APPLIED SCIENCE –I (PHYSICS)
OCTOBER 2012

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

I. a)What are giga and fento?

Ans: Giga and fento are two prefixes used to indicate multiples and submultiples. Giga stands for 10^9 and fento for10^{-15}.

b) Define rotational kinetic energy. Give expression for it.

Ans: A body rotating about a fixed axis possess kinetic energy because its constituent particles are in motion even though the body as a whole in not in translation. This energy by virtue of its rotational motion is called rotational kinetic energy. If I is the moment of inertia and ω its angular velocity, the rotational kinetic energy is given by ½ $I\omega^2$.

PART B

II. (Answer any two full questions. Each carries 8 mark.)

a) Obtain the expression for range of a projectile deduce the condition for maximum range.

Ans: The horizontal displacement of the projectile is the R. (4)

Acceleration is 0.

Hence, Horizontal displacement = R

Horizontal acceleration = 0

Time taken,$T = \frac{2u\sin\theta}{g}$ (Time of flight)

Horizontal velocity = u cosΘ

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

Substituting the above values, R= u cosΘ * T

$= u\cos\Theta * \frac{2u\sin\theta}{g}$

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

For a given value of u, the range is maximum when $\sin 2\Theta$=1.

Therefore maximum range is $R_{max}=u^2/g$. When $\sin 2\Theta = 1$, $2\Theta=90^0$ or $\Theta = 45^0$.

Hence to get the maximum range, the angle oh projection should be 45^0

b) Explain why the outer end of road is at a higher level than the inner on the current portion of the road. (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 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,

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

III. Define impulse of a force and show that it is equal to change in momentum. (4)

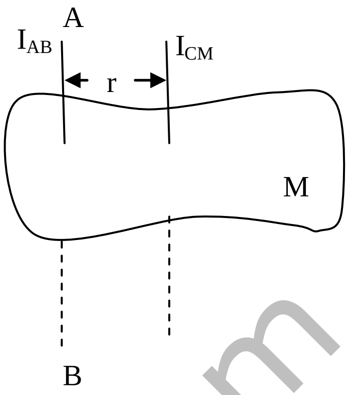
Ans: impulse is a large force acting on a body for a very short time. If a force F acts on a body for a short time t, the impulse

I = F . t

= ma . t
= m((v-u)/t). t
I= mv-mu. I.e., impulse is changing momentum.

b) Define parallel and perpendicular axes theorem.

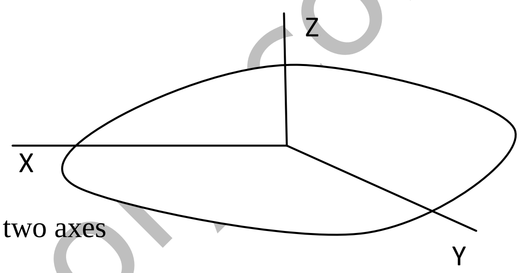
<u>Theorem of Parallel axes</u>: -



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

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

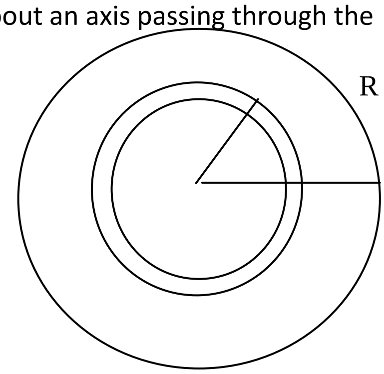
<u>Theory of perpendicular axes</u>:-



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

$$I_x + I_y = I_z$$

IV. Obtain an expression for the moment of inertia of a disc about an axis passing through the center 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,

$$I = \int_0^R (2M/R^2) x^3 dx$$
$$I = 2M/R^2 \int_0^R x^3 dx$$
$$I = 2M/R^2 \, [x^4/4]_0^R$$
$$I = \frac{1}{2} MR^2$$

b) State Hook's law. Deduce the expression for bulk modulus. (4)
Ans: Hook's law states that within elastic limit, stress provided is directly proportional to the strain produced in the body, i.e. Stress/ Strain = Constant . This constants called modulus of elasticity. Bulk modulus comes into play when a body is subjected to a uniform normal force distributed over the whole of its surface. In such case the body is either squeezed or enlarged keeping its shape constant. But the volume under goes a change. If P is the normal force/unit area, V the original volume and ν the change in volume, the bulk strain is ν/V. Hence the bulk modulus 'K' will be K=P/ (ν/ V) = PV/ ν.
PART C
(Answer one full question from each unit. Each question carries 15 marks)
UNIT 1

V. a) Explain the recoil velocity of a gun. (3)

Ans: When a gun is fired, the bullet moves forward with high velocity. Since the total momentum of the bullet and the gun before firing is 0, the forward momentum generated on the bullet is balanced by the backward momentum generated in the gun. If the M and m are the masses, and V and ν are the velocities of the gun and the bullet respectively, by law of conservation of momentum, $MV + m\nu = 0$.
Or, $V = -m\nu/M$ (recoil velocity).

b) When a body is thrown up, show that time of ascent is equal to time of descend. (6)

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, 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.

