University of Ruhuna

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

June/July – 2015

Subject: Physics
Course Unit: PHY1114

Time - 03 hours

Answer SIX questions only

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

All symbols have their usual meaning

($G = 6.67\times10^{-11} kg^{-1}m^3/s^2$, $g = 10\ ms^{-2}$)

Part A

1.

a) A ball is thrown upward in the air by a passenger on a train that is moving with a constant velocity. If the effects due to wind is neglected,

i. describe the path of the ball as seen by the passenger and a stationary observer outside the train.

ii. how would the above observations change if the train was moving with a constant acceleration along the track?

b) A balloon is rising vertically upwards at a constant velocity of $10\ ms^{-1}$. When it is at a height of 45 m from the ground, a parachute bails out from it. After 3 s parachute opens and then decelerates in the downward direction at a constant rate of $5\ ms^{-2}$.

i. What is the height of the parachute above the ground when the parachute is opened? (Neglect air resistance during this period.)

ii. How far is the parachute from the balloon at this instant of time? (Assume that the speed of the balloon is not changed after the parachute is released.)

iii. With what velocity does the parachute hit the ground?

iv. How long the parachute take to reach the ground after releasing from the balloon?

2.

a) If the earth were to suddenly contract to half of its present size without any change in its mass, calculate the number of hours a day?

b) A solid sphere rolls down on an inclined plane of inclination θ. If the coefficient of sliding friction between the sphere and the plane is μ, show that at the limiting condition to roll the sphere without sliding on the plane is, $\mu = \frac{2}{7}\tan\theta$.

(Note - Moment of inertia of a solid sphere around any axes passing through its center is $\frac{2}{5}MR^2$)

3.

a) A rocket moves forward by ejecting matter in the background direction by burning fuel. A rocket ejects matter with the speed of v_0 relative to the rocket. If there are no any external forces acting on the rocket and the gravity is neglected, show that the speed of the rocket v_f is given by following expression.

$$v_f = v_i + v_0 \ln\left(\frac{m_f}{m_i}\right)$$

Where v_i is the initial velocity of the rocket and, m_i and m_f are the initial and final masses of the rocket.

b) A rocket of initial total mass 1.0×10^5 kg takes off from earth emitting matter with the speed of 4.5×10^3 ms^{-1} relative to the rocket. It burns out all its fuel in 4.0 min emitting matter at a steady rate. The mass of the rocket after it burned out its fuel is 1.0×10^4 kg.

i. If air friction and gravity are neglected, calculate the speed of the rocket after all fuel is burned out?

ii. Calculate the upward thrust on the rocket produced by burning fuel.

iii. Calculate the initial and final acceleration of the rocket if gravity is not neglected.

4.

a) What is meant by Conservative and Non-Conservative forces?

Apply the relationship, $\frac{\partial}{\partial x}(F_y) = \frac{\partial}{\partial y}(F_x)$ to determine whether the following forces are conservative or not.

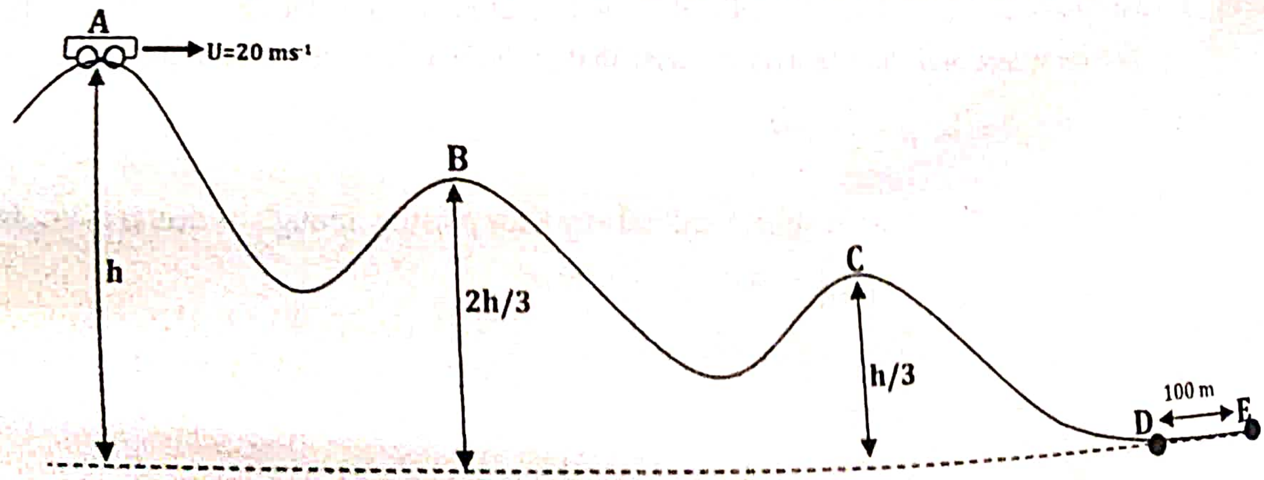
i. $F = x^2\hat{i} + xy\hat{j}$

ii. $F = y^3\hat{i} + 3xy^2\hat{j}$

b) A small roller coaster is passing at point A with a speed u = 20 ms^{-1} on a curved track at a height h = 30 m as shown in the figure. The roller coaster always remains in contact with the track. Assume that the friction between the roller coaster and the track is negligible.

i. Find the speed of the roller coaster at points B and C on the track.

ii. The brakes are applied from point D (h=0), so that the roller coaster comes to rest at point E. If the retarding force is constant, calculate the deceleration of the roller coaster.



5\.
a) A solid iron ball and a solid aluminum ball of same diameter are released together from the surface of a deep lake. Which ball will reach the bottom of the lake first? Briefly explain your answer.

b) State the Bernoulli's equation for fluid motion by explaining all its parameters. State clearly under what conditions that the equation is valid.

