APPLIED SCIENCE –I (PHYSICS)
MARCH 2013

PART A

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

I. a) Write the limitations of dimensional analysis (2)

Ans: (i) Numerical constants, trigonometric ratios, angles etc appearing in a formula cannot be deduced from dimensional method.

(ii)This fails if a physical quantity depends on more than 3 others quantities.

(b) Define radius of gyration and write expressions for it. (2)

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

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

PART B

Answer any two full questions. Each question carries 8 marks

II. a) Explain why there is a speed limit for a vehicle going round a curved road (4)

Ans: For a vehicle to go round a curved road, the centripetal force is provided by the force of friction. 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 normal reaction will contribute to the centripetal force. Then the optimum speed v, the radius of the curve r and the angle of banking θ is related by the equation

$$\tan\theta = \frac{v^2}{rg}$$

b) Write down the equation of motion of the body moving under gravity. (4)

Ans: the equations of motion are

$$V = u + at,\ S = ut + \frac{1}{2}at^2,\quad V^2 = u^2 + 2as$$

When a body is moving under gravity a=g

Therefore the above equations become

$$V = u + gt,\ S = ut + \frac{1}{2}gt^2,\quad V^2 = u^2 + 2gs$$

III. a) The moment of inertia of a wheel about an axis of rotation is 3.1 kgm^2 and its kinetic energy of rotation is 600 J. What is its angular velocity? (4)

Ans: $I = 3.1\ kg\ m^2$

$K.E_{rot} = 600$ J

$\omega = ?$

Rotational kinetic energy $= 1/2\ I\omega^2$

Ie, $600 = 1/2 * 3 * \omega^2$

$\omega^2 = 2*600/3.1 = 387.097$

$\omega = 19.67$ rad/s

b)When a body is thrown up, show that time 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, we get

$0 = u - gt_1 \quad or\ t_1 = u/g$ → (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.

$$S = ut + ½ at^2$$

ie, $h = 0 + ½ g{t_2}^2$

Sub (1) in the above eq^n

$$\frac{u^2}{2g} = ½ g{t_2}^2$$

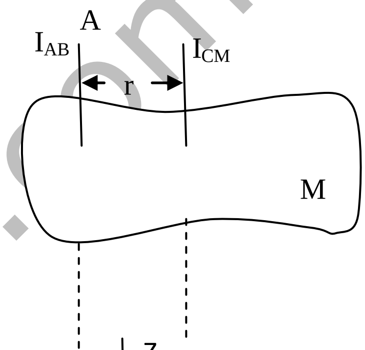
$$\rightarrow \quad {t_2}^2 = \frac{u^2}{g^2}$$

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

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

ie, time of ascent =time of descent

IV. a) Define parallel and perpendicular axis theorem (4)

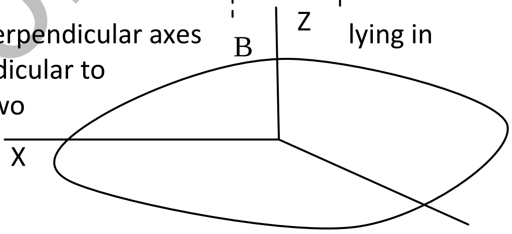


Ans: <u>Theorem of Parallel axes</u>: - The moment of inertia I_{AB} of any rigid body about a given axis is equal to the sum of its moment of inertia I_{CM} about a parallel axis passing through the centre of gravity and product of the mass of the body and the square of the distance between the axes

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

<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 young's modulus (4)

Ans: Stress is the restoring force setup per unit area inside the body. It is measured by the applied force per unit area.

Stress = F/A

Strain is the fractional deformation resulting from a stress. It is measured by the ratio of change in dimension of a body to the original dimension.

