APPLIED SCIENCE –I (PHYSICS)
MARCH 2011

PART A

(Answer the following questions in one or two sentence. Each question carries 2 marks)

I. a) Write the advantages of SI system over other systems of unit.

Ans: 1.SI is universally accepted system

2. SI is a coherent system.

3. SI is compressive

b) Define angular momentum. Give the relation between torque and angular momentum.

Ans: Angular momentum is the moment of linear momentum about an axis. L= Pr=mvr=Iω.

A torque is required to produce an angular momentum. $T=I\alpha = I((\omega_1 - \omega_2)/ t)$.

I.e. $T = ((L_2 - L_1)/ t) = dL/dt$.

II. a) A body projected vertically will reach the same point with the magnitude of the velocity. Justify this statement and find the time of flight.

Ans: For a body projected vertically up, V=0, a= -g.

Therefore v= u+at.

0 = u – gt

u = gt………..(1)

During the downward journey, u=0, a=g. Let v the velocity at the point where it started its journey. We get v=0+gt, ie v=gt…………………….(2)

Here (1) and (2) supports the fact that these two velocities are the same; since the time of ascent is equal to the time of descent.

<u>Time of flight:</u>

Considering the vertical motion of the projectile, the vertical displacement is zero.

Initial vertical velocity, u_y=u SinΘ

Vertical acceleration, a_y= -g

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

$0= u\, Sin\Theta * T – \frac{1}{2} g T^2$

$\frac{1}{2} g t^2= u\, Sin\Theta * T$

$T = 2u\, Sin\Theta/g$

b) Define circular motion.' Can a body move with uniform velocity along a circular path'. Give reason. (4)

Ans: When a point object is moving on a circular path with a constant speed, then the motion of the object is said to be a uniform circular motion. But when a body is in uniform circular motion, the velocity of the object(represent by the tangent to the circular path at a given instead) is changing its direction continuously, hence it is a case of uniformly accelerated motion.

III. a) Starting from Newton's 2^{nd} law, velocity the relation F=ma. (4)

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,

Fαma ➔ f=kma Here k=1

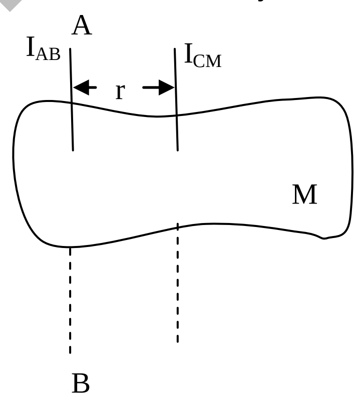
Therefore F=ma

b) Compare linear K.E and rotational K.E. Prove that for a body rotating with unit angular velocity its moment of inertia is equal to twice its rotational K.E. (4)

Ans: when a body of mass m is moving along a straight line with a velocity v, it has a translational K.E, E= ½ mv^2. A body rotating about a fixed axis possesses K.E because its constituent particles are in motion even though the body is not in translation from one place to another. This energy of a body due to its rotational motion is called rotational kinetic energy. If I is the moment of inertia and ω its angular velocity, the rotational K.E is ½ $I\omega^2$. For a body moving with unit angular velocity, ω=1, K.E= ½ I

I.e. moment of inertia, I=2(K.E)

IV. a) State and explain parallel and perpendicular axes theorems. (4)



Ans: <u>Theorem of Parallel axes</u>: -

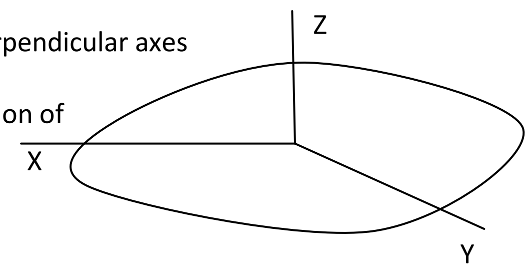
The moment of inertia I_{AB} of any rigid body about a given axis is equal to the sum of its moment of inertia I_{CM} about a parallel axis passing through the centre of gravity and product of the mass of the body and the square of the distance between the axes

$$I_{AB} = I_{CM} + Mr^2$$

<u>Theory of perpendicular axes</u>:-

The sum of moments of inertia of a plane about two mutually perpendicular axes lying in its plane is equal to the moment of inertia about an axis perpendicular to the plane passing through the point of intersection of the first two axes

$$I_x + I_y = I_z$$



b) Distinguish between stress and strain. Deduce the expression for bulk modulus. (4)

Ans: Stress is measured by the applied force per unit area. Stress = F/A. Stress is the fractional deformation from a stress. It is measured by the ratio of the change in dimension of a body to the original dimension.

