UNIVERSITY OF RUHUNA

BACHELOR OF SCIENCE GENERAL DEGREE – LEVEL I (SEMESTER I) EXAMINATION – NOVEMBER/DECEMBER- 2019

TIME: Three (03) hours

SUBJECT: PHYSICS

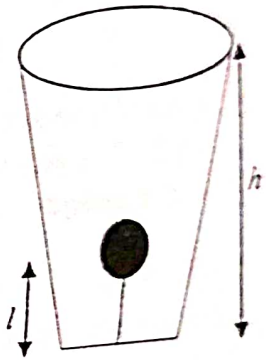
COURSE UNIT: PHY 1114

Answer only 05 questions

Part II

(All symbols have their usual meaning)

1. Solid sphere of volume V and densiity ρ_m is immerserd in a liquid of density ρ_l, contained in a vessel, where $\rho_l > \rho_m$. The sphere is connected to the bottom of the vessel by the support of inextensible, massless string as shown in the figure. Height of the vessel is h and the vessel is fully filled by the liquid. The height to the centre of mass of the sphere from the bottom of the vessel is l.



a) Define an inertial frame of reference.
What is meant by a pseudo force?
Draw any two pairs of forces relating to the Newton's 3rd law in the system. [04 marks]

b) Write down an expression for the tension, T_1, of the string using given quantities. [04 marks]

c) The connected string is suddenly broken, find the time taken to reach the sphere to the top of the vessel in terms of given terms. Neglect all resistive forces on this calculation. [04 marks]

d) Sphere is again connected by a same string and the vessel is moved downward with acceleration a, find the new tension T_2. If the vessel is in a free fall, what would be the tension? [06 marks]

e) Now the vessel is moved horizontally with acceleration a, towards the right. Draw the position of the sphere and the string in a diagram. Indicate the direction of the acceleration on the same diagram.
By giving necessary relations clearly explain your answer. [07 marks]

2.

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 any collision, elastic and inelastic collations.

i. What is meant by the coefficient of restitution in relating to 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 velocity u_1 collides with another moving particle of mass m_2 with u_2. Show that the total momentum is zero in C.O.M. frame.

[10 marks]

b) A large asteroid of radius 5 km and average density 2500 kg m^{-3}moving in an opposite direction to the earth, relative to the sun, with the speed equal to that of the earth makes a head-on collision with the earth. The earth takes one year to orbit the sun once on a circular orbit of circumference 10^{12} m. The mass of the earth is about $6 \times 10^{24}\ kg$.

i. What is the momentum of the asteroid before the collision?
ii. What is the total momentum of the earth asteroid system?
iii. By what percentage will the collision change the earth's momentum?
(Assume that the mass of the asteroid is added to the earth after the collision.)

[15 marks]

3. A coordinate system xyz rotates with angular velocity ω relative to an inertial coordinate system XYZ. The acceleration of a moving particle with velocity V_R in rotating coordinate system xyz, with respect to the initial coordinate system XYZ, is denoted by,

$$\overline{a_F} = \overline{a_R} + 2\bar{\omega} \times \bar{V}_R + \bar{\omega} \times (\bar{\omega} \times \bar{r}) + \frac{d\bar{\omega}}{dt} \times \bar{r}$$

where r is the position vector of the particle w.r.t. the frame xyz, at time t.

An air parcel of mass m moving from tropic of cancer (located 30^0 N) to the equator (0^0) under the pressure gradient.

a) Considering a time dependent vector in rotating reference frame, derive the above relation.

b) Write down an expression for the real force acted on the air parcel. [10 marks]

c) Indicating the significance, discuss each term of the expression. [02 marks]

d) Discuss briefly the effect of Coriolis and Centripetal forces on the air parcel in relating to the expression. [08 marks]

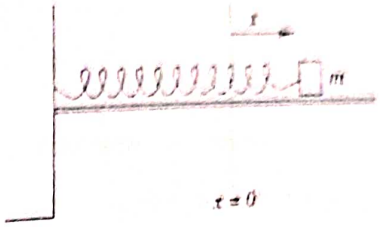
4.

