CANDIDATE NAME	

CIVICS GROUP	2	1	-			REGISTRATION NUMBER	

PHYSICS

9749/02

Paper 2 Structured Questions

August/September 2022

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and registration number on all the work you hand in.
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 Examiner's Use	
1	**7**
2	**5**
3	**8**
4	**9**
5	**10**
6	**8**
7	**8**
8	**25**
s.f.	
Total	**80**

This document consists of **24** printed pages and **no** 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.	$v = v_0 \cos \omega t$ $= \pm \omega \sqrt{\left(x_0^2 - x^2\right)}$
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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

1 A uniform metal rod AB of mass 1.2 kg and length 0.40 m is pivoted at end A. End B is suspended by a light spring as shown in Fig. 1.1. The other end of the spring is supported at X.

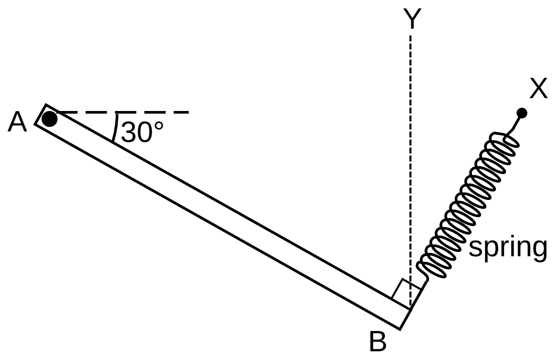

Fig. 1.1

When the rod is in equilibrium, it makes an angle of 30° below the horizontal and lies stationary with the axis of the spring perpendicular to the rod.

(a) On Fig. 1.2, draw a labelled diagram showing the forces acting on the rod.

Label the forces clearly.

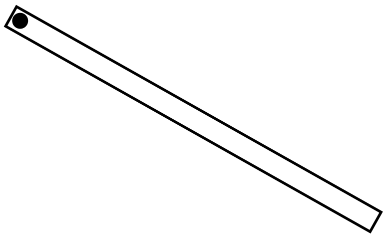

Fig. 1.2 [1]

(b) Calculate the tension in the spring.

tension = ………………………………. N [2]

(c) Determine the magnitude of the reaction force at pivot A.

force = ………………………………. N [3]

(d) The spring in Fig. 1.1 is now replaced with a spring of larger spring constant and of same natural length.

State the change in angle, if any, between the rod and the spring.

....

.... [1]

[Total: 7]

2 A rubber ball of mass 0.30 kg is positioned directly above a basketball of mass 0.50 kg as shown in Fig. 2.1

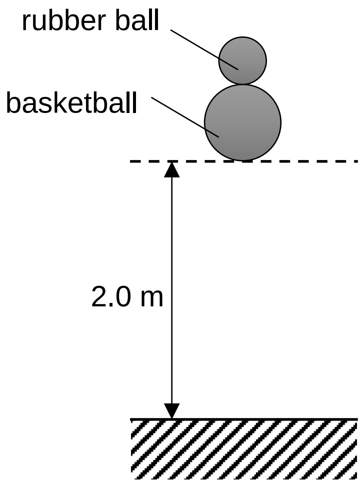

Fig. 2.1

The balls are released from a height of 2.0 m from the ground. Assume air resistance is negligible.

(a) (i) State the *principle of conservation of momentum*.

....

....

....

....

.... [1]

(ii) Explain why the principle of conservation of momentum is not applicable to the system of stacked balls.

....

....

....

....

.... [1]

(b) Determine the speed of the stacked balls just before they hit the ground.

speed = ……………………………… m s^{-1} [1]

(c) The collision between the balls and ground is elastic. At the instant the basketball loses contact with the rubber ball, it moves with a speed of 3.2 m s^{-1}. The rubber ball is observed to move off at a higher speed than the basketball.

