Name: ______________________________ (   ) CT Group: 24S0 ________

RAFFLES INSTITUTION

2023 YEAR 5 PROMOTIONAL EXAMINATION

2 October 2023

H2 PHYSICS

Section B

INSTRUCTIONS TO CANDIDATES

Write your name, index number and CT Group.

Write your answers to Section B in the spaces provided on the question paper.

You are advised to write all your workings and answers clearly. Marks may be deducted for unclear workings.

For Examiner's Use		
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Deductions		
Total		/ 95

This document consists of **14** printed pages.

Section B (50 marks)

1 A ball is kicked with an initial velocity u at an angle of 32.0° from the ground towards a vertical wall. The ball hits the top of the wall after a time of 1.40 s. The path of the ball, assuming negligible air resistance, is shown in Fig. 1.1.

The horizontal distance between the initial position of the ball and the base of the wall is 20.0 m.

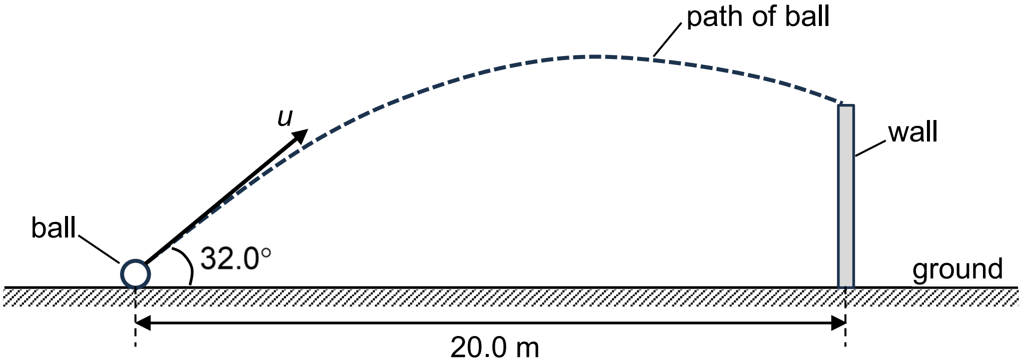

Fig. 1.1 (not to scale)

(a) Calculate the horizontal component of u.

horizontal component of u = ... m s^{-1} [1]

(b) Calculate the vertical component of u.

vertical component of u = ... m s^{-1} [1]

(c) Calculate the time for the ball to reach its maximum height above the ground.

time = ... s [2]

(d) **(i)** The ball is kicked at time $t = 0$ s.

On Fig. 1.2, sketch the variation with time t of the vertical component v_y of the velocity of the ball until it hits the wall at $t = 1.40$ s.

Include in your sketch, the values of the initial vertical velocity, the time at maximum height and the final vertical velocity of the ball when it hits the top of the wall.

Take direction upwards as positive.

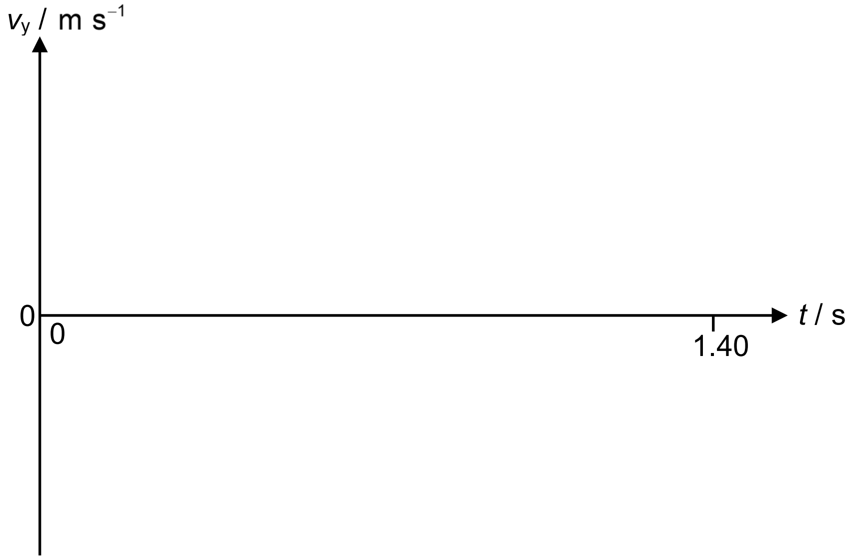

Fig. 1.2

[2]

(ii) Explain how the graph in Fig. 1.2 may be used to determine the height of the wall.

