APPLIED SCIENCE –I (PHYSICS)
MARCH 2014

PART-A

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

I. a) Write down the dimensional formula for power (2)

Ans: The dimensional formula for power is ML^2T^{-3}

$$Power - Work/time = \frac{Force \times Displacement}{Time}$$

D.F: $\frac{MLT^{-2} \times L}{T} = ML^2T^{-3}$

b) State Hooke's law (2)

Ans: Hooke's law states that the strain produced in a body is directly proportional to the stress provided the stress is not very large.ie, Stress/Strain=Constant.

This Constant is called Modulus of elasticity.

PART-B

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

II. (a) When a body is thrown up, show that the time taken of ascent is equal to the time of descent. (4)

Ans: Let a body be projected vertically up with a velocity u. Let time taken to reach the maximum height (time of ascent) be t_1.At the height point, velocity is zero using v = u+ at_1, we get

$0 = u - gt_1$ or $t_1 = u/g$ → (A)

Let h be the maximum height reached.

$$V^2 = u^2 + 2as$$
$$0 = u^2 - 2gh$$
$$Or, h = u^2/2g \rightarrow (1)$$

Let t_2 be the time of ascent for downward travel, initial velocity is zero.

$$S = ut2 + ½\, at2^2$$

Ie, $h = 0 + ½\, g{t_2}^2$

Sub (1) in the above eq^n

$$\frac{u^2}{2g} = ½\, g{t_2}^2$$

$$\rightarrow {t_2}^2 = \frac{u^2}{g^2}$$

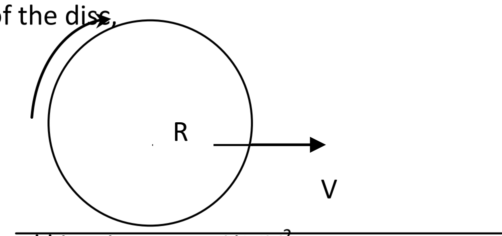
$$\rightarrow t_2 = u/g \rightarrow (B)$$

Comparing (A) & (B), $t_1 = t_2$

I.e. time of ascent =time of descent

(b) Derive kinetic energy of a disc rolling on a horizontal surface

Ans: Consider a disc of radius R and mass M. When it rolls, it has both linear velocity (v) and angular velocity (ω).Consequently, it has two types of kinetic energies – translational and rotational. If ω is the angular velocity and I is the moment of inertia about the axis of the disc,



Rotational kinetic energy $=\frac{1}{2} I\omega^2$.

For a disc rolling about its own axis, moment of inertia is $½MR^2$

If v is the linear velocity, ω=V/R

Hence rotational kinetic energy=½ ($½MR^2$) $(V/R)^2$

$=1/4\ MV^2$

In addition to the fractional kinetic energy, the disc has a translational kinetic energy $½MV^2$.

Therefore the total kinetic energy of the rolling disc is $3/4\ MV^2$.

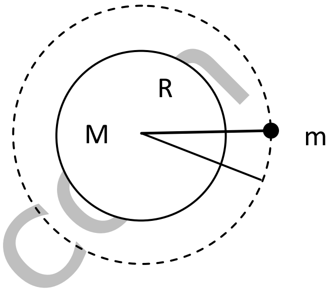
III. a) Illustrate Centripetal force in banking of curves (4)

Ans: If a vehicle is moving along horizontal curve, the weight of the vehicle is balanced by the -normal reaction while the force of friction provides the centripetal force. For the vehicle to turn without depending on the fractional force, the outer portion of the curved path is raised slightly above the inner. This process is called banking. Then a component of the normal reaction will contribute to the centripetal force. If v is the optimum speed and rather radius of the curve, the angle of banking 'θ' is given by,

$$\tan\theta = v^2/rg$$

b) Derive an expression for orbital velocity of a satellite (4)

Ans: 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)

Equating (1)&(2)

