APPLIED SCIENCE –I (PHYSICS)
OCTOBER 2013

PART A

Answer the following questions in one or two sentences. Each question carries 2 marks.

I. a) What are nano and femto? (2)

Ans: Nano and femto are two prefixes used to indicate multiples and submultiples .Nano stands for 10^{-9} and femto for 10^{-15}

b)Give the relation between angular momentum and angular velocity (2)

Ans: Angular velocity = ω

Angular momentum =P.r (Moment of linear momentum)

i.e, $L = mv.r$

$= mr.r\omega \quad (v = r\omega)$

$= mr^{2\omega} = I\omega$

Therefore $\boxed{L = I\omega}$ is the relation between angular velocity and angular momentum.

PART B

(Answer any two full questions .Each question carries 8 marks)

II. a)Derive the equation for the displacement of body during the n^{th} second of its motion (4)

Ans: Consider a particle having an initial velocity u and acceleration a .To calculate the distance travelled in n^{th} second, we have to find out the total distance travelled in n sec(S_1) and to subtract the total distance travelled in (n-1) seconds(S_2) from it. The distance S_n covered in n^{th} seconds is

$$Sn = S1 - S2$$

$$= un + \frac{1}{2}an^2 - [u(n-1) + 1/2(n-1)^2)]$$

$$= u + an - 1/2\,a$$

$$Sn = u + a(n - 1/2)$$

b) Derive an expression for acceleration due to gravity (4)

Ans: Suppose a stone is held close to the surface of the earth. Then the distance between the stone of mass m and earth of mass M is equal to radius R of the earth. If g is the acceleration due to gravity, the gravitational attractive force is mg

Therefore $\frac{GMm}{R2} = mg$

$\rightarrow \boxed{g = \frac{GM}{R2}}$

III. a)Obtain an expression for the period of a simple pendulum using dimensions (4)

Ans: Assuming that the period t of a simple pendulum depends on the length l of the pendulum, the mass m of the bob, and the acceleration due to gravity g. Then the period can be expressed as ,

$$t = kl^x m^y g^3 \quad \rightarrow(1)$$

Here k is the dimensionless constant. Taking dimensions of both sides,

$$L^0M^0T^1 = L^xM^yL^3T^{-2z}$$

$$L^0M^0T^1 = L^{x+3}M^yT^{-2z} \quad \rightarrow(2)$$

Since the powers of L,M & Tare the same on both sides of eq^n (2)

$$0 = x + z$$

$$0 = y$$

$$1 = -2z$$

Solving we get x=1/2, y=0, z=-1/2

Subtracting the values of x, y& z in (1)

$$t = k\, l^{\frac{1}{2}} m^0 g^{\frac{-1}{2}}$$

$$t = k\sqrt{\frac{l}{g}}$$

b) Define torque and angular momentum and give the relation between them (4)

Ans: * A torque is required to produce an angular momentum

$$T = I\alpha = I\left(\frac{\omega_2-\omega_1}{t}\right) = \frac{I\omega_2 - I\omega_1}{t}$$

$$= \frac{L_2-L_1}{t} = \frac{dL}{dt}$$

*Torque is defined as the product of force f and perpendicular distance r between the line of action of the force and the axis of rotation.

Angular momentum L of a rotating body is the product of its moment of inertia and angular velocity ω . $L = I\omega$

IV. a)Can a body possess zero velocity and still accelerate ? Give example (4)

Ans: Yes. There can be situations in which a body possessing zero velocity can have acceleration. An example is a stone thrown up. When it reaches the topmost point ,its velocity will be zero .At the same time , its acceleration will be double .Same is the case of a simple pendulum at the extreme points.

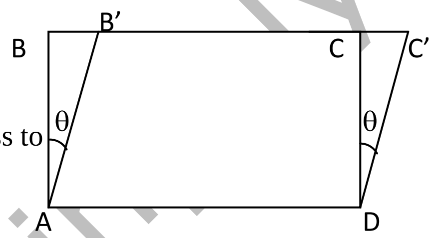
b)Explain Young's modulus, Bulk modulus and Rigidity Modulus of a material (4)

Ans: <u>Young's modulus</u> : It is ratio of the longitudinal stress to the longitudinal strain

$$Y = \text{Longitudinal stress}/\text{Longitudinal strain} = (F/A)/(l/L) = \frac{FL}{Al}$$

<u>Rigidity modulus</u> : It is the ratio of shearing stress to shearing strain

$$\eta = \frac{\frac{F}{A}}{\theta} = \frac{F}{A\theta}$$



<u>Bulk Modulus</u> : It is the ratio of the bulk stress to

$$K = \frac{P}{\frac{v}{V}} = \frac{PV}{v}$$

PART C

(Answer the full question from each unit. Each question carries 15 mark)

V. a)State Newton's second law of motion. Hence Derive the equation for force. (3)

Ans: Newton's second law states that the rate of change of momentum of a body is proportional to the applied force and takes place in the direction in which the force acts.