....

.... [1]

(e) In practice, air resistance is not negligible.

Describe qualitatively the effect, if any, of air resistance on the component of the velocity of the ball in

(i) the horizontal direction,

....

.... [1]

(ii) the vertical direction.

....

....

....

.... [2]

2 **(a)** A circular track is fixed horizontally on a smooth table. A spring, fixed at one end to a stand, is used to project a small ball along the frictionless track. Fig. 2.1. shows the top view of the setup.

The spring is compressed and the ball is placed next to it. When the spring is released, the ball goes round the track in a horizontal circle with uniform speed.

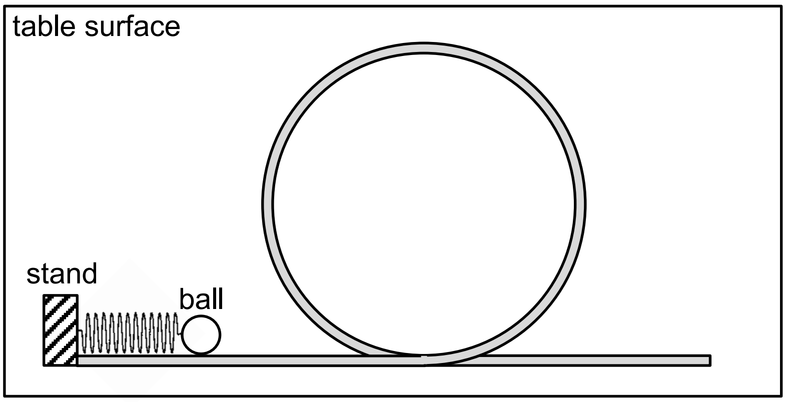

Fig. 2.1 (top view)

Explain how the kinetic energy of the ball can remain constant while a resultant force acts on the ball as it goes round the track.

....

....

....

.... [2]

(b) The circular track is now placed upright such that it forms a vertical circle of diameter 0.60 m. Point P is at the top of the track. Fig. 2.2 shows the front view of the setup.

The spring of force constant $80\ \text{N m}^{-1}$ is compressed again and the ball of mass 45 g is placed next to it. The spring is then released and the ball is projected horizontally onto the track.

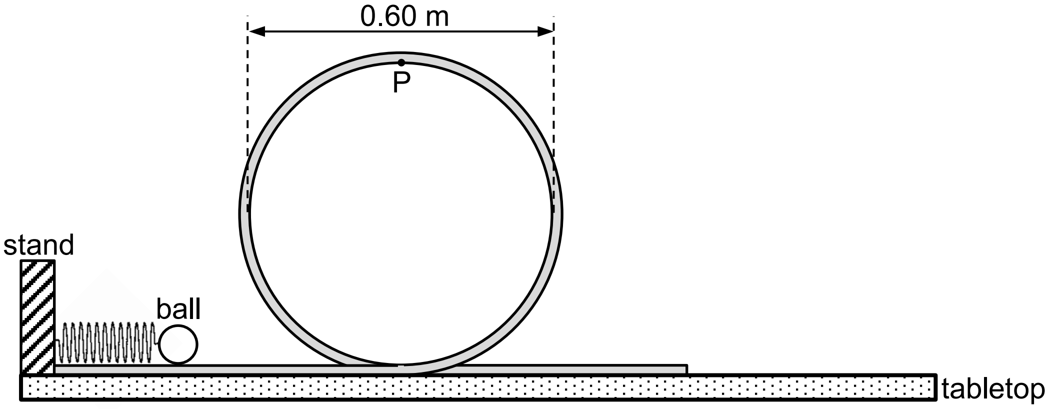

Fig. 2.2 (front view)

(i) **1.** Determine the minimum speed of the ball at point P such that it just completes the vertical circle without falling off the track.