Using energy considerations, calculate the speed of the rubber ball as it loses contact with the basketball.

speed = ……………………………… m s^{-1} [2]

[Total: 5]

3 Fig. 3.1 shows two positive point charges q_1 and q_2 affixed to positions X and Y respectively, on a circular nylon frame centred at point O. The circular frame has a radius *r.*

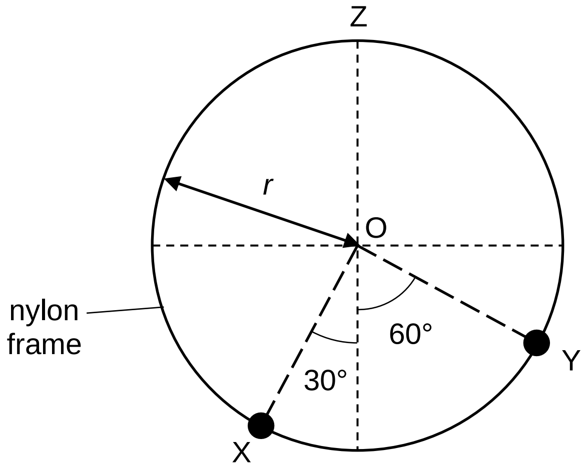

Fig. 3.1

At point O, the direction of the net electric field strength is directed upwards along OZ.

(a) (i) Show that the ratio $\frac{q_1}{q_2}$ is 1.7.

[1]

(ii) Hence, sketch in Fig. 3.2 the variation of electric field strength with distance along the straight line XY.

Fig. 3.2

[2]

(b) Given that $r = 0.50$ m and $q_2 = 200$ nC, determine the

(i) magnitude of electric field strength at O,

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

(ii) total electric potential at O,

electric potential = ……………………………… V [1]

(iii) the work done in moving an additional third charge $q_3 = -2q_2$ from infinity to point O.

work done = ………………………………eV [2]

[Total: 8]

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

....

....

.... [1]

(b) A charged particle is initially located at point P on the plane of the page and is moving to the right with speed *v*.

The charged particle moves within the vicinity of a non-uniform magnetic field that is generated by a long, straight wire carrying current I to the right. The wire is located on the same plane of page as the initial position of the charged particle.

As a result, the particle travels along a curved path of non-uniform radius.

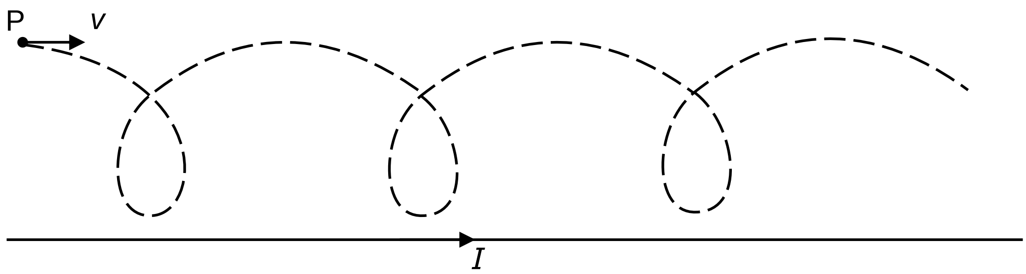

Fig. 4.1

(i) **1.** On Fig. 4.1, sketch a representation of the magnetic field lines on the plane of paper generated by the long straight wire. [2]

2. State the sign of the charged particle.

.... [1]

(ii) Explain, using energy considerations, why the speed of the charged particle remains constant throughout the motion.

....

....

.... [2]

(iii) State an assumption made for the speed of the charged particle to remain constant.

....

.... [1]

(c) Two long parallel wires X and Y are separated by a distance of 5.0 cm and carry currents 7.0 A and 8.0 A respectively. Both the currents are directed out of the plane of paper.

Point Z is located 3.0 cm from wire X and 4.0 cm from wire Y as shown in Fig. 4.2.

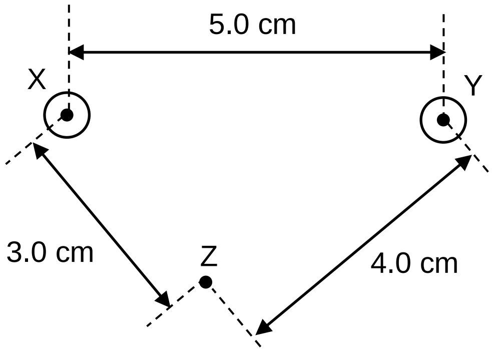

Fig. 4.2 (not to scale)

Determine the magnitude of magnetic flux density at point Z due to wires X and Y.

magnitude of magnetic flux density = ... T [2]

[Total: 9]

5 Two resistors of resistance 1.2 kΩ and 1.6 kΩ, and a thermistor are connected to an ideal cell of electromotive force of 9.0 V.

An ideal voltmeter is placed between points A and B of the circuit, as shown in Fig. 5.1.