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

$V^2 = \frac{GM}{R+h}$ ➔ $V = \sqrt{\frac{GM}{R+h}}$ → (3)

Eq^n (3) gives the eq^n for orbital velocity

IV. a) What is impulse? Calculate the impulse required to stop a car of mass 2000 kg moving with a speed of 30 m/s

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

$$I = F.t$$
$$= ma.t$$
$$= m\left(\frac{v-u}{t}\right).t = m(v-u) = mv - mu$$

So, impulse is measured by the change in momentum

Here, m = 2000kg, u = 30 m/s ,v = 0 m/s

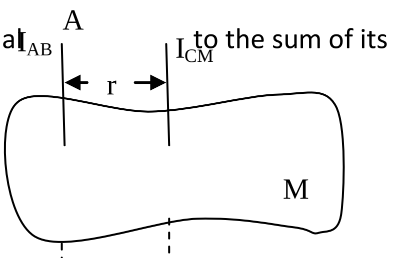
Therefore $I = mv - mu$

= 60,000 kg m/s

b) State and explain parallel and perpendicular axes theorem.

Ans: Theorem of Parallel axes: -

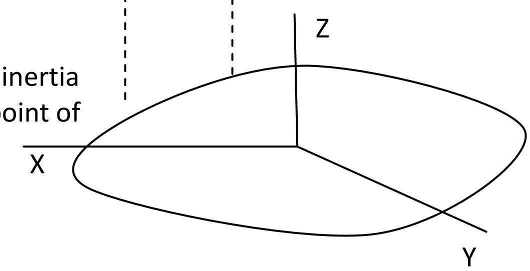
The moment of inertia I_{AB} of any rigid body about a given axis is equal to the sum of its moment of inertia I_{CM} about a parallel axis passing through the centre of gravity and product of the mass of the body and the square of the distance between the axes



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

Theory of perpendicular axes:-

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



$$I_x + I_y = I_z$$

PART C

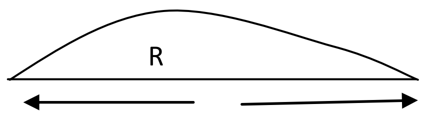
(Answer one full question from each unit. Each question carries 15 marks).

UNIT 1

V. a) Coefficient of viscosity of water in SI is 10^{-3}.Find its value in CGS units using dimensional analysis.(3 Mark)

Ans: Dimensional formula of coefficient of viscosity is $ML^{-1}T^{-1}$. Let M_1, L_1 & T_1 be the units in SI and M_2, L_2 & T_2 those in CGS.
Therefore $10^{-3} M_1L_1^{-1}T_1^{-1} = x M_2L_2^{-1}T_2^{-1}$
i.e., $x=10^{-3} *(M_1/M_2) (L_1/L_2)^{-1}(T_1/T_2)^{-1}$ ……………….. (1)
M_1= 1Kg, M_2 = 1g
$M_1/M_2 = 1000 = 10^3$
L_1= 1m, L_2 = 1cm
$L_1/L_2 = 100 = 10^2$
$T_1 = T_2$ = 1s
T_1/T_2= 1
Substitute in (1), $x = 10^{-3}*10^3*(10^2)^{-1}*1^{-1}$
$= 10^{-3}*10^3*10^{-2}$
$= 10^{-2}$
Therefore the value of coefficient of water is 10^{-2} in CGS unit.

b) Obtain an expression for maximum range for a body projected with a velocity 'u' .What will be its maximum range when velocity is doubled? (6 mark)
Ans: The horizontal displacement of the projectile is R. In this motion, there is no acceleration.Hence,
Horizontal displacement=R
Horizontal acceleration=O
Time taken=T



