UNIVERSITY OF RUHUNA

BACHELOR OF SCIENCE GENERAL DEGREE – LEVEL I (SEMESTER I) EXAMINATION – AUGUST/SEPTEMBER 2017

SUBJECT: Physics **TIME: Three (03) hours**

COURSE UNIT: PHY 1114

Part II

Answer only 05 questions

$$g = 10\ ms^{-2}$$

(All symbols have their usual meaning)

1.

a) The equation of motion of a body is given by the following equation,

$$\frac{dv(t)}{dt} = 6 - 3v(t),$$

where $v(t)$ at time t is the speed in ms^{-1} and t is in seconds. The body was at rest at $t = 0$.

i. Find the terminal speed of the body.

ii. What is the initial acceleration of the body?

iii. Show that the speed varies with time by the relation, $v(t) = 2(1 - e^{-3t})$.

iv. Find the speed of the body when the acceleration is half of the initial value.

$$\left[Note: \int \frac{dx}{a - bx} = -\frac{1}{b} ln(a - bx) \right]$$

[16 marks]

b) A body moving with constant speed v enters in to a circular track of radius r. Show that, in the circular path, the body experiences an acceleration $v^2/_r$ directed towards the center of the track.

A ball tied to the free end of a string of length 0.5 m **swings** in a vertical plane under the influence of gravity. When the string makes an angle 20^0 with the vertical, ball has a speed of $1 \cdot 5$ m/s. Find the magnitude and direction of the **acceleration** of the ball when $\theta = 20^0$.

[09 marks]

2.

a) Newton's second law of motion can be applied in the standard form only in certain type of reference frames. Explain this statement and give some examples where it cannot be applied.

Consider a floater of mass m and volume V which is attached to the bottom of a beaker by a light string so that it floats under water of density d. Explain, using suitable diagrams, the location of the floater and the water level in each of following cases

i. If the beaker is moving to the right with a constant velocity

ii. If the beaker is moving to the right with a constant acceleration.

iii. If the beaker is moving downward with a constant velocity

iv. If the beaker is moving downward with a constant acceleration of g.

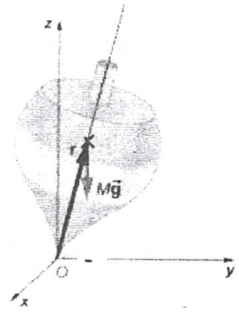
v. Write down an expression for the tension of the string, when the beaker is **at rest** and in the cases of **part ii and part iv** above.

[15 marks]

b) State Newton's second law of motion as applicable to rotational motion.

A spinning top does not fall down but precesses. Explain the reasons.

Show that the precession angular frequency of a spinning top of mass M, is given by, $= \frac{Mgr}{I\omega}$; where I is moment of inertia about the symmetric rotating axis, ω is the angular frequency and r is the height to the center of gravity along the axis.



[10 marks]

3.

a) A **collision** is an event in which two or more bodies exert forces on each other for a relatively short time. According to the coefficient of restitution, there are two special cases of collisions, elastic and inelastic collisions.

i. Giving examples discuss elastic and inelastic collisions.

ii. What is meant by the center of mass reference frame of a system of particles?

iii. A particle of mass m_1 moving with speed u_1 undergoes a head-on-collision with another particle of mass m_2 moving with speed u_2 in the same direction ($u_1 > u_2$). Show that the total momentum of the two particles in C.O.M. frame before the collision is zero.

iv. Hence show that for elastic collisions in C.O.M frame, the velocities before and after the collision of two identical masses are same in magnitude but opposite in directions.

[15 marks]

b) Object A of mass 10 kg and speed 100 m s^{-1} collides head-on with the object B of mass 40 kg and speed 50 m s^{-1} moving along the same direction. Assume an elastic collision.

i. Find the speed of the C.O.M. frame of the system relative to the ground.
ii. Find the speed of each object in the C.O.M. frame before the collision.
iii. Find the speed of each object in the C.O.M. frame after the collision.
iv. Calculate the speed of each object in the Laboratory frame after the collision.

