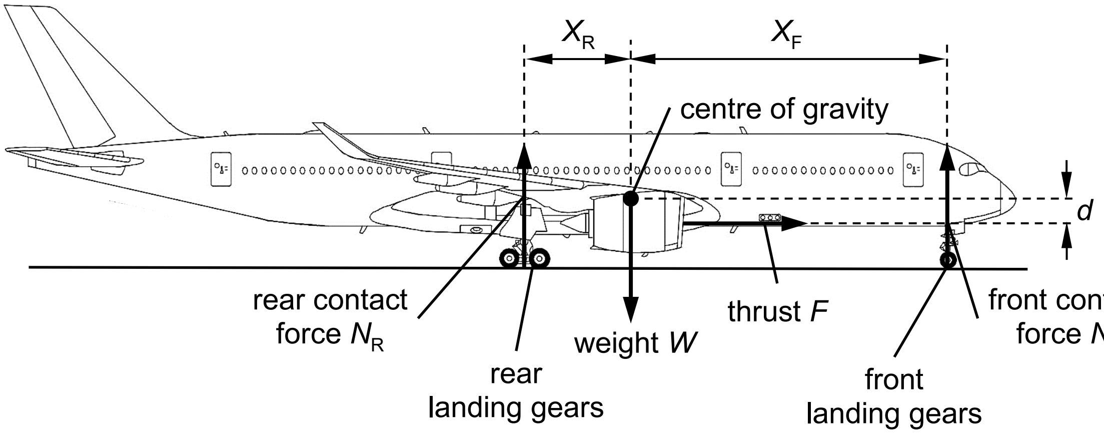

Fig. 7.5

N_F and N_R are the contact force acting on the rear and front landing gears respectively. W is the weight of the aircraft. F is the thrust acting on the aircraft by the exhaust gas.

The centre of gravity is a vertical distance d above the line of action of F. The centre of gravity is a horizontal distance X_R from the rear landing gears and a horizontal distance X_F from the front landing gears.

For the aircraft accelerating from rest:

(i) take moments about the centre of gravity, to show that

$$N_R = \frac{WX_F + Fd}{X_F + X_R}$$

[3]

(ii) determine a similar expression to that in **(c)(i)** for N_F.

[1]

(iii) Use your expressions in **(c)(i)** and **(c)(ii)** to show that there is weight transfer between the front and rear landing gears when the aircraft is accelerating from rest.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(d) A passenger aircraft consumes jet fuel at a rate of 5.5×10^3 kg h^{-1} when cruising. A flight from Singapore to Munich takes 12 hours.

(i) Calculate the total energy used during cruising flight of 12 hours.

total energy = ………………………….. J [2]

(ii) Suggest what is meant by a specific energy of 0.260 kW h kg^{-1}.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(iii) Determine the mass of the lithium battery needed to supply the total energy in **(d)(i)**.

mass = ………………………….. kg [2]

(e) (i) Use your answer in **(d)(iii)** to explain if the aircraft can be purely battery-powered for a flight from Singapore to Munich.

……………………………………………………………………………………………

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

(ii) Suggest two advantages that the jet engine aircraft has over the battery-powered electric aircraft.

1. ………………………………………………………………………………………….

…..…………………………………………………………………………………………

2. ………………………………………………………………………………………….

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

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