Explain your working.

speed = ... m s^{-1} [3]

2. Calculate the initial compression of the spring for the ball to have the minimum speed at point P as determined in **(b)(i)1**.

compression = ... m [2]

(ii) If the ball is replaced with one of a greater mass, state and explain how this will affect your answers

1. in **(b)(i)1.**,

....

....

.... [1]

2. in **(b)(i)2**.

....

....

.... [1]

(iii) The initial compression of the spring is reduced and the ball leaves the track at point Q as shown in Fig. 2.3.

On Fig. 2.3, draw the path of the ball after it leaves the track at point Q.

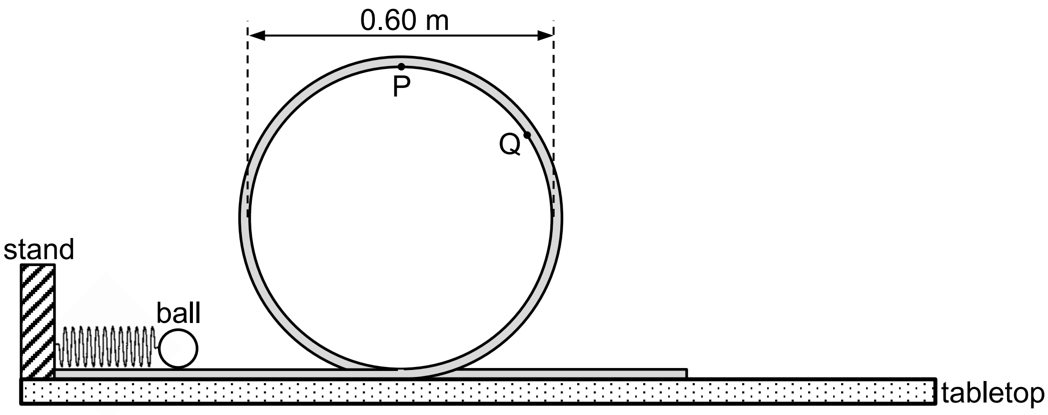

Fig. 2.3 (front view)

[1]

3 **(a)** A satellite of mass m orbits the Earth of mass M in a circular path as shown in Fig 3.1.

The Earth and the satellite may be considered to be point masses with their masses concentrated at their centres.

The satellite has speed v and the radius of its orbit about the Earth is r.

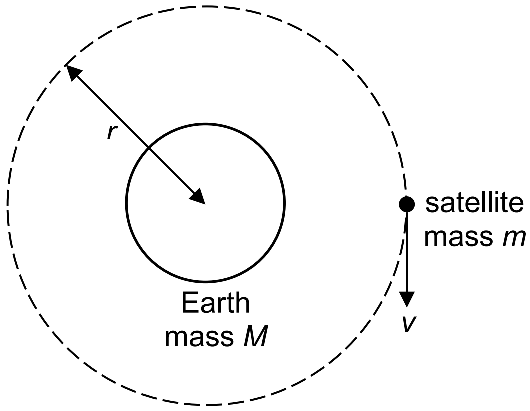

Fig. 3.1

(i) Show that the potential energy E_p and kinetic energy E_k of the satellite are related by the expression $E_p = -2E_k$. Explain your working.

[2]

(ii) The radius of the Earth is R_E. The kinetic energy of the satellite at $r = 4R_E$ is E.

On Fig. 3.2, sketch the variation with orbital radius r, from $r = R_E$ to $r = 4R_E$, of the satellite's

1. gravitational potential energy (label this graph E_p),

2. kinetic energy (label this graph E_k),

3. total energy (label this graph E_T).

