UNIVERSITY OF RUHUNA

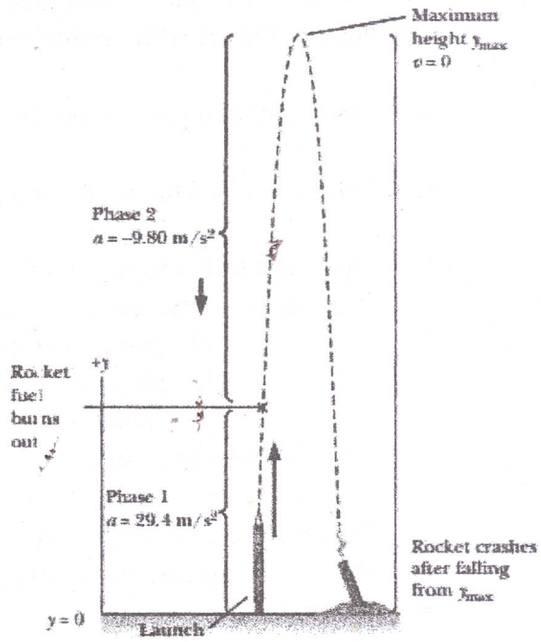
BACHELOR OF SCIENCE (GENERAL) DEGREE – LEVEL I (SEMESTER I) EXAMINATION – JUNE 2023

SUBJECT: Physics
COURSE UNIT: PHY1114

Part - II
Answer only 05 questions **TIME: Two and half hours**
(All symbols have their usual meaning)

1.

a) A rocket moves straight upward, starting from rest with an acceleration of 29.4 m s^{-2}. It runs out of fuel at the end of 4 s and continues its motion.



i. What is the rocket velocity and position at the end of 4 s?
ii. Calculate the maximum height the rocket reaches.
iii. Find the velocity the instant before the rocket crashes on the ground.

[09 marks]

b)

i. What is meant by conservative and non-conservative forces? Give two examples for each case.
ii. If a system includes non-conservative forces, show that the changing mechanical energy is work done by the non-conservative forces.

[06 marks]

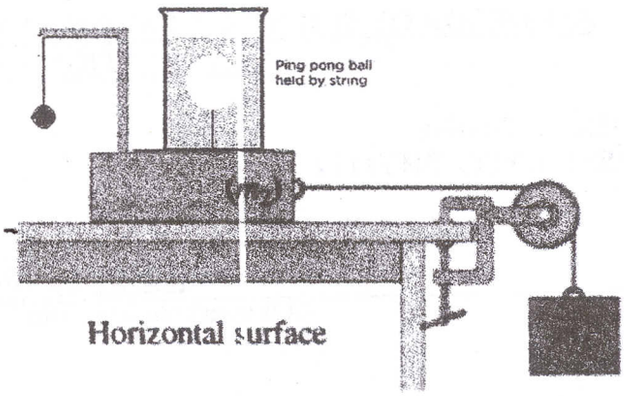
c) An object of mass m is pulled upward by a string of tension T along a rough inclined plane. The inclination of the plane is θ and the kinetic frictional force between the plane and the object is f_k.

i. Distinguish all conservative and non-conservative forces acting on the block.
ii. If the block is started at rest at the bottom of the inclined plane initially, using energy relations obtain an expression for the velocity of the block after it is pulled a distance S along the inclined plane.
iii. Under what condition the velocity given by above expression is physically valid?

[10 marks]

2.

The figure shows an experimental setup prepared to observe the acceleration of a mass system. A water beaker with a pin-pong ball connected to the bottom is fixed on the platform at the right. Conversely, a light ball of mass m is hanging on the stand set to the same platform on the left, making all system mass m_2. The angle θ that the thread supporting the light ball of mass m, where m is negligible compared to the m_1 and m_2, makes with vertical reads by an electronic display. There is no friction anywhere.



i. Draw any two pairs of forces relating to Newton's 3rd law in the system.

[02 marks]

ii. If $m_1 > m_2$ find the acceleration of the system.

[03 marks]

iii. Draw the followings in a diagram to indicate their locations while the system accelerates. Indicate the direction of the acceleration on the same diagram.

a) position of mass m with connection string
b) ping-pong ball with connection strings
c) water level of the beaker

Explain why the positions are changed to above a), b), and c) by giving necessary relations.

[10 marks]

iv. How is θ, related to the system's acceleration?
If $m_2 = 250$ kg and $m_1 = 1250$ kg, what is the angle θ given by the display?