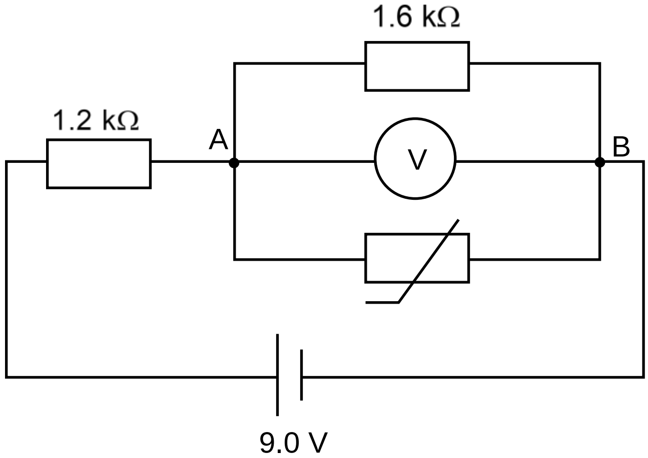

Fig. 5.1

The variation with temperature of the resistance R_T of the thermistor is shown in Fig. 5.2.

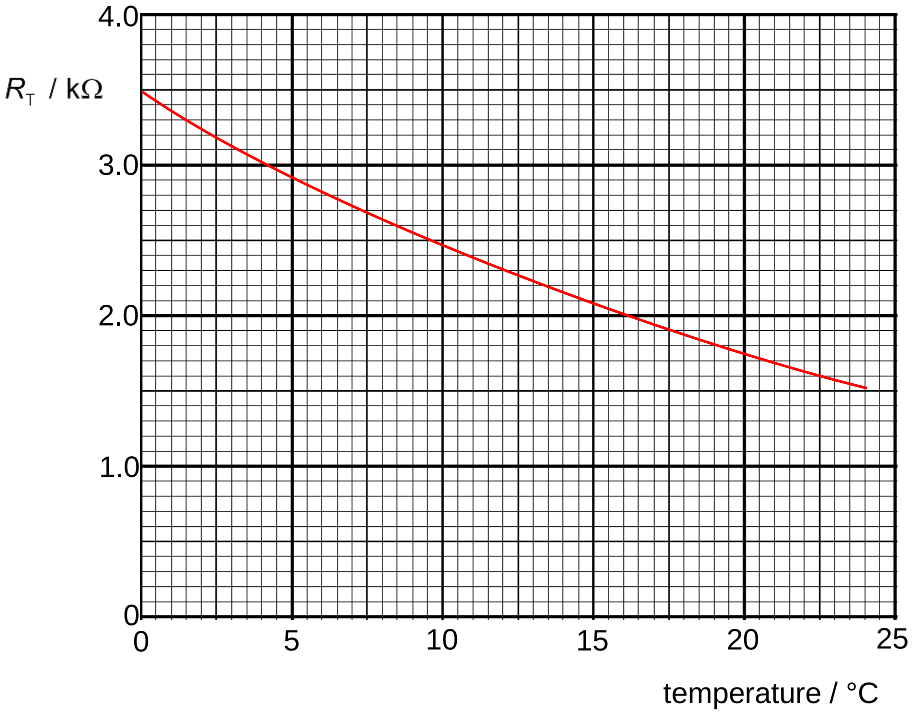

Fig. 5.2

(a) The thermistor has a current temperature of 22.5 °C. Determine the

(i) total resistance between points A and B,

resistance = ……………………………… Ω [2]

(ii) reading on the voltmeter,

voltmeter reading = ……………………………… V [2]

(b) The temperature of the thermistor is now changed. The new voltmeter reading is now 4.0 V.

Find the

(i) total resistance between points A and B,

resistance = ……………………………… Ω [2]

(ii) temperature of the thermistor.

temperature = ……………………………… °C [2]

(c) A student suggests that the voltmeter, reading up to 10 V, could be calibrated to measure temperature.

Suggest two disadvantages of using the circuit of Fig. 5.1 with this voltmeter for the measurement of temperature in the range 0 °C to 25 °C.

1. ....

....

2. ....

.... [2]

[Total: 10]

6 **(a)** **(i)** Explain what is meant by a *progressive transverse* wave.

progressive ....

....

transverse ....

....

.... [2]

(ii) Explain whether a longitudinal wave can be polarised.

....

....

....

....

....