One type of strain is longitudinal strain

Longitudinal strain = $Change\ in\ length/original\ length = l/L$

young's modulus is the ratio of longitudinal stress to the longitudinal strain

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

PART C

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

a)Obtain the dimensional formula of the universal gas constant from the equation ,PV=RT (3)

Ans: PV=RT

P : Pressure=Force/Area = $\frac{MLT^{-2}}{L^2} = ML^{-1}T^{-2}$

V : Volume =L^3

Therefore R = PV/T

Taking dimensional formula

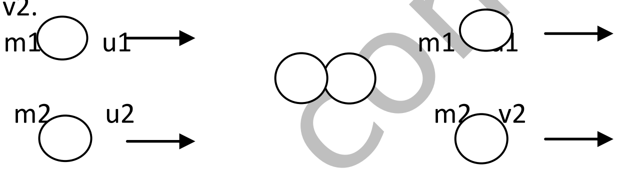
R : $ML^{-1}T^{-2}$. L^3 . K^{-1} = $ML^{-1}T^{-2}K^{-1}$

b) A particle is projected with a velocity 49m/s at angle 30^o to the horizontal. Calculate maximu height, time of flight and horizontal range.

Ans: Here u=49m/s, Θ=30^0

Maximum height, $H=u^2Sin^2\Theta/2g$.
$H=49^2*Sin^2 30^0/2*9.8=30.625m$.
Time of flight, $T= 2uSin\Theta/g$
$T=2*49*Sin30/9.8 =5s$.
Horizontal range, $R=u^2Sin2\Theta/g$.
$R=49^2*Sin(2*30)/9.8=212.18m$.

c) State third law of motion and deduce the law of conservation of momentum. Give an example to illustrate the third law. (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.

VI. a) Write the advantages and disadvantages of friction. (3)
Ans: Advantage:
1. Walking will not be possible. We would slip.
2. Brake work due to friction.
3. Helps to write on board or paper.
Disadvantage:
1. Unnecessary expense of energy.
2. Cause wear and tear of machines.
3. Reduces efficiency.

b) A stone of mass 900g is tied to the end of the string of length 60cm, is whirled in a horizontal circle with a constant speed. If the stone makes 24 rotations in 25 seconds, what is the centripetal acceleration and force?
Ans: M=900g=0.9kg
K=60cm=0.6m
Ω=24 rotations/25 sec=24*2π/25 rad/sec.
Centripetal acceleration= $r\omega^2=21.83m/s^2$
Centripetal force, $F=mr\omega^2=19.65N$.

c) Find the initial velocity and acceleration of a particle travelling with a uniform acceleration in a straight line, if it traverses 55m in the 8th second and 85m in the 13th second of its motion. (6)
Ans: $S_n=u+a(n – ½)$.

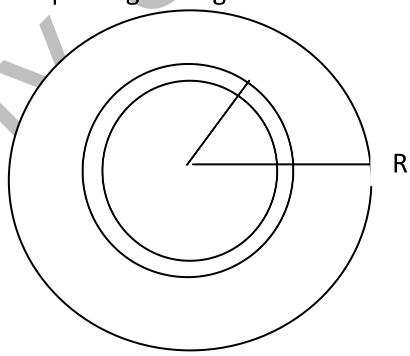
55= u+a(8 – ½)
55=u+ 15/2 a
110=2u+15a………(1)
85= u+a(13 – ½)
85= u+25/2 a
170=2u+25a……….(2)
Solving, a=6m/s^2, u=m/s.

UNIT 2

VII. Define torque of rotating body and give the relation between torque and angular momentum. (3)

Ans: The rotating or turning effect produced by a force is called the moment of the force or torque. A torque is required to produce an angular momentum. T=I((ω2-ω1)/t) = ω2I-ω1I)/t =(L2-L1)/t = dL/dt.
I.e. T=dL/dt.

b) Derive an expression for the moment of inertia of a disc about an axis passing through the center and perpendicular to its plane.
(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) An artificial satellite is moving in circular orbit near earth. Prove that its time period is given by,
$T = 2\pi\sqrt{\frac{R}{g}}$. (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. Obtain the relation $g=GM/R^2$

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) What is geostationary satellite? Deduce its orbital velocity. (6)

Ans: An orbital artificial satellite whose orbital period is the same as the rotational period of earth. h= 36000km.

Orbital velocity, $v_0 = \sqrt{\frac{GM}