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

ie, $h = 0 + \frac{1}{2}gt_2^2$

Sub (1) in the above eq^n

$$\frac{u^2}{2g} = \frac{1}{2}gt_2^2$$

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

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

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

ie, time of ascent =time of descent

c) A body travels 100m during 4th second and 150m during the 9th second of its motion. Find the distance traveled by the body during the 11th second of its motion.

Ans: S_n=u+a(n- 1/2)
100=u+a(4 – 1/2)
100=u+a7/2
200=2u+7a………………………..(1)
150=u+a(9-1/2)
150=u+a17/2
300= 2u+17a……………………….(2)
Solving,
a=10m/s^2,u=65m/s
S_{11}=65+10(11-1/2)
S_{11}=65+105
S_{11}=170m

VI. a) Write the advantages of SI system over the other system unit. (3)

Ans: 1.SI is universally accepted system
2. SI is a coherent system.
3. SI is compressive

b) Derive the expression for the period of a simple pendulum . (6)

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 $T \propto l^x m^y g^z$……………………………(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 900g tied at the end of string is whirled round horizontally in a circle of radius 2m, with a speed of 120 rev/min. Calculate the centripetal acceleration and force. (6)
Ans: M=900g =0.9g
R=2m
ω= 120rev/min = 120*2π rad/60sec = 4π rad/s.
Centripetal acceleration $a= r\omega^2 = 2*(4\ \pi)^2 = 315.8\ m/s^2$
Centripetal force $F= mr\ \omega^2 = 0.9*32\ \pi^2 =284.24$ N

UNIT 2

VII. a)Define radius of a gyration.
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

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

b) A circular disc of mass 0.5kg and radius 0.1m is rotating about a target in its plane. If it makes 5 rotations/min, Calculate its rotational kinetic energy. (6)
Ans: M=0.5kg
R=0.1m
ω= 5rotation/min = 5*2π rad/60sec = 0.52 rad/s.
Rotational kinetic energy = ½ $I\omega^2$.
I: Moment of inertia for a disc about a tangent in its plane is 5/4 $Mr^2 = 6.25*10^{-3}kgm^2$.
Therefore rotational kinetic energy = ½ $*6.25*10^{-3}*(0.52)^2 = 8.45*10^{-4}J$
c) Derive the equation for time period of a satellite. (6)
Ans: Time taken by a satellite to complete one revolution is called its period T. If an artificial satellite is revolving at a height h from the surface of the earth, Distance covered in time T = 2π(R+h).
Velocity, v_0= 2π(R+h)/T
Or, T = 2π(R+h)/ v_0 where v_0 is orbital velocity. We know that $v_0 = \sqrt{\frac{GM}{R+h}}$
Therefore $T = \frac{2\pi(R+h)}{\sqrt{\frac{GM}{R+h}}}$
I.e. $T = 2\pi\sqrt{\frac{(R+h)^3}{GM}}$
Substituting $GM=gR^2$, $T = 2\pi\sqrt{\frac{(R+h)^3}{gR^2}}$
Since the satellite is revolving close to the earth, h<<R.
Therefore $T = 2\pi\sqrt{\frac{R^3}{GM}}$ or, $T = 2\pi\sqrt{\frac{R}{g}}$

VIII. a) Explain 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 universal law of gravitation. Derive the expression for orbital velocity of a satellite. (6)

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.

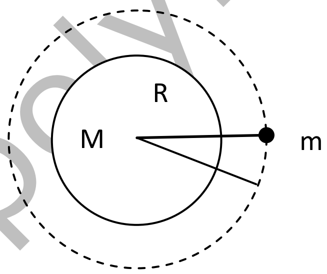
$F \alpha m_1 m_2/r_2$.The proportionality is removed by introducing a constant called universal gravitational constant G. G = $6.67*10^{-11}Nm^2/kg^2$. Orbital velocity is the velocity with which a satellite revolves around the earth. The velocity with which a satellite moves in a closed orbit is called 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 10kg weight is attached to one end of a copper wire 4m long and diameter 2mm. Find the extension produced in Young's modulus of wire is equal to $1.25*10^{11}N/m^2$. (6)

Ans: m=10kg

L = 4m

Diameter=2mm, Radius=1mm

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

Y= $1.25*10^{11}N/m^2$

We have, Y = FL/Al

Therefore, l =FL/YA = mg. L/Y.A

I.e. l = $(10*9.8*4) / (1.25*10^{11}*3.14*10^{-6}) = 9.98*10^{-4}$m.