Consider a body of mass moving with a velocity u. When an unbalanced force F acts on it for a time t, its velocity changes to v. So, its initial momentum = mu

Final momentum = mv

Therefore changes in momentum = mv-mu

Rate of change of momentum $= \frac{mv-mu}{t}$

$$= \frac{m(v-u)}{t} = m\left(\frac{v-u}{t}\right) = ma$$

According to the second law ,the rate of change of momentum is proportional to force F. Thus,

$F \alpha ma$ ➔ F=kma Here k=1

Therefore F=ma

b) Define recoil of a gun. Applying law of conservation of momentum, obtain an expression for recoil velocity

Ans: Recoil velocity is the velocity with a gun moves backward when a bullet fired from it. When a bullet is fired from a gun the bullet moves forward with a high velocity. Since the total momentum of the gun and the bullet before firing is zero, this forward momentum of the bullet is balanced by the backward momentum generated in the gun. M and m are the masses and V and v are the velocities of the gun and the bullet respectively, the law of conservation of momentum implies that $MV + mu = 0$

Or, $V = -\frac{mv}{M}$ [-ve sign shows that the gun recoils backward]

c) A stone is dropped into water from a bridge 44.1 m above the water level. Another stone is thrown vertically downward one second later. Both stones reach water surface simultaneously. Find the downward velocity of the second stone ($g=9.8\ m/s^2$) (6)

Ans: Time taken for the first stone to fall freely from the bridge from 44.1 m height will be t

$$S = ut + \frac{1}{2}at^2$$

$$44.1 = 0 + \frac{1}{2} \times 9.8t^2$$

Therefore $t = \sqrt{\frac{2\times 44.1}{9.8}} = 3\ s$

Thus the second stone thrown after 1s with velocity u should cover a distance 44.1 m in 2 seconds. Taking motion of the second stone,

$$S = ut + \frac{1}{2}at^2$$

$$44.1 = u.2 + \frac{1}{2} \times 9.8 \times 2^2$$

$$= 2u + 19.6$$

$\Rightarrow$ 2u=24.5 $\Rightarrow$ u=12.25 m/s

VI. a)Why wheels are made circular?

Ans: Wheels have to overcome kinetic friction for the vehicle to move.Kinetic friction is of two types-sliding and rolling.Since wheels are made circular,the velocity of the point of contact of the wheel with respect to the floor remains zero although the center of wheel moves forward .Thatis rolling friction is quit small compared to sliding friction. Hence wheels are made circular.

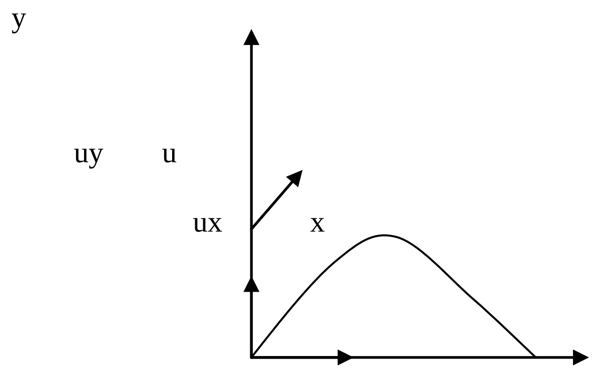
b)Derive an expression for: (6)

The maximum height reached.

Horizontal range in the case of a body projected upward.

Ans:

Consider the vertical displacement H of the projectile.



Initial vertical velocity = $u\ \sin\Theta$

Final vertical velocity = 0

Vertical acceleration = -g

Vertical displacement = H

We have, $v^2 = u^2 + 2as$

Therefore $0=u^2\sin^2\Theta -2gH$

Or,

$$H = \frac{u^2 sin^2\Theta}{2g}$$

ll. The horizontal displacement of the projectile is R. Acceleration is 0.Hence,

Horizontal displacement = R

Horizontal acceleration = 0

Time taken = T

Horizontal velocity = $u = \cos\Theta$

W have, $S = ut + \frac{1}{2}at^2$

Therefore $R = u\cos\Theta$.T+0

We know that the time of flight, $T = \frac{2u\sin\Theta}{g}$

Therefore, $R = \frac{u\cos\Theta * 2u\sin\Theta}{g}$

$$R = \frac{u^2 \sin 2\Theta}{g}$$

A train moves around a bend of radius 100m with a speed of 72kmphr.Calculate the angle of bending and find the height of outer rail over inner rail if the distance between the rails is 1.52m.

