University of Ruhuna

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

July - 2014

Subject: Physics

Course Unit: PHY1114 **Time - 03 hour**

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 body starting from rest relative to a train falls freely from the roof of a carriage of a train. Compare the times of fall, if the train is stationary, moving horizontally with constant velocity or moving with constant acceleration. Explain your answer.

A particle moves such that its displacement S along a certain direction varies with time (t) according to the relationship $S = 12t - 2t^2$.

i. Find a relationship for speed, v, of the particle as a function of t.
ii. Calculate the distance traveled when t=1 sec.
iii. Show that the motion is reversed when t=3 sec.
iv. Use above results to find the total distance traveled after 4 seconds.

(b) A gun is placed at the top of a hill of height 10 m. It fires two bullets within a certain time period at the same speed of $5\sqrt{3}\ ms^{-1}$. One bullet is fired horizontally and the other one at an angle of 60^0 upward direction to the first bullet. The two bullets collide in the space at a certain point P. (Consider that both bullets are fired from the same point, and the point located 10 m vertically below that point at the bottom of the hill as the origin and X-Y plane as the plane of motion of the bullet)

Find,

i. the time interval between the firings.
ii. the coordinates of the point P.

2.

(a) What is meant by conservative and non-conservative forces?

i. For a particle moving under a conservative force $\bar{F}$, write down a relationship between $\bar{F}$ and its scalar potential U.

ii. If a particle undergoes a non-conservative force in addition to the conservative forces, show that the work done by non-conservative force is equal to the change in total mechanical energy of the system.

(b) An object of mass m is pulled upward along a rough inclined plane by a string of tension T. 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.

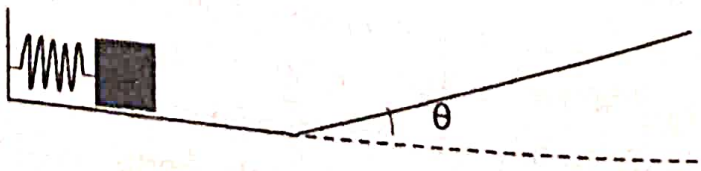
ii. If the block is started at rest at the bottom of the inclined plane initially, using **energy relations** obtain an expression for the velocity of the block after it is pulled a distance S along the inclined plane.

iii. Under what condition the velocity given by above expression is physically valid?

(c) A block of mass 0.5 kg is pressed against a spring of spring constant 625 Nm^{-1} as shown in the figure. The spring is compressed by 10 cm and released so that the block moves along frictionless horizontal and inclined surfaces.

i. Calculate the maximum distance d the block travels up along the inclined plane ($\theta = 30^0$).

ii. Find the speed of the block when it is at halfway to its maximum height?

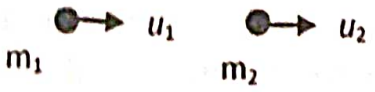


3. A frequent flyer was interested to study the forces acting on a passenger while flying in an airplane. He designed a special chair as shown in the figure.

Electronic sensors were fixed to the seat as well as backrest so that the values of the vertical and horizontal forces acting on the seat could be read. A block of mass 10 kg was placed on the frictionless chair and the forces acting on the seat (F_v) and the back rest (F_h) were studied. Assume that there is no friction between the block and the chair. Calculate the values of F_v and F_h under following conditions.

a) When the air plane is moving at a constant speed along the runway.
b) When it is accelerated along the runway so that it increases the speed from 20 km/h to 200 km/h within 10 sec period.
c) When it is taking off at an angle of 45^0 to the track at the speed of 200 km/h.
d) When it is accelerated again in the same acceleration given in part (b) in the direction given in part (c).
e) A passenger was holding a glass of juice with a piece of ice cube at the center of the liquid surface, so that the liquid surface is horizontal when the air plane is at rest. He did not change the position of the glass relative to the airplane throughout the motion.
Draw the surface of the juice, the location of the ice cube and draw the forces acting on the ice cube in cases (a), (b), (c) and (d) given above.

4. What is meant by the center of mass reference frame of a system of particles?
(a) A particle of mass m_1 moving with velocity u_1 collides with another moving particle of mass m_2 with velocity u_2.



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

(b) If physical or chemical properties of particles in a collision are changed, such a collision is called a reaction. What is meant by the threshold energy of a reaction?

Consider the following reaction due to the head-on collision of particle of mass m_1 and velocity u_1 with another particle of mass M which is at rest.

$$m1 + M \rightarrow m2 + m3 + Q$$

The products of the reaction are two particle of mass m_2 and m_3. Q is the energy released or absorbed in the reaction.

i. Find the final velocities of product particles with reference to the C.O.M frame.

ii. Hence write down the kinetic energies of particles before and after the collision.

iii. Write down energy relation for above reaction and find the energy released or absorbed during the reaction.

iv. Hence find the threshold energy for the reaction.

v. Consider the head-on collision of p (proton) on a H (hydrogen) atom at rest.

$$p + H + 13.6\,eV \rightarrow p + p + e$$

Calculate the threshold energy for this reaction.
(Electron mass can be neglected in comparing with the mass of the proton)

5. Suppose a frame R of coordinate system xyz rotates with angular velocity $\bar{\omega}$ about an axis OQ w.r.t. a fixed frame F of coordinate system XYZ. Origins of both frames are overlapped. Vector A ($A_x i + A_y j + A_z k$) is a time dependent vector in frame R.

(a) What is the velocity of A w.r.t. rotating frame R?

(b) What is the velocity of A w.r.t. fixed frame F?
(use the rate of change of unit vectors to express the answer)

(c) Show that the velocity of any fixed vector **B** in the rotating frame R is given by $\bar{\omega} \times \bar{B}$ w.r.t. the fixed frame.