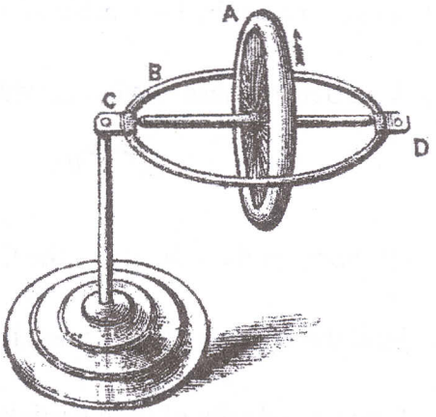
[06 marks]

v. If you can vary m_1 and m_2, what is the largest value of the angle reading you could read? Explain your answer.

[04 marks]

3

As shown in the Figure a gyroscope is kept on a stand at C by one end of the axle. The other end of the axle is initially held at D and then released.



Gyroscope.

i. Sketch the diagram on your answer sheet and show the forces acting on the gyroscope wheel just after releasing the holding end of the axle.

[02 marks]

ii. Suppose the wheel is not rotated around its axle, which type of motion is undergone by the gyroscope due to the forces given in part (i)? Giving expressions briefly explain your answer.

[02 marks]

iii. Then if the wheel is rotated around the axle in the clockwise direction with angular velocity ω, what other motion would you expect? Giving expressions briefly explain your answer.

[08 marks]

iv. What changes in the precession of the bicycle wheel are expected when the angular velocity ω of the wheel is decreasing? Explain your answer analytically (with the necessary formula).

[05 marks]

v. The precession of a top is shown in the diagram. Show that the rate of precession of the top and the gyroscope is the same.

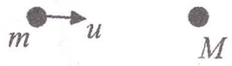
[08 marks]

4.

(a) What is meant by the Centre of Mass reference frame of a system of particles?

[02 marks]

(b) A particle of mass m moving with velocity u collides with another mass M, which is at rest.



i. Write down the velocity of the C.O. M frame of above system.

[02 marks]

ii. Find the velocity of each mass in the C.O.M frame.

[02 marks]

iii. Find the velocity of each particle after the collision within the C.O.M frame.

[04 marks]

iv. Find the velocity of each particle after the collision within the lab frame.

[04 marks]

v. Hence show that the fractional energy loss by mass m is given by, $\frac{4m}{(m+M)^2}$

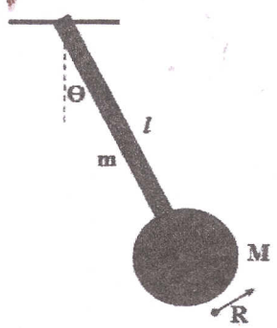
[08 marks]

vi. Hence discuss the condition needed to transfer the maximum of energy to the target particle in the collision.

[03 marks]

5.

A physical pendulum consists of a uniform rod of length l and mass m and a solid disk of radius R and mass M attached together. The system is suspended from a pivot at one end of the rod as shown in the figure. The system is then pulled out at a small angle and released to oscillate freely in the vertical plane. Neglect any friction and possible air resistance.



a) Show that the moment of inertial of a uniform rod of mass m and length l about its one end perpendicular to the rod is given by $\frac{1}{3}ml^2$. [08 marks]

b) Show that the moment of inertia of the system about an axis through the pivot point normal to the vertical plane is given by $\frac{1}{3}(m+3M)l^2+\frac{1}{2}MR^2$. [07 marks]

c) Determine the period of oscillations of the system. [10 marks]

6.

a) Two simple harmonic motions of the same frequency moving in perpendicular directions are given by the equations $x = a\sin(\omega t + \varphi)$ and $y = b\sin(\omega t)$.

i) Obtain an expression for the superposition of those two waves in terms of x, y and the phase angle φ.

ii) Determine the resultant motion when the phase angle $\varphi = 0$.

iii) Sketch the resultant motion described by part (ii). [10 marks]

b) In a double-slit experiment, monochromatic light with a wavelength of 600 nm passes through two narrow slits that are separated by a distance of 0.02 mm. The resulting interference pattern is observed on a screen placed 1.0 m away from the slits. Calculate the distance between the central maximum and the first-order maximum in the interference pattern. [05 marks]

c) Two strings of linear mass densities μ_1 and $\mu_2 (= 3\mu_1)$ are joined together and stretched with the same tension T. A transverse wave pulse with amplitude A is created in the string with lower density and the pulse is moving towards the boundary of the two strings.

(i) Determine the amplitudes of the reflected and the transmitted waves.

(ii) Draw the shapes of the incident wave pulse and the corresponding reflected and transmitted wave pulses. [10 marks]

(Hint: The characteristic impedance (z) of a material is given by $z = \mu v$, where μ is the linear mass density and v is the wave speed).

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