a) [05 marks]

i. What is meant by a conservative force?
ii. Give one example each for a conservative force and non-conservative force.
iii. For a particle moving under a conservative force, $\bar{F}$, write down a relationship between $\bar{F}$ and its scalar potential U.
iv. Apply general test to determine whether the following forces are conservative
1. $\bar{F} = x\hat{\imath} + y\hat{\jmath}$
2. $\bar{F} = x^2\hat{\imath} + xy\hat{\jmath}$

[10 marks]

b) A mass $m = 0.2$ kg on a frictionless horizontal surface, is connected to a spring with force constant k as illustrated in the figure. The mass is pulled by stretching the spring for distance 0.1 m and released it from rest. The potential energy of the mass at any position is given by $\frac{1}{2}kx^2$.



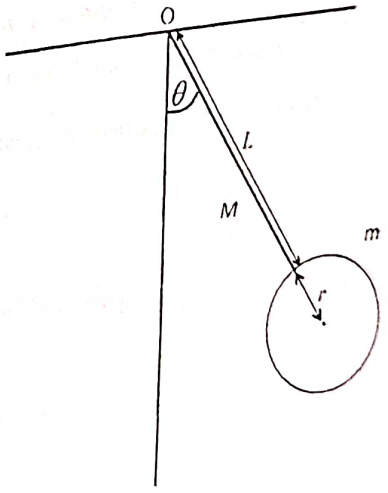
i. Draw the potential energy variation of the mass with the distance x.

ii. What is the total energy of the mass and mark the total energy variation on the same graph in part i.

iii. Show that the oscillatory motions of the mass attached to the spring is in stable equilibrium condition.

iv. If the spring constant $k = 5$ N m^{-1}, calculate the velocity of the mass when $x = 0.08$ m. [15 marks]

5. Consider a physical pendulum made out of a thin uniform disk of radius r and mass m, connected to a thin uniform rod of mass M and length L as shown in the *Figure*. The system is pivoted from the point O and is free to oscillate in a vertical plane. Neglect any friction and possible air resistance.



a) Show that the moment of inertia of a thin uniform rod of mass M and length L about an axis passing through the end perpendicular to the rod is $\frac{1}{3}ML^2$ [08 marks]

b) Moment of inertia of the disk about an axis going through its center, perpendicular to its plane is $\frac{1}{2}mr^2$. Find the moment of inertia of the physical pendulum about an axis through pivot point O normal to the vertical plane. [07 marks]

c) If the pendulum is displaced by a small angle θ in a vertical plane as shown in the figure, it performs small oscillations. Derive an expression for the period of small oscillations of the physical pendulum. [10 marks]

6.

a) A sinusoidal wave traveling at 400 ms^{-1} in the positive X direction has an amplitude of 3cm and a frequency of 300 Hz. At $t = 0$s one of the wave crest lies exactly on the $x = 1$ m line in the XY coordinate system.

(i) Calculate the following quantities: ***Wavelength*** (λ), ***Angular frequency*** (ω), ***Angular wave number*** (k), ***Period*** (T) and ***phase constant*** (ϕ).

(ii) Write down the equation of this traveling wave as a function of time and position.

[08 marks]

b) 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.

(i) Find the resultant wave by using the superposition principle.
(ii) Explain nodes and antinodes.
(iii) Derive an expression for transverse speed.
(iv) Derive an expression for strain.

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

[08 marks]

c) Two sinusoidal waves combining in a medium are described by the wave functions $y_1 = 3.0\sin(\pi x - 0.6\pi t)$ and $y_2 = 3.0\sin(\pi x + 0.6\pi t)$ where the amplitude and x are measured in meters and t is in seconds.

(i) Determine the ***maximum*** transverse position and ***maximum*** transverse speed of an element of the medium at $x = 0.25$ m.

(ii) Find the ***first two*** smallest values of x corresponding to ***antinodes***.

[09 marks]

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