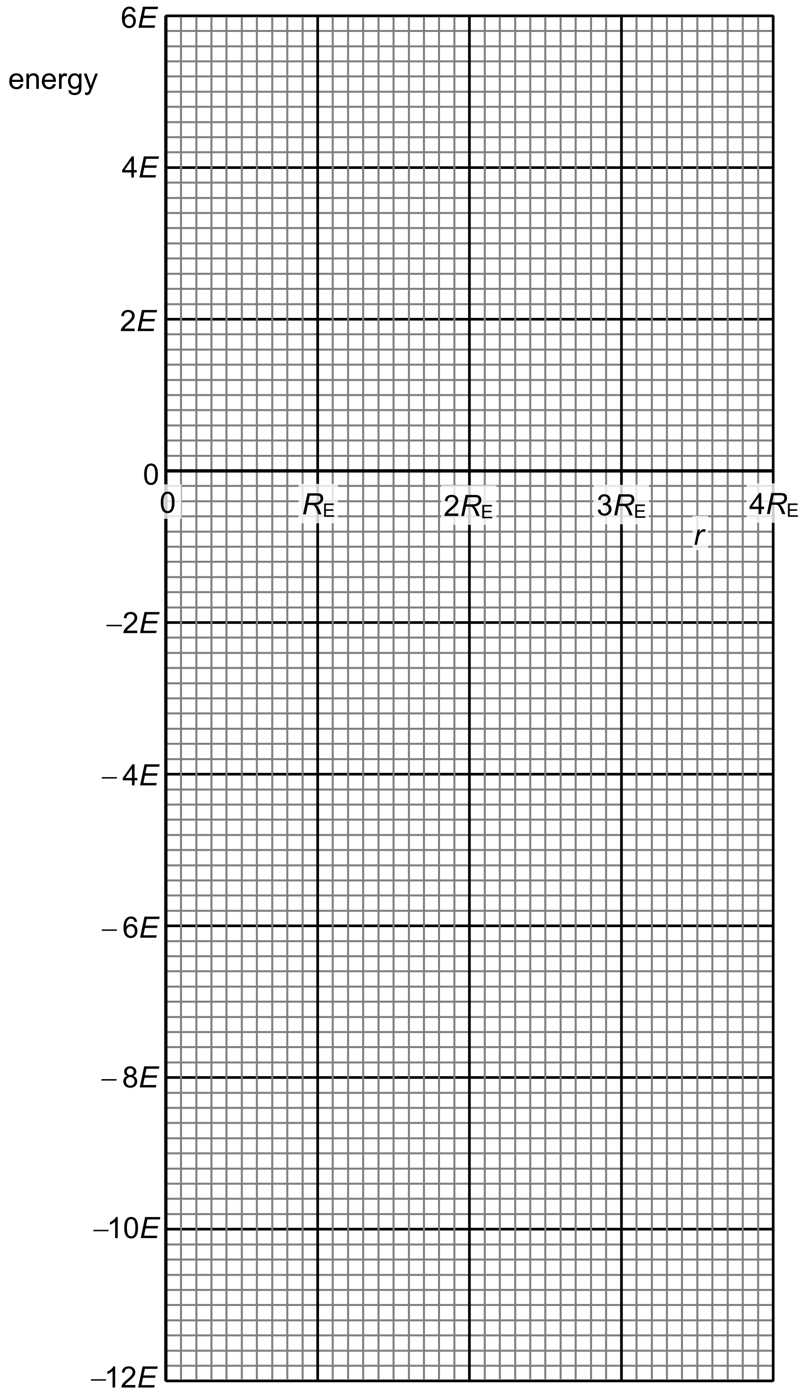

Fig. 3.2

[3]

(b) Launched on 24 November 1998, the International Space Station (ISS) serves as a cutting-edge facility dedicated to fostering collaborative scientific research. It revolves around the Earth in a circular orbit within the outermost layer of the Earth's atmosphere, at a height of 408 km above the Earth's surface.

The Earth has radius R_E of 6.37×10^6 m and mass M of 5.98×10^{24} kg.

(i) Determine, with appropriate calculations, whether the ISS could be in a geostationary orbit.

....

.... [3]

(ii) Explain why the ISS needs to fire its engine thrusters periodically to maintain its desired orbit.

....

....

....

.... [2]

4 **(a)** A point source of light of power 480 W emits light uniformly in all directions. A detector of diameter 6.0 cm is placed at a distance of 5.0 m from the point source, such that light falls normally on the detector.