.... [2]

(b) A microwave emitter produces polarised microwaves that passes through a microwave polariser before reaching a microwave detector. The emitter, receiver and polariser are initially aligned along the horizontal axis as shown in Fig. 6.1.

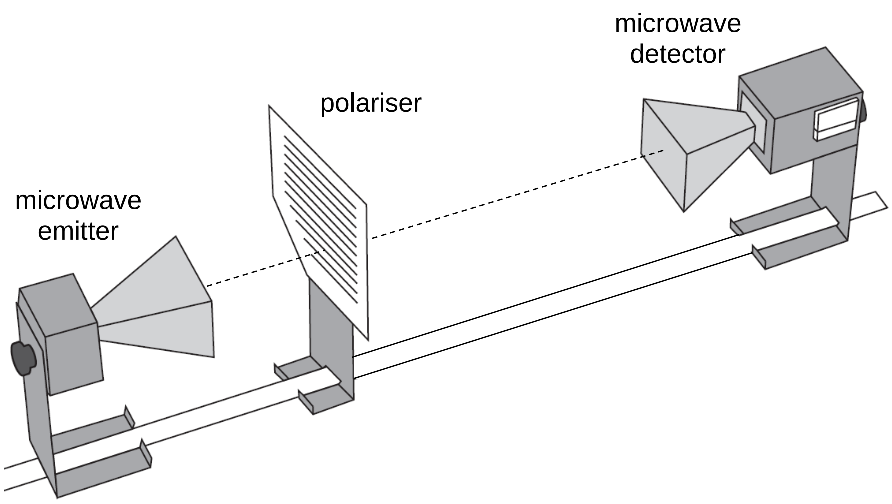

Fig. 6.1

Fig. 6.2 shows the variation with time of the electric field strength of the detected signal.

Graph A shows the variation obtained with the initial set up as per Fig. 6.1, which results in the maximum possible field strength that can be received via the set up.

Graph B shows the variation of the field strength after the polariser has been rotated about the horizontal axis by an angle θ.

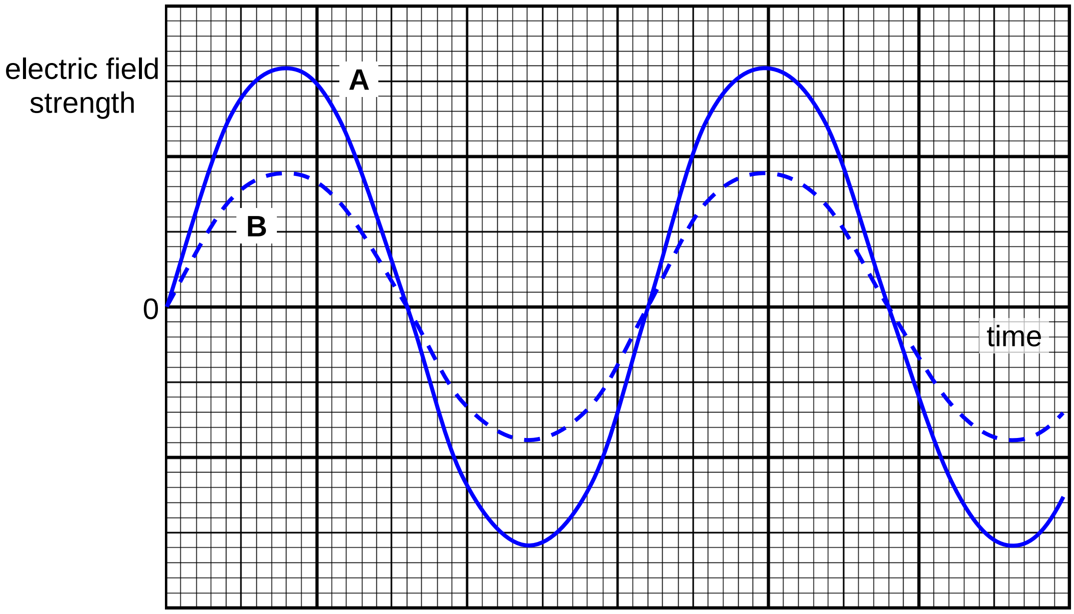

Fig. 6.2

(i) Use Fig. 6.2 to determine θ.