Horizontal velocity = $u \cos \Theta$
Using the relation $s= ut + 1/2\ at^2$, we get $R=u \cos \Theta\ T$.
But the time of flight $T=2u \sin \Theta /g$. Substituting this value of T,
$R = u \cos \Theta * 2u \sin \Theta / g$
$R = u^2 \sin 2 \Theta /g$
From this equations, it is clear that R changes when θ changes. For a given value of u, the range is maximum when $\sin 2\Theta$ is maximum. Maximum value of $\sin 2 \Theta =1$
Maximum range is, $R_{max}= u^2/g$
When velocity is doubled, u= 2u.
$R_{max}= (2u)^2/g = 4u^2/g$

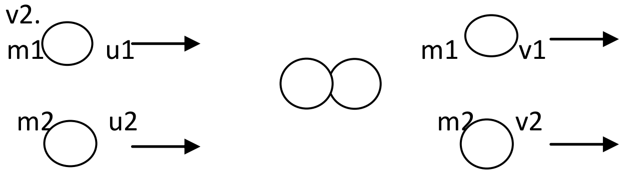
c) A newtron having a mass of $1.67x10^{-27}$kg and moving at 10^8 m/s collides with a deuteron at rest and sticks to it . Calculate the speed of the combination(mass of deutron=$3.34*10^{-27}$kg).
Ans: $m_1u_1+m_2u_2=m_1v_1+m_2v_2$.
Here $v_1=v_2=v$, $u_2=0$
Thus, $m_1u_1+0=(m_1+m_2)v$
Therefore $v= m_1u_1/m_1+m_2$
$= 1.67x10^{-27}x10^8/(1.67x10^{-27}+3.34x10^{-27})$
$= 3.33x10^7$m/s

VI. a) Sand is thrown on track covered with snow in hilly areas. Why?(3 mark)
Ans: When a hilly area is covered with snow, the friction will get reduced, and there is chance for accidents. When sand is thrown on such tracks, friction increases, and chances for accident get reduced.

b) Prove the law of Conservation of momentum from Newton's second and third laws.(6)

Ans: Law of conservation of momentum states that when two or more bodies collide, the sum of their momenta before impact is equal to the sum of momenta after impact.

Consider two bodies of masses m1 and m2 moving along a line with velocities u1 & u2 respectively. After colliding for a time t,their velocities are v1 and v2.



Momentum of m2 before Collision = m_2u_2 .

Momentum of m2 after Collision = m_2v_2 .

Changes of momentum in t seconds = m_2v_2- m_2u_2 .

Rate of change of momentum m2 = $(m_2v_2-m_2u_2)/t$.

A change of momentum will occur only by a force. In this case the force causing the change in momentum is action of the body m_1 on m_2.

Therefore

$$Action = \frac{m2v2 - m2u2}{t}$$

Change of momentum of first body in t seconds = $m_1v_1=m_1u_1$.

Rate of change of momentum of the first body =$(m_1v_1-m_1u_1)/t$.

This rate of change of first body is the reaction. Since action and reaction are equal and opposite.

$(m_2v_2 - m_2u_2) /t = - (m_1v_1-m_1u_1)/t$

$m_1u_1+m_2u_2=m_1v_1+m_2v_2$

i.e., total momentum before collision is equal to the total momentum after collision.

c) A body moving with uniform acceleration describes 10m in the 2^nd second and 20m in the 4^th second of its motion. Calculate the distance moved by it in the 5^th second. (6)

Ans: Distance travelled during the n^th second is

S_n= u + a (n-1/2)

10 = u+a (2-(1/2))

10 = u+3/2a

20 = 2u+3a……….(1)

20 = u+a (4-(1/2))

20 = u+7/2a

40 = 2u+7a……….(2)

By solving (1) and (2), we get, a= 5m/s^2, u = 2.5m/s.

Therefore distance moved in the fifth second is,

S_5 = 2.5+5(5-(1/2)) =25m.

UNIT 2

VII. a) Explain the term 'Elastic fatigue'.

Ans: The property of an elastic body due to which its behavior becomes less elastic under the action of repeated alternating deforming forces.

b) What do you understand by geostationary satellites? Deduce the value of its height above the surface of the earth in km.(Radius of earth is 6400km,and g of earth is 9.8mm/s^2).