Calculate the amount of light energy incident on the detector in 4.0 minutes.

energy = ... J [3]

(b) Three ideal polarising filters P_1, P_2 and P_3 are held in line with one another and with their transmission axes at different angles. A parallel beam of unpolarised light of intensity I_0 is directed towards the filters as shown in Fig. 4.1.

The light beam is incident on P_1 with its transmission axis vertical. The transmission axis of P_2 is at an angle θ to the vertical. The transmission axis of P_3 is at an angle 2θ to the vertical.

The intensity of the light beam emerging from P_3 is $\frac{I_0}{8}$.

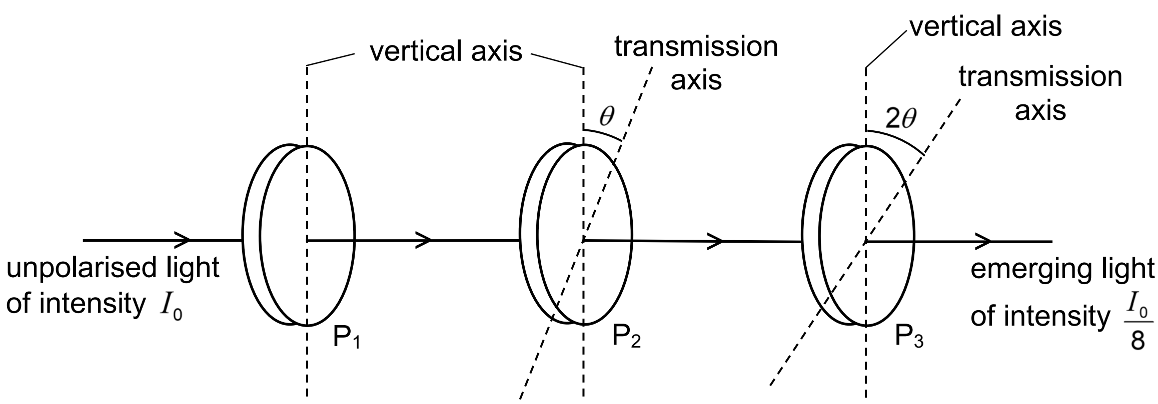

Fig 4.1

(i) Show, using Malus' law, that the value of θ is $45°$. Explain your working.

[2]

(ii) The transmission axis of polarising filter P_3 is rotated from its current position. The angle of rotation ϕ from its current position is as shown in Fig. 4.2.

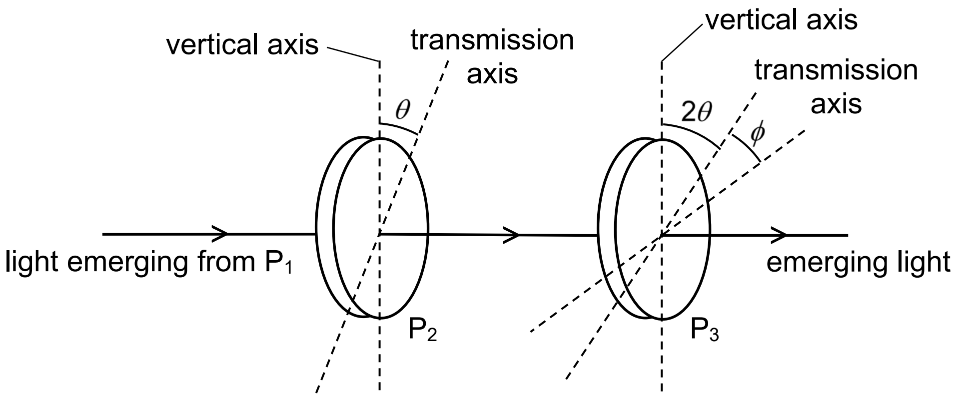

Fig. 4.2

1. Explain why the intensity of the light beam emerging from P_3 is zero when $\phi = 45°$.

.... [1]

2. On Fig. 4.3, sketch a graph to show the variation with ϕ of the intensity of the light beam emerging from P_3 from $\phi = 0°$ to $\phi = 360°$.