[10 marks]

4. A space ship rotates with angular velocity $\overline{\omega} = 2t\hat{\imath} - t^2\hat{\jmath} + (2t+4)\hat{k}$ relative to an inertial reference frame. An astronaut of mass 50 kg is travelling in the space ship. The position of the astronaut with respect to the space ship is given by $\overline{r} = (t^2+1)\hat{\imath} - 6t\hat{\jmath} + 4t^3\hat{k}$. Find the following quantities when t = 1 sec.

a) Velocities of the astronaut with respect to the space station and to the inertial reference frame, respectively. [08 marks]

b) Accelerations of the astronaut with respect to the space station and the inertial reference frame, respectively. [08 marks]

c) The Coriolis force, the Centrifugal force and the Effective force experience by the astronaut. [06 marks]

d) Explain with reasons, the development of patterns of trade winds in Northern Hemisphere of the earth. [03 marks]

(If necessary following equations can be used in appropriate manner, $\overline{a_F} = \overline{a_R} + 2\overline{\omega}\times\overline{V}_R + \overline{\omega}\times(\overline{\omega}\times\overline{r}) + \frac{d\overline{\omega}}{dt}\times\overline{r}$, all terms have their usual meaning.)

5.

a) Equation of motion of a simple harmonic oscillator is given by $\frac{d^2x}{dt^2} + \omega_0 x = 0$. The general solution of this equation of motion takes the form $x(t) = x_m \sin(\omega_0 t + \phi)$.

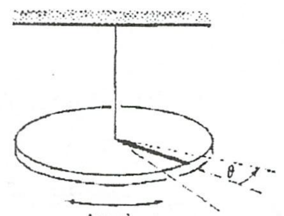
i. The oscillator is started at time $t = 0$ from $x = 0$ with initial velocity $\dot{x} = 0.2\, m s^{-1}$. If $\omega_0 = 1\, rad\, s^{-1}$, calculate the amplitude and phase constant of the motion.

[05 marks]

ii. If the oscillator is started at $t = 0$ from rest with an initial position $x = -1.2\, m$, calculate the amplitude and phase constant of the motion. [04 marks]

iii. If mass of the oscillator is 2 kg and it performs simple harmonic motion in a horizontal plane, under the conditions given in **part (i)**, find the total energy of the system. [04 marks]

b) A torsion pendulum of mass m oscillate without friction about a verticle axis as shown in the figure. I is the moment of inertia about the rotating axis of the disk.



i. Derive the equation of motion for this torsion pendulum for small angular simple harmonic motion.

[04 marks]

ii. The torsion pendulum, which is at rest, is released at $\theta = \theta_0$. Find a solution for the equation of motion derived in **part (i)** in terms of I, C (torque constant), and θ_0. [04 marks]

iii. When a torque of 5 Nm is applied to the above torsion pendulum, it moves through an angle of $8°$. If the pendulum is then released, it oscillates as a torsion pendulum with a period of 0.5 seconds. Determine the moment of inertia of the pendulum.

[04 marks]

6.

a) Consider two sinusoidal waves, $y_1 = y_m \sin(kx - \omega t)$ and $y_2 = y_m \sin(kx + \omega t)$ traveling in opposite directions.

(note: $\sin(c) + \sin(d) = 2\sin\left(\frac{c+d}{2}\right)\cos\left(\frac{c-d}{2}\right)$)

i. Find the resultant wave by using the superposition principle. [04 marks]

ii. Explain nodes and antinodes in the resultant wave using a figure. [04 marks]

iii. Derive an expression for transverse speed of the resultant wave. [03 marks]

iv. Derive an expression for the strain of the resultant wave. [03 marks]

b) A standing-wave pattern is observed in a thin wire with a length of 3.00 m. The wire is fixed at both ends. The equation of the wave is of the form $y = (0.002\ m)\sin(\pi x)\cos(100\pi t)$. Here x and t are measured in meters and seconds respectively.

i. How many loops does this pattern exhibit? [04 marks]

ii. What is the fundamental mode frequency of vibration of the wire? [03 marks]

iii. If the original frequency is held constant and the tension in the wire is increased by a factor of 9, how many loops will be seen in the new pattern?

[04 marks]