θ = ... ° [2]

(ii) Determine the ratio

$$\frac{\text{intensity of signal after rotation by } \theta}{\text{intensity of signal at maximum field strength}}$$

ratio = ... [2]

[Total: 8]

7 Electrons are often used in diffraction experiments to study the regularly repeating atomic structure in crystals. In such experiments, an electron gun is used to direct a beam of electrons towards a thin slice of crystal. The scattered electrons form scintillations when they impinge on a phosphor-coated screen.

(a) In one experiment, electrons are accelerated from rest through a potential difference of 45 V.

(i) Show that the electrons reach a speed of 4.0×10^{6} m s^{-1}.

[1]

(ii) Determine the wavelength associated with the moving electron.

wavelength = ……………………………… m [2]

(b) Fig. 7.1 below shows a hypothetical one-dimensional crystal consisting of a single row of atoms with regular spacing of $d = 2.0 \times 10^{-10}$ m.

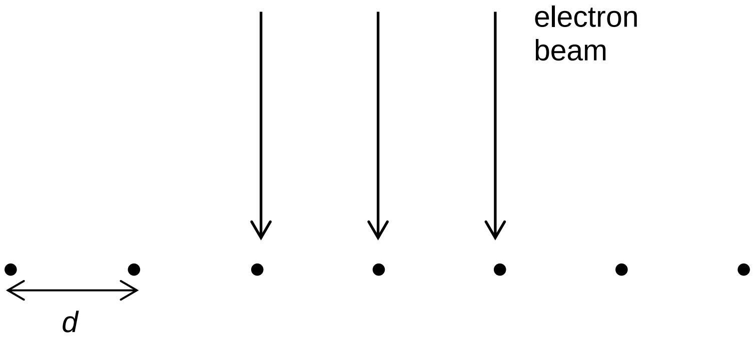

Fig. 7.1

(i) Explain why the electrons scattered by the crystal form a line of bright spots on the screen.

....

....

....

....

....

....

....

....

.... [3]

(ii) Explain how the spacing between the bright spots will vary as the accelerating potential of the electron gun increases.

....

....

....

.... [2]

[Total: 8]

8 SpinLaunch is a California-based company established in 2014 with the goal of building an alternative method of lauching spacecraft into Low Earth Orbit (LEO). Instead of burning through massive amounts of rocket fuel at lift-off to gain altitude, the company is developing a launch system which uses kinetic energy as its primary method. The advantages include reducing the costs of launching satellites and having an environmental impact that is smaller than traditional rockets, as it avoids fossil fuels as well as the exhaust gases emitted as a result of fuel combustion. In addition, since the projectile doesn't have to carry much fuel, more of the mass can be dedicated to the transport of payloads such as satellites.

Scaled Down Prototype

The most recent accelerator prototype from the company is located in New Mexico, United States of America and is a one-third scale of the eventual accelerator. Designated as the A-33, the prototype accelerator cost USD $38 million and has a height of 50.4 m, as shown in Fig. 8.1.