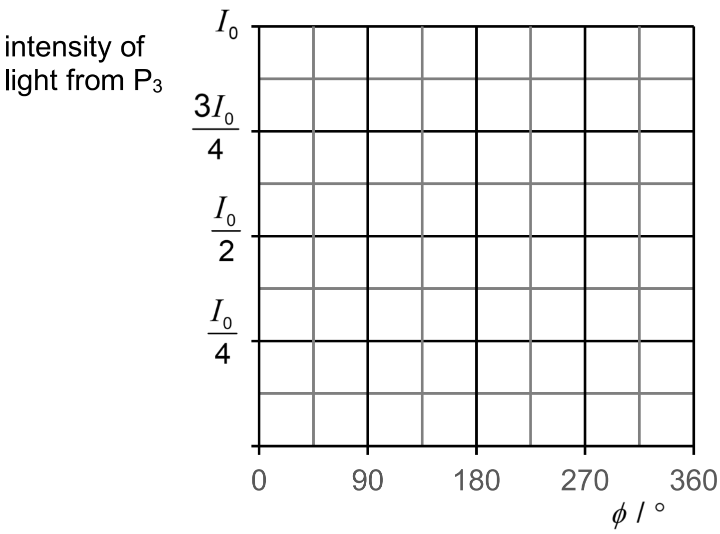

Fig. 4.3

[2]

5 **(a)** State the *principle of superposition*.

....

....

....

.... [2]

(b) Fig. 5.1 shows an experimental setup involving two coherent point sources of radio waves, S_1 and S_2, placed 50 cm apart from each other.

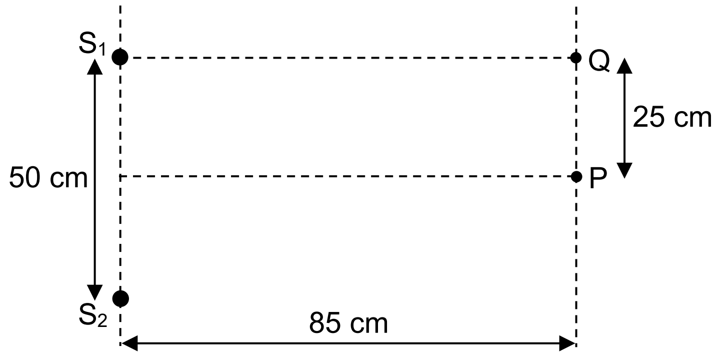

Fig. 5.1 (not to scale)

Points P and Q are at a horizontal distance of 85 cm from sources S_1 and S_2. Point P is equidistant from the two sources and point Q is directly in front of source S_1.

A receiver detects a high intensity signal at point P. The next high intensity signal is detected when the receiver is moved 25 cm upwards from point P to point Q.

(i) State what is meant by *coherent sources*.

....

.... [1]

(ii) State the phase difference between sources S_1 and S_2.

.... [1]

(iii) A student claims that the separation Δx between the consecutive high intensity signals detected by the receiver at points P and Q is given by the same formula as that for the fringe separation in a Young's double-slit experiment, which is

$$\Delta x = \frac{\lambda D}{d}$$

where $D = 85\ \text{cm}$, $d = 50\ \text{cm}$ and λ is the wavelength of the radio waves emitted.

Explain, with reference to the data given, why the student's claim is incorrect.

....

....

....

....

.... [2]

(iv) Determine the wavelength λ of the radio waves.

λ = ... cm [2]

(v) The receiver is now moved horizontally from point Q to S_1 along the line QS_1. Along the way, the intensity of the signal detected by the receiver fluctuates.

Determine the number of high intensity signals detected by the receiver as it is moved from point Q to S_1, excluding the high intensity signal detected at point Q.

number of high intensity signals = ... [2]

(c) A narrow beam of monochromatic light of unknown wavelength is incident normally on a diffraction grating of 833 lines per millimetre. A large screen is placed parallel to the plane of the diffraction grating at a large distance away to observe the interference pattern.

The entire interference pattern consists of only five bright spots.

Determine the minimum possible wavelength of the light. Show your working clearly.

minimum wavelength .... nm [2]

END OF SECTION B