Ans: An artificial satellite whose orbital period is the same as the rotational period of the earth is called a geostationary satellite. The period of a satellite is,

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

For geostationary satellite T = 24hrs = 864400 seconds. Therefore, $864400 = \frac{2\pi\sqrt{(6400000+h)^3}}{9.8*6400000^2}$

$$\frac{9.8 * 86400^2 * 6400000^2}{4 * 3.14 * 3.14} = (6400000 + h)^3$$

$$h = 35954 * 10^3 m = 35954 km$$

c) A circular disc of mass 300kg and diameter 4m rotates with an angular velocity of 90 rpm. When a torque is applied, its velocity is reduced to 60 rpm in 30 s. Find the value of the torque.

Ans: M=300 kg, R=2m, ω_1=90 rpm , ω_2 =60rpm , t= 30s.

$Torque, T = I\alpha$

$Moment\ of\ Inertia, I = \frac{1}{2} MR^2$

$I=1/2*300*2^2 = 600\ kg\ m^2$

$Angular\ accelaration, \alpha = \frac{\omega_2 - \omega_1}{t}$

Initial angular velocity ω_1=90 rpm = 2π*90/60 = 3π rad/s.

Angular velocity after 30s ω_2=60 rpm = 2π*60/60 = 2π rad/s.

Therefore angular acceleration $\alpha = \frac{\omega_2 - \omega_1}{t} = \frac{3\pi - 2\pi}{30} = 0.033\pi = 0.1037\ rad/s^2$

Therefore torque, $T = I\alpha$ = 600*0.1037 = 62.22Nm.

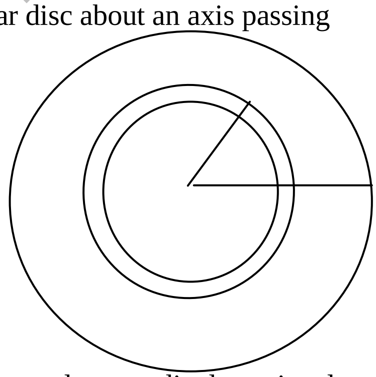
VIII. a) Distinguish between 'g' and 'G'. (3)

Ans: g is the acceleration due to gravity. It is the acceleration experienced by a particle which is falling freely to the earth. Its value is 9.8 m/s^2.

G is the universal gravitational constant. It can be defined as the numerical value of the force of attraction between two masses of 1kg each, separated by a distance of 1m.G=6.67*10^{-11}kg-^{1}m^{3}s^{-2}.

b) Derive an expression for the moment of inertia of a uniform circular disc about an axis passing through its centre and perpendicular to its plane.

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,

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

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

$$\boldsymbol{I = 2M/R^2\, [x^4/4]_0^R}$$

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

c) A steel wire of length 4.7m and area of cross section 3*$10^{-5}m^2$ under a given load. What is the ratio of Young's modulus of steel to that of copper?

Ans: Steel: $L_{s=}$4.7m ,A_s= 3*$10^{-5}m^2$, l_s , F_s.

Copper : $L_{s=}$3.5m ,A_c= 3*$10^{-5}m^2$, l_c , F_c.

Given that $l_s=l_c$ and $F_s=F_c$.

We know y=FL/Al

Taking ratio of Young's Modulus of steel to copper, we get

$$\frac{Ys}{Yc} = \frac{\frac{FL_s}{lA_s}}{\frac{FL_c}{A_c l}}$$

I.e.,

$$\frac{y_s}{y_c} = \frac{L_s A_c}{A_s L_c}$$

$$\frac{y_s}{y_c} = \frac{4.7 * 4 * 10^{-5}}{3 * 3.5 * 10^{-5}}$$

$$\frac{y_s}{y_c} = 1.7$$