(d) Hence write down the velocity in part (b) in terms of ω and vector **A**.

(e) Show that the true velocity v_F in fixed frame is given by,

$$\overline{v_F} = \overline{v_R} + \bar{\omega} \times \bar{r}$$

Where **r** is the time dependent vector in frame R and $\overline{v_R}$ is the velocity in frame R.

(f) Hence show that the true acceleration a_F for any moving object in a rotating frame R is given by,

$$\overline{a_F} = \overline{a_R} + 2\bar{\omega} \times \overline{v_R} + \bar{\omega} \times (\bar{\omega} \times \bar{r})$$

(g) If the position of a particle with respect to frame xyz (R frame)is given by $\bar{r} = -6t\hat{j} + 4t^3\hat{k}$ and $\bar{\omega} = -t^2\hat{j} + (2t + 4)\hat{k}$, find the following quantities when $t = 1$ *sec*.

i. Apparent velocity of the particle (v_R).
ii. True velocity of the particle (v_F).
iii. Apparent acceleration of the particle (a_R).

6.

(a) State Newton's law of gravitation.

Obtain an expression for the gravitational acceleration on a mass m at a distance r from the center of the earth. The mass of the earth is M and the gravitational constant is G ($r > R$, radius of the earth).

Define gravitational field intensity.
A uniform sphere of radius R and density ρ_1 is covered with a uniform coating of thickness d and density ρ_2. Use Gauss' law to find the gravitational field intensity $\bar{E}$

i. at the distance R
ii. at a distance r ($> R+d$)

(b) An asteroid of mass 10^9 kg released from rest at far away (assume at infinity) in the outer space moves towards earth.
When it reaches a point 4×10^8 m from earth,

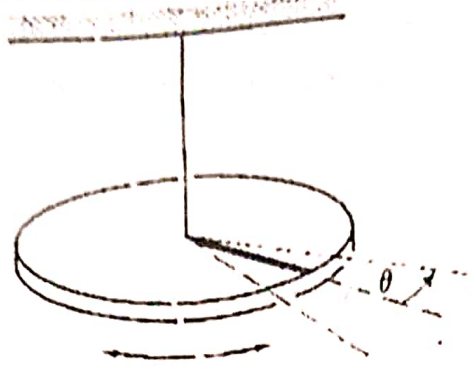
i. find the change in its potential energy.
ii. find the work done by the force of gravity on the asteroid.
iii. calculate the speed of the asteroid at that point.
iv. how much work that has to be done against the asteroid by some other mechanism in order to reduce the speed by half of the answer in part (iii) when it reaches the same point.

(Mass of the earth, $M_E = 5.98\times10^{24}$ kg)

Part B

7.

(a) Consider the torsion pendulum shown in the figure. Show that the period of oscillations of the torsion pendulum is equal to $T = 2\pi\sqrt{\frac{I}{C}}$. I is the moment of inertia of the disk about an axis passing through its center perpendicular to the disk and C is the torsion constant.



Angular oscillations

(b) When a torque of 5Nm is applied to the above disk, the disk moves through an angle of 12°. If the disk is then released, it oscillates as a torsion pendulum with a period of 0.5 sec. Determine its moment of inertia.

(c) If three point masses of mass m each are placed on top of the disk along the circumference symmetrically, explain how you find the moment of inertia of the system now. If m=50 g and radius of the disk is 8 cm find the moment of inertia of the system.

(d) Find the period of oscillations of the new system.

8.

(a) A sinusoidal wave with an amplitude of 1cm and frequency of 100 Hz travels at the speed of 200 ms^{-1} in the positive X direction. A crest of the wave is located at x =1m at time t = 0 sec.

i. Calculate the values of quantities A, v, λ, k, f, ω, T and φ_0 (phase constant).

ii. Write an expression for the displacement of the wave as a function x and t.

iii. Draw a snapshot of the wave at $t=0$ sec.

(b) Consider the two sinusoidal waves

$$y_1 = a\sin(kx - \omega t)$$

$$y_2 = a\sin(kx - \omega t + \phi)$$

i. Use the principle of superposition to find the resultant wave.

ii. What should be the values of phase differences between the two waves for constructive and destructive interference?

iii. Two loud speakers 2 m apart emit two identical sound waves of frequency 3410 Hz, which are inphase, into a room where the speed of sound is 341ms^{-1}. A listener stands 80 m in front of the loud speakers and 60 m to one side of the center line. Is the interference at this point ***constructive***, ***destructive*** or ***something else in between***?

9.

(a)

i. Derive the expression $\Delta p = \Delta p_m \sin(kx - \omega t)$ for the pressure variation in a sound wave given by $s = s_m \cos(kx - \omega t)$.

ii. The faintest sound the human ear can detect at a frequency of 1000 Hz correspond to an intensity of 1x10^{-12} Wm^{-2}. Density of air is 1.2 kgm^{-3} and the speed of sound is 343 ms^{-1}. Calculate the pressure amplitude and displacement amplitude for this sound level.

(b)

i. Derive the expression $v = \sqrt{\frac{T}{\mu}}$ for the wave speed on a stretched string.

(<u>Do not</u> use dimension analysis)

ii. A taut string of mass per unit length 5x10^{-2} kgm^{-1} is under a tension of 80 N. How much power must be supplied to the string to generate a sinusoidal wave of amplitude 6 cm and frequency 60 Hz?

iii. If the string has to transfer energy at a rate of 1000 W, what must be the value of the amplitude if all other parameters remain the same?