Bulk modulus comes into play when a body is subjected to a uniform normal force distributed over the whole of its surface. If v is original volume and v the change in volume, bulk strain is v/v. Hence the bulk modulus K= Pv/v.

PART C

V. a) Define impulse. Give its unit. (3)

Ans: Impulse is a large force acting on a body for a very short time. I=Ft

Therefore its unit is Ns.

b) A football is kicked with a velocity ‘v’ at an angle Θ with the horizontal. Derive the equation for maximum height and horizontal distance travelled by the ball. (6)

Ans: <u>Maximum height (H):</u>

Consider the vertical displacement H of the projectile.

Initial velocity = u SinΘ
Final vertical velocity=0
Vertical acceleration= -g
Vertical displacement= H
Using the relation $v^2=u^2+2as$.
$0= u^2Sin^2\Theta - 2gH$
Or, $H= u^2Sin^2\Theta/ 2g$

<u>Horizontal Range(R):</u>

The horizontal displacement of the projectile is R. In this motion, there is no acceleration.
Hence, horizontal displacement=R.
Horizontal acceleration=0.
Time taken=T.
Horizontal velocity= u cosΘ
Using the relation $S= ut+ ½ at^2$, we get R= u CosΘ. T
But, T=2 u SinΘ/g
Therefore R= u cosΘ. 2 u SinΘ/g
$R= u^2 Sin2\Theta/g$

c) A body travels 25m during 6^{th} second. Find out the distance travelled during 15^{th} second.
Ans: $S_n= u+a (n – ½)$
25= u+a(6 – ½) = u+ (11/2) a
50= u+11a………(1)
30= u+a(8 – ½) = u+ (15/2) a
60= u+ 15a………(2)
Solving, $a= 2.5m/s^2$, u= 22.5m/s
Therefore $S_n= 22.5+2.5(15 – ½)$
$S_n=58.75m$.

VI. a) Write the applications of the dimensional method. (3)
Ans: The three applications of dimensional method,
1. To convert a physical quantity from one system of units to another.
2. To check the correctness of an equation.
3. To derive simple relations between physical quantities.

b) Derive the expression for period of simple pendulum.
Ans: Let the period ‘T’ of the simple pendulum depend on the length ‘l’ of the pendulum, mass ‘m’ of the bob and acceleration due to gravity ‘g’ .
Therefore $T \alpha l^x m^y g^z$……………………………(1)
Or, $T=K. \alpha l^x m^y g^z$
Taking dimensions on both sides ,
$L^0M^0T^1 = (L^1M^0T^0)^x (L^0M^1T^0)^y (L^1M^0T^{-2})^z$
$L^0M^0T^1 = L^{x+z} M^y T^{-2z}$
Equating the powers of M,L and T on both sides .
0=y
0= x+z
1= -2z
Solving, we get, x=1/2, y=0, z= -1/2.
Substituting in (1),
$T=K l^{1/2} g^{-1/2}$
I.e. $T = K\sqrt{\frac{l}{g}}$

c) A stone of mass 0.1kg is tied to the end of a string of length 0.2m is whirled in a horizontal circle with an angular velocity 2rad/sec. Find the linear velocity centripetal acceleration and centripetal force.

Ans: M=0.1kg

r=0.2m

ω=2 rad/s

Linear velocity, v = rω = 0.2*2 = 0.4m/s.

