University of Ruhuna

Bachelor of Science (General) Degree Level I (Semester I) Examination

July - 2016

Subject: Physics

Course Unit: PHY1114

Time - 03 hours

Answer SIX (06) Questions only.

Answer at least 01 (ONE) question from part B.

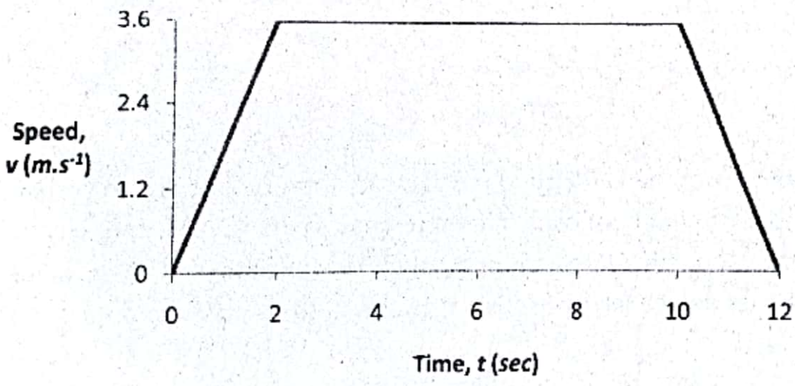
All symbols have their usual meaning

($G = 6.67\times10^{-11}\ kg^{-1}.m^3/s^2$, $g = 9.8\ m.s^{-2}$)

Part A

1.

a) Consider a lift with passengers moving in upward direction. The total mass of the lift and the passengers is 1500 *kg*. The variation of the speed of the lift with time is shown in the following graph.



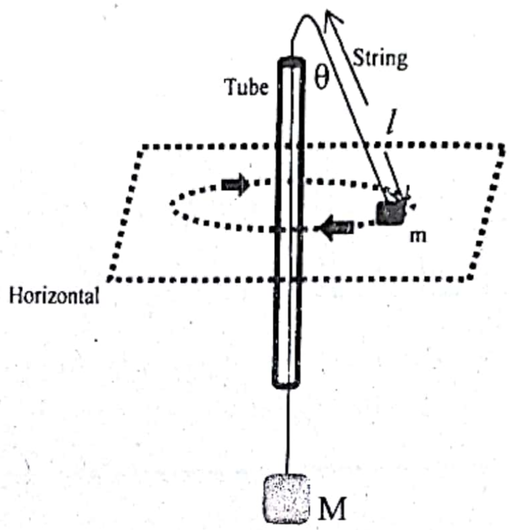
i. Calculate the tension of the rope pulling the lift upward at time t equal to 1 *sec*, 6 *sec* and 11 *sec*, respectively.

ii. What is the height to which the lift takes the passengers?

iii. Find the average speed for the entire motion.

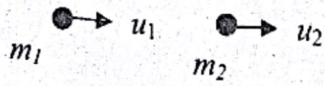
[15 marks]

b) A large mass M and a small mass m hang at two ends of a string that passes through a smooth tube as shown in the figure. The mass m moves around a circular path which lies in the horizontal plane. The length of the string from the mass m to the top of the tube is l and θ is the angle this string makes with the vertical. Find the frequency of rotation of the mass m so that the mass M remains stationary?



[10 marks]

2. What is meant by the center of mass reference frame of a system of particles?
A particle of mass m_1 moving with velocity $\vec{u}_1$ collides (head on collision) with another mass m_2 moving mass of with velocity $\vec{u}_2$ ($|\vec{u}_2| < |\vec{u}_1|$) in the same direction.



i. Write down the velocity of the C.O. M. frame of the above system.
ii. Find the velocity of each mass reference to the C.O.M. frame.
iii. Hence show that the total momentum is zero in the C.O.M. frame.

Consider the target object (m_2) which is at rest ($u_2 = 0$) before the collision for answering the following parts

iv. Write down the velocity of m_2 after the collision in C.O.M. frame.
v. After the collision find the velocities of m_1 & m_2 reference to the lab frame.
vi. What is the energy given to the target object (m_2) by the mass m_1 in this collision and show that the energy gain by the target object is equal to the energy given by m_1.
Hence find the fractional energy loss of the mass m_1.