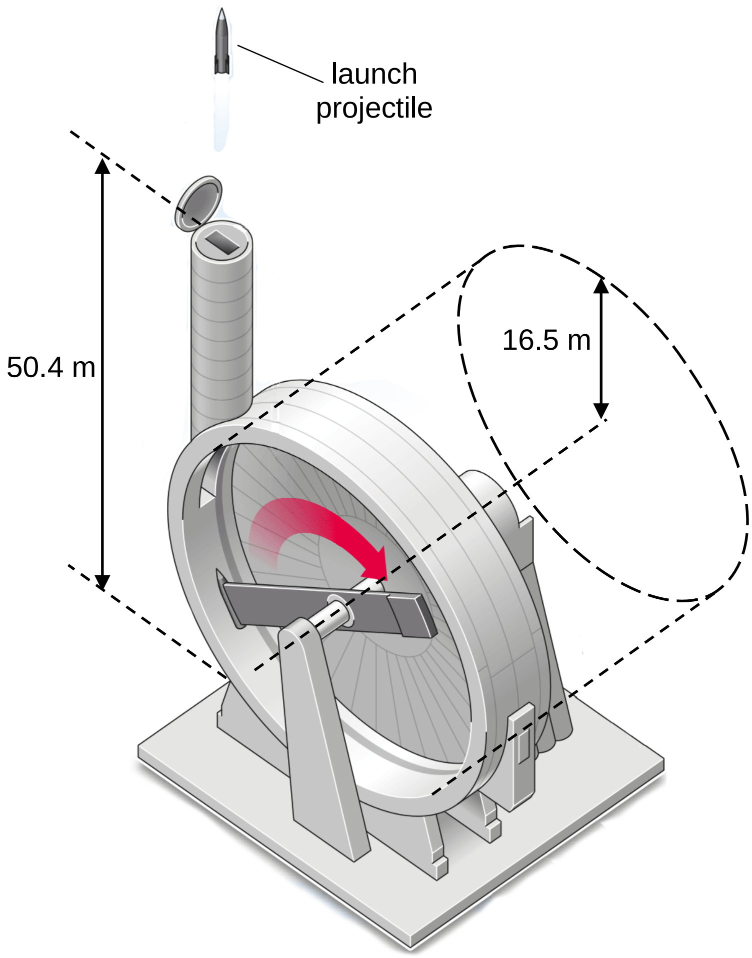

Fig. 8.1

For the latest test launch held in April 2022, the accelerator launched a 50.4 kg projectile at a maximum speed of 536 m s^{-1}, and reached a maximum height of 9300 m. The prototype accelerator required an hour to evacuate air out of the vertically-oriented centrifuge chamber, and then took an additional hour to gradually increase the rotational speed of the arm before releasing the launch projectile at an angle of 86.7° from the horizontal.

(a) Assuming that air resistance on the launch projectile is negligible,

(i) show that the magnitude of the vertical component of the initial velocity is 535 m s^{-1},

[1]

(ii) determine the time taken for the launch projectile to reach the ground,

time taken = ………………………………… s [2]

(iii) find the maximum height attainable by the launch projectile with respect to the ground.

maximum height = ………………………………… m [2]

(b) **(i)** Find the ratio of $\dfrac{\text{maximum gravitational potential energy attained in real life}}{\text{maximum gravitational potential energy in absence of air resistance}}$.

ratio = ………………………………… [1]

(ii) Suggest if the ratio in **(b)(i)** is larger or smaller for a traditional fuel-combustion rocket.

....

....

....

.... [2]

Full Scale Design

SpinLaunch's design for the eventual full-scale accelerator will involve a Kevlar-carbon-fiber rotating arm within the circular vacuum chamber, as shown in Fig. 8.2. The launch projectile is expected to have a mass of 200 kg and will be flung above the stratosphere. Thereafter, a rocket will fire to provide the final velocity boost necessary for positioning into LEO. At those altitudes, there is hardly any atmosphere and therefore there is minimal drag on the launch projectile. Hence, a couple of minutes of fuel combustion will be sufficient to boost the launch projectile's speed to sufficiently high orbital speeds.