Ans: $\tan\Theta = \frac{v^2}{rg}$

$\tan\Theta = \frac{(72 * 1000/3600)^2}{100 * 9.8} = 0.408$

$\Theta = \tan^{-1}(o.408) = 22^0$

$\tan\Theta = \frac{height\ of\ outer\ rail\ over\ inner}{distance\ between\ the\ rails}$

$0.408 = \frac{h}{1.52}$

$h = 1.52 * 0.408 = 0.62m$

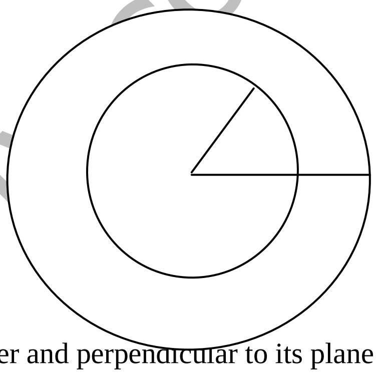
UNIT 2

VII. a) Distinguish between deforming force and restoring force. (3)

Ans: Deforming force is that which is applied to change the3 configuration of the body. Restoring force is the internal force which tends to bring the body back to its original configuration

b) Derive an expression for moment of inertia of a uniform circular disk about an axis passing through its center and perpendicular to its plane. (6)

Ans: Let M be the mass and R the radius of the disc. The disc R
Can be imagined to be made up of a large number of rings of Small width and of gradually increasing radius from 0 to R.
Consider such a ring of radius x and width dx.



Total mass of the disc = M.

Mass per unit area of the disc = $\frac{M}{\pi R^2}$

Area of the ring of radius x and width dx = 2πxdx

Mass of the ring = $2\pi x dx(\frac{M}{\pi R^2})$= 2xdx M/$R^2$.

Moment of inertia of this ring about the axis passing through the center and perpendicular to its plane is therefore aMx^3dx/R^2.Therefore the moment of inertia of the disc can be obtained by integrating between the limits x=0 to x=R. Thus,

$I = \int_0^R (2M/R^2)\, x^3 dx$

$I = 2M/R^2 \int_0^R x^3 dx$

$I = 2M/R^2\ [x^4/4]_0^R$

$I = \frac{1}{2} MR^2$

c) Calculate the orbital velocity required to maintain a satellite in circular orbit at 160km above earth. Radius of earth is 6400km and acceleration due to gravity at this height is 9.8m/s^2. Also find the time period of the satellite.

Ans: Orbital velocity $v_0 = R\sqrt{\frac{g}{R+h}}$

I.e., $v_0 = 6400 * 10^3 * (\frac{9.8}{(6400+160)*10^3})^{1/2} = 7822.42\ m/s$

Time period, $T = 2\pi\sqrt{\frac{(R+h)^3}{gR^2}}$

i.e., $T = 2\pi[\frac{[(6400*160)*10^3]^3}{9.8*(6400*10^3)^2}]^{\frac{1}{2}}$

$T = \frac{1.68*10^{10}}{20.03*10^6} = 838.5\ s$

VIII. a)What is the difference between ordinary and geostationary satellite?

Ans: Satellite is an object revolving around a planet. It can be natural or artificial. An artificial satellite whose orbital period is the same as the rotational period of the earth is called a geostationary satellite.

b) The distance of moon from earth is $3.8 * 10^5$ km and its mass is $7.36*10^{22}$ kg. Find the angular momentum of the moon about the earth. The angular velocity of moon around the earth is $6.46*10^{-5}$ rad/sec.

Ans: Angular velocity, $\omega = \frac{v}{r} = 6.46 * 10^{-5}$ rad/sec.

R= $3.8 * 10^5$ km = $3.8 * 10^8$ m.

M= $7.36*10^{22}$ kg

Angular momentum, $L = mR^2\omega$

Here, L =$7.36 * 10^{22} * (3.8*10^8)^2 * 6.46*10^{-5}$

= $6.87 * 10^{35}$ kg rad/sec.

c) The diameter of a brass road is 6mm.What force in Newton will stretch by 0.2% of its length? ($Y=9*10^{10}$ Nm^{-2}). (6)

Ans: Diameter = 6 mm , Radius = 3 mm

l / L= 0.2% = 0.2/100

Y= $9*10^{10}$ N/m^2

$$Y = \frac{F/l}{l/L} = \frac{Fl}{Al}$$

$$F = \frac{YAl}{L} = \frac{9*10^{10}*\pi(3*10^{-3})^2*0.2}{100}$$

F = 5089.38 N