[All parts carry equal marks.]

3. a) The earth is rotating about its axis with constant angular speed ω. Consider motion of an air parcel directed from North Pole to equator with a velocity of v_R relative to the earth.

i. The true acceleration of the parcel is given by,

$$\bar{a}_F = \bar{a}_R + 2\bar{\omega}\times\bar{v}_R + \bar{\omega}\times(\bar{\omega}\times\bar{r})$$

Give the meanings of each term in the above equation.

ii. Hence find the effective force on the air parcel, with respect to the earth frame.

iii. Discuss all terms in the expression for the force on the air parcel and the significance of each term.

[10 marks]

b) An object is falling from rest towards the center of the earth radially from a height of 100 m above a point on the equator of the earth. Calculate the horizontal displacement of the object due to the coriolis force. Indicate the direction of displacement.

(Solar days/year =365.5, Sidereal days/year =366.5, Radius of the earth $=6.38\times10^6\,m$, Solar day 24 hrs.)

[15 marks]

4.

i. What is meant by a conservative force?

[02 marks]

ii. Which of the following forces are conservative?

Wind resistance on a moving car,

Force exerted by a linear spring obeying Hooke's law,

Forces given by,

$$F = y^3\hat{\imath} + 3xy^2\hat{\jmath}$$

$$F = x^2\hat{i} + xy\hat{j}$$

[06 marks]

iii. Write down the relationship between a conservative force and the associated potential.

[02 marks]

iv. Using the above relationship derive an expression for the gravitational potential $V(r)$, at a distance r ($r \geq R_E$) from the center of the earth in terms of the mass of the earth and the gravitational constant G. R_E is radius of the earth.
Sketch $V(r)$ as a function of r.

[09 marks]

v. Explain the followings.
a) Formation of the sun.
b) Formation of black holes
c) Formation of white dwarfs.

[06 marks]

5.

a) Introducing all parameters state Bernoulli's theorem.
This theorem is a result of a conservation of law. Explain briefly.

[05 marks]

b) Explain the following phenomena using Bernoulli's theorem.
Lifting of airplane.
Swinging of a cricket ball.
Mechanism of a spray gun.
Using a cylindrical shape for rocket bullet.

[05 marks]

c) A fluid flows through a horizontal pipe of varying cross section. Assuming the flow is streamline and applying Bernoulli's equation, show that the pressure in the pipe is greatest where the cross sectional area is greatest.

[06 marks]

d) Water flows through a horizontal pipe. If one end of the pipe is closed with a valve, the reading of the pressure gauge attached to the pipe is $3\times10^5\ N.m^{-2}$. The reading of the pressure gauge falls to $1\times10^5\ N.m^{-2}$ when the valve is opened. Calculate the speed of the water flowing through the pipe. (Density of the water is $1000\ kg.m^{-3}$)

[09 marks]

6.

a) A body falls freely to the ground from outside of a certain height of a carriage of a train. Compare the time of fall, when the train is stationary, moving with constant velocity or moving with constant acceleration along a horizontal track.

[05 marks]

b) A monkey sitting on a tree falls freely at the same instant when a gun is fired at the monkey. Would the bullet hits the monkey while in free fall?
Prove your answer.

[08 marks]

c) Define work.
Explain positive, negative and zero work with examples.

[02 marks]

d) A body of mass 2 kg is placed on an inclined plane of 30^0 to the horizontal. The body moves 2 m along the plane under an applied horizontal force of 70 N alone the plane. The coefficient of kinetic friction between the object and the plane is 0.1.
Compute,
i. work done by the applied force.
ii. work done by the frictional force.
iii. work done by the net force along the plane on the body.
iv. the speed of the body after moving 2 m **using energy relations.**

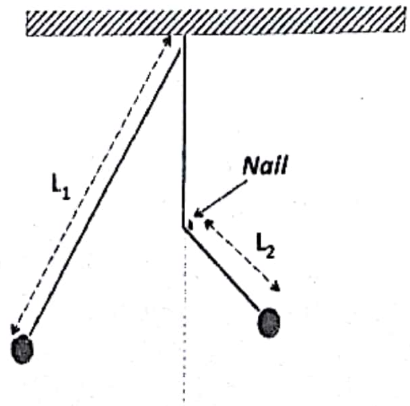
[10 marks]

7.

a) By applying Newton's second law for rotational motion, show that the period of a simple pendulum of mass $\boldsymbol{m}$ and length $\boldsymbol{L}$ can be given as $T = 2\pi\sqrt{\frac{L}{g}}$. State all assumptions made.