An open container of large uniform cross sectional area A, resting on a horizontal surface, holds two liquids (do not mix each other) of densities ρ and 2ρ, each of height $H/2$. Both liquids satisfy the conditions for the application of Bernoulli's equation. The lower density liquid is open to the atmospheric pressure P_0. A tiny hole of area s (s<<A) is punched on the vertical side of the container at a height h.

i. Derive an expression for the initial speed of flow of the liquid through the hole. Consider two cases, when $h>H/2$ and $h<H/2$, separately.

ii. When $h<H/2$, obtain an expression for the horizontal distance x, to the location where the liquid passing through the hole, fall on to the horizontal surface under gravity.

iii. Determine the height h to the hole at which the hole should be punched so that the horizontal distance calculated in part (ii) is a maximum (x_m). Find the distance x_m in terms of given quantities.

(Neglect air resistance in calculations.)

6\. Consider a freely moving small air volume in the atmosphere represented by a time dependent vector $\bar{A}(A_x\hat{i}+A_y\hat{j}+A_z\hat{k})$ with respect to the earth.

i. Write down an expression for the time derivative of vector $\bar{A}$ with respect to the earth.

ii. If the earth is rotating with angular velocity $\bar{\omega}$ with respect to a fixed star, show that the time derivative of vector $\bar{A}$ with respect to the fixed star is given by,

$$\left(\frac{d\bar{A}}{dt}\right)_{star}=\left(\frac{d\bar{A}}{dt}\right)_{earth}+\bar{\omega}\times\bar{A}.$$

iii. Hence show that the true velocity of the air volume is given by,

$$\bar{v}_{true}=\bar{v}_{apperant}+\bar{\omega}\times\bar{r}$$

Where $\bar{r}$ is the position vector of the air volume.

iv. Show that the true acceleration of the air volume is given by,

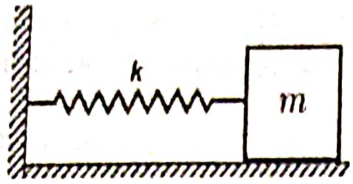
$$\bar{a}_{true}=\bar{a}_{apperant}+2\bar{\omega}\times\bar{v}_{apperant}+\bar{\omega}\times(\bar{\omega}\times\bar{r})$$

Describe the last two terms [$2\bar{\omega}\times\bar{v}_{apperant}$ and $2\bar{\omega}\times\bar{v}_{apperant}$] of the above expression.

v. If $\bar{\omega}=2t\hat{i}-t^2\hat{j}+(2t+4)\hat{k}$ and $\bar{r}=(t^2+1)\hat{i}-6t\hat{j}+4t^3\hat{k}$,
find the apparent and the true velocities of the air parcel at time t = 1 sec.

Part B

7. a)



Consider the spring mass system as shown in the figure. k is the spring constant and m is the mass. The mass m is sitting on a frictionless surface. The mass m is displaced some distance x to the right and released from rest.

i. Using Newton's 2[nd] law, show that the motion is Simple Harmonic.

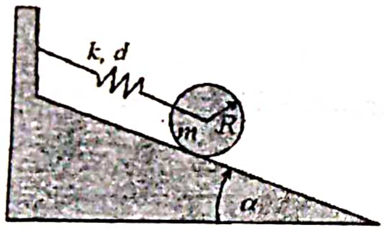
ii. Find the period of motion.

iii. General solution for this type of equation of motion is given by $x(t) = a\sin(\omega t + \phi)$. Derive expressions for the **velocity** and **acceleration**.

iv. Show that the total energy of the system is constant.

b) A particle performs a Simple Harmonic Motion with an amplitude 10 cm and a time period of 0.5 seconds. The time was started to measure when it was passing its center of oscillations. Calculate its displacement, velocity and acceleration at 0.1 seconds after it crossed the mean position.

c)



A solid cylinder of mass m is attached to a massless spring as shown in the above figure. The cylinder can roll without slipping along the incline plane. The moment of inertia of the cylinder around the rotating axis is $\frac{1}{2}mR^2$. Spring constant is k and its unstretched length is d. Show that the center of mass of the cylinder executes simple harmonic motion with the period $T = 2\pi\sqrt{\frac{3m}{2k}}$.

8.

(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 = 2Sin[(C+D)/2] Cos[(C-D)/2])

i. Obtain the resultant wave equation by using the superposition principle.

ii. Explain nodes and antinodes.

iii. Derive an expression for the transverse speed.

iv. Derive an expression for strain.

(b) A sonometer string and a tuning fork of frequency 256 Hz, when vibrating together, produce 4 beats per second. When the fork is slight loaded, 6 beats are heard per second. What is the frequency of the string

(c) A wire under certain tension emits a note of fundamental frequency 256 Hz. When the tension is changed by adding a 1 kg weight, the frequency of the fundamental note raised to 320 Hz. Find the initial tension

9.

(a)

i. Define the term intensity of a sound wave.

ii. Explain the term decibel.

iii. The sound from a drill gives a noise level of 90 dB at a point several meters away from it. What is the noise level at this point when four such identical drills are working at the same distance away?

(b) Two sound waves, one in air and the other in water are of equal intensity. Calculate the ratio of their pressure amplitudes if the velocity of sound in water, velocity of sound in air, density of water and density of air are 1430 ms^{-1}, 330 ms^{-1}, 1×10^3 kgm^{-3} and 1.2 kgm^{-3} respectively.

(c) Two stationary sources S_1 and S_2 emit sound of frequency f. An observer is moving at a speed of V_D from S_1 to S_2 along the straight line joining them. Obtain an expression for the number of beats per second heard by the observer.