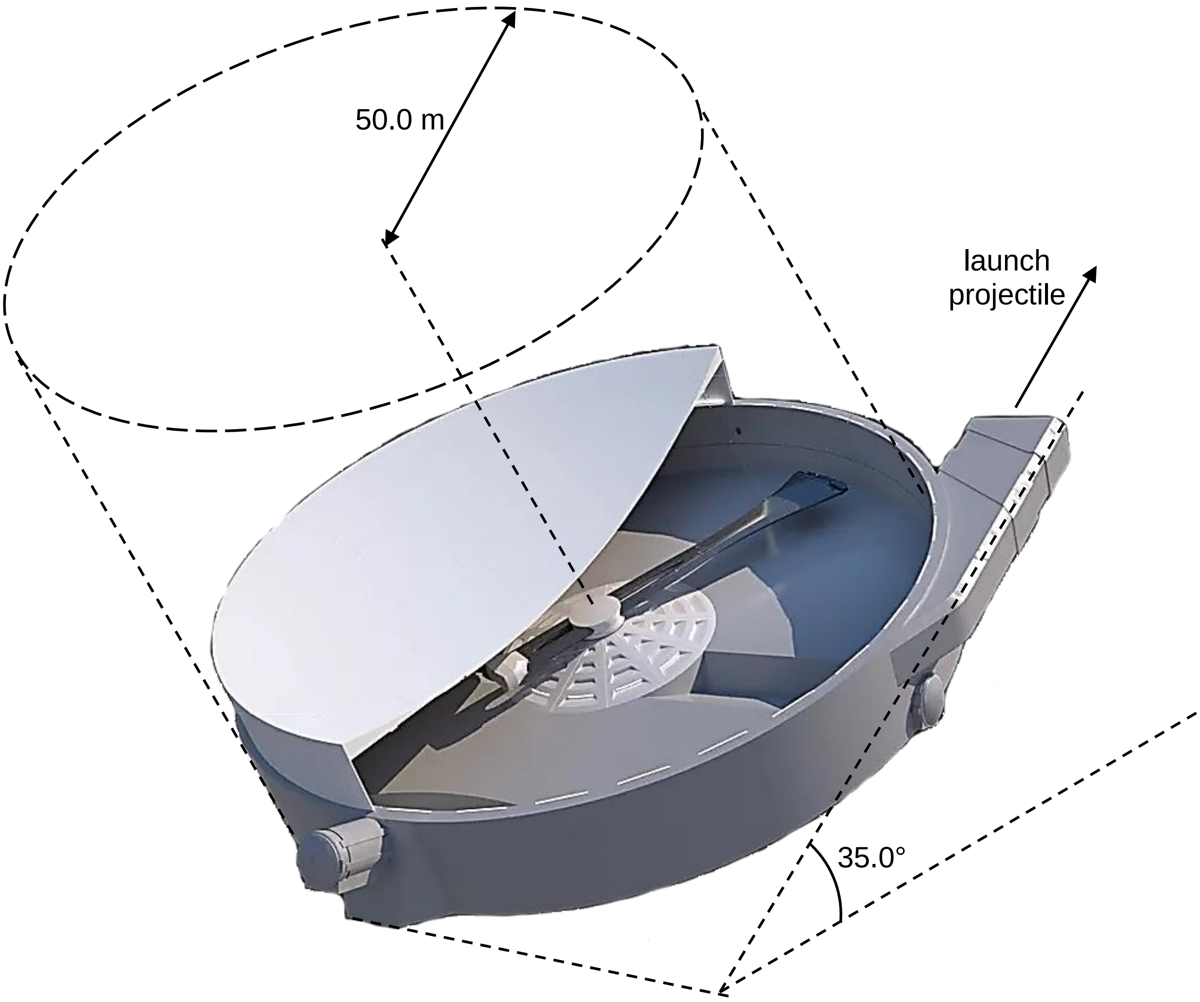

Fig. 8.2

The full-scale accelerator will feature a vacuum chamber that spins the launch projectile around a radius of 50.0 m. It will gradually ramp up the rotational speed to 450 revolutions per minute before launching the projectile at speed of 8000 km per hour, directed 35.0° above the horizontal.

Once the launch projectile reaches an altitude of 61 000 m, a traditional fuel-combustion rocket ignites in order to accelerate to the desired speed of 28 200 km per hour.

(c) **(i)** Determine the angular speed of Earth's rotation about its own axis.

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

(ii) To allow for a more efficient launch, the accelerator should be sited somewhere along the equator of the Earth.

State and explain the direction that the launch projectile be directed towards, in order to achieve further energy efficiency.

....

....

.... [2]

(d) **(i)** Show that the linear speed of the launch projectile in the full-scale design just before launch is 2360 m s^{-1}.

[1]

(ii) Find the ratio of $\dfrac{\text{kinetic energy of launch projectile at launch}}{\text{kinetic energy of launch projectile just before launch}}$.

ratio = ………………………………… [1]

(iii) Using energy considerations, explain why the interior of the accelerator has to be in vacuum.

....

.... [1]

(e) **(i)** The effective power supplied in spinning up the launch projectile is 100 kW.

Determine the amount of time (in minutes) required to spin the launch projectile up to launch speed from rest.

time = ………………………………… min [2]

(ii) Humans can briefly survive being subject to accelerations of up to 9 *g*'s.

Suggest if this method of launch is suitable for sending humans up to satellite bodies such as the International Space Station.

....

.... [2]

Low Earth Orbit (LEO)

Low Earth Orbit (LEO) is an orbit around Earth with a period of 128 minutes or less. This is a region of Earth's atmosphere that is below an altitude of 2,000 km, about one-third of Earth's radius. Fig. 8.3 shows the variation of gravitational potential ϕ with distance from Earth's surface. The Earth has a radius of 6400 km.