[07 marks]

b)

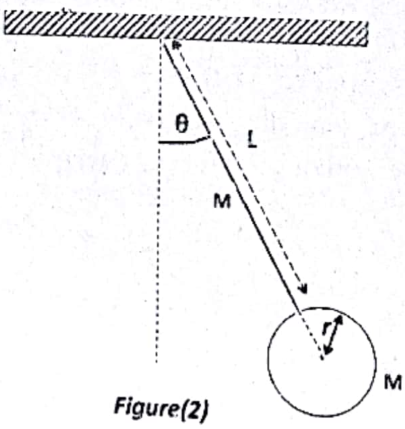


Figure(1)

Consider the simple pendulum shown in *Figure(1)*. The total length L_1 of the pendulum string is 1.2 m. But the nail on the wall restricts its motion to right side by reducing its length to $L_2 = 0.3$ m. Calculate the period of small oscillations of the pendulum.

[06 marks]

c)



Figure(2)

Consider the physical pendulum made out of a hoop of radius r and mass M, connected to a thin rod of mass M and length L as shown in *Figure(2)*. Derive an expression for the period of small oscillations of the physical pendulum. Moment of inertia of the hoop about an axis going through its center, perpendicular to its plane is Mr^2. Moment of inertia of the thin rod about an axis going through its one end perpendicular to the rod is $\frac{1}{3}ML^2$.

[12 marks]

8. a) The equation of a transverse wave on a string is given by $y=(0.120)\sin\left(\frac{\pi}{8}x+4\pi t\right)$ (All quantities are given in SI units).

i. Calculate the wavelength, period and speed of propagation of this wave.

ii. Determine the transverse speed and acceleration at $t=0.2\,\text{sec}$ for the point on the string located at $x=1.6$ m.

[07 marks]

b) In a cathode ray oscilloscope, the motion of an electron under two mutually perpendicular electric fields is given by the following simple harmonic motions.

$$x=4\cos\omega t$$

$$y=4\cos\left(\omega t+\frac{\pi}{2}\right)$$

Find the resultant path of the electron.

[05 marks]

c) Two strings of linear mass densities m_1 and $m_2(>m_1)$ are joined together form one end and stretched between two fixed point under the same tension T. If a transverse wave pulse incident from less dense medium discuss the motion of the pulse after it hits the boundary of the two media by drawing suitable figures.

[05 marks]

d) A rope is made up of a number of identical strands twisted together. At one point, the rope becomes frayed so that only a single strand continues (See *Figure(3)*). The rope is held under tension and wave of amplitude $1cm$ is sent from the single strand. The wave reflected back along the single strand has an amplitude of 0.5 cm. How many stands are there in the rope?

Figure(3)

[08 marks]

9.

a) What is meant by resonance?

[05 marks]

b) Fifty tuning forks are arranged in the order of increasing frequency and any two successive forks give 5 beats per second when sounded together. If the frequency of the last fork is twice as much as the first, find the frequency of the first fork.

[06 marks]

c) A 25 *cm* long tube with one open end resonates at fundamental mode with a tuning fork when filled with Oxygen. Find the length of the tube that would resonate at the same mode for the same tuning fork when filled with Hydrogen. Velocities of sound in Oxygen and Hydrogen are 320 $m.s^{-1}$ and 1280 $m.s^{-1}$ respectively.

[06 marks]

d) Phase velocity V_p of a transverse wave in a crystal of atomic separation d is given by $V_p = \dfrac{c \sin\left(\frac{kd}{2}\right)}{\left(\frac{kd}{2}\right)}$, where c is a constant. Show that the group velocity is equal to $c \cos\dfrac{kd}{2}$.

[08 marks]