Centripetal acceleration, a = $v^2/r = 0.4^2/0.2 = 0.8\ m/s^2$

Centripetal force, F= mv^2/r = 0.1*0.8 = 0.08N

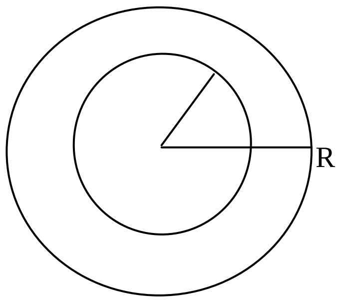
VII. a) Define radius of gyration. Give its equation and unit. (3)

Ans: If the whole mass M of a body is supposed to be concentrated at a point of distance 'K' from the axis such that MK^2 has the same axis , the length K is called radius of gyration

$$K = \sqrt{\frac{I}{M}}$$

Unit of radius of gyration is m.

b) A disc of mass M and radius R is rotating about an axis passing through its center and perpendicular to its plane. Derive the expression for the moment of inertia of the disc. (6)



Ans : Let M be the mass and R the radius of the disc. The disc 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 period of a satellite rotating at a height 36000km from the surface of earth is $6*10^{24}$kg and radius is 6370km. (6)

Ans: h=36000km

M=$6*10^{24}$kg

R=6370km

G= $6.67*10^{-11}\ Nm^2kg^{-2}$

Period of revolution, $T = 2\pi\sqrt{\frac{(R+h)^3}{GM}}$

$$T = 2\pi\sqrt{\frac{(6370*10^3+36000*10^3)^3}{6.67*10^{-11}*6*10^{24}}}$$

$$T = 86622.16\ s$$

VIII. a) Explain the concept of geostationary satellite. (3)

Ans: An artificial satellite whose orbital period is same as the rotational period of the earth is called geostationary satellite. Its orbital period is 24hrs, and is at a distance of 36000km from the surface of earth.

b) State Newton's law of gravitation. Derive the expression for orbital velocity of a satellite.

Ans: Newton's universal law of gravitation states that every body in universe attracts every other body with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

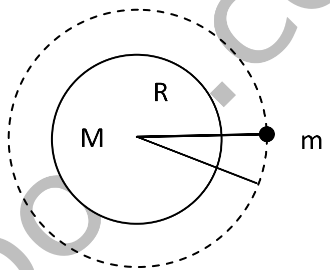
$F \alpha m_1 m_2/r_2$.The proportionality is removed by introducing a constant called universal gravitational constant G. G = $6.67*10^{-11}Nm^2/kg^2$. Orbital velocity is the velocity with which a satellite revolves around the earth. The velocity with which a satellite moves in a closed orbit is called orbital velocity. Consider a satellite of mass m revolving around the earth of mass M and radius R. Let the satellite be revolving at a height h above the surface of the earth .the necessary centripetal force for rotation is provided by the gravitational force .if v is the velocity of the satellite ,

Centripetal force = $\frac{MV^2}{R+h}$ → (1)

Gravitational force = $\frac{GMM}{(R+h)^2}$ →(2)

$$\frac{MV^2}{R+h} = \frac{GMM}{(R+h)^2}$$

$$V^2 = \frac{GM}{R+h} \rightarrow \boxed{V = \sqrt{\frac{GM}{R+h}}} \rightarrow (4)$$



Eq^n (4) gives the eq^n for orbital velocity

c) A mass of 50kg is suspended from the end of wire of length 100cm and diameter 2mm. Calculate the elongation of wire if the young's modulus of the wire is $12.5*10^{10}Nm^{-2}$. Compute the elongation of the wire if the mass is replaced by 100kg.

Ans: m=50kg

L=100cm=$100*10^{-2}$m

Diameter=2mm, radius= 1mm

Therefore A= $\pi r^2 = 3.14*(1*10^{-3})^2 = 3.14*10^{-6}m^2$.

Y= FL/Al

l= FL/AY

l=$490*100*10^{-2}/(3.14*10^{-6}*12.5*10^{10}) = 1.25*10^{-3}$m.

If the mass is replaced by the 100kg, force becomes double. Therefore in the equation for elongation, l becomes double the first value. I.e. l becomes $2.5* 10^{-3}$m.