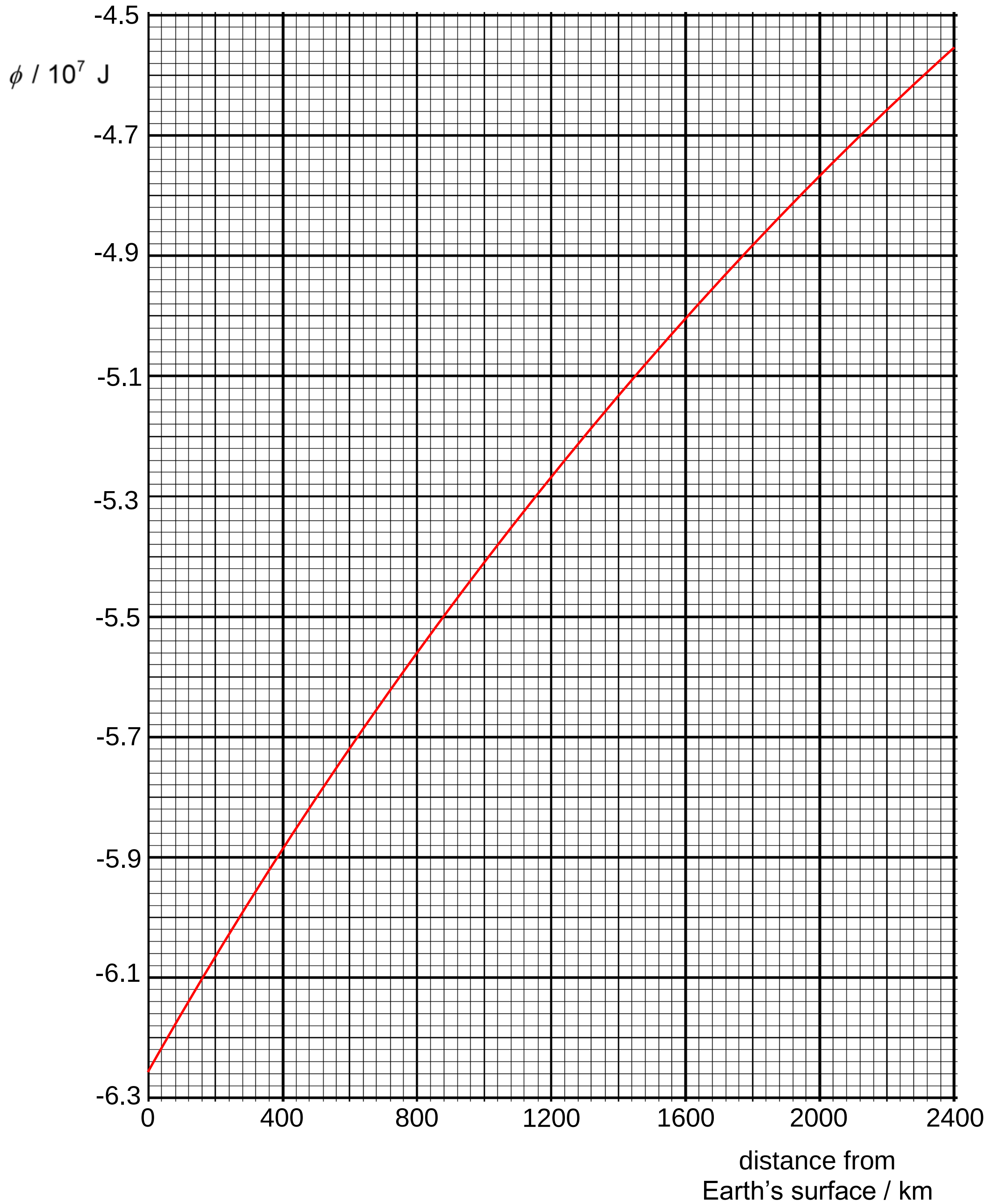

Fig. 8.3

(f) **(i)** State what is meant by *gravitational potential*.

....

....

.... [1]

(ii) Use Fig. 8.3 to determine the gravitational field strength *g* at an altitude of 2000 km.

Show your working clearly.

g = ………………………………… N kg^{-1} [2]

(iii) Your answer to part **(f)(ii)** is clearly non-zero.

Explain why astronauts onboard the International Space Station which orbit the Earth in a LEO, experience weightlessness despite being subject to Earth's gravitational field.

....

....

.... [2]

(iv) A launch projectile of mass 200 kg is launched via SpinLaunch and successfully docks with the International Space Station, which orbits the Earth at an altitude of 400 km.

Use Fig. 8.3 to find the work done against gravity in doing so.

work done = ………………………………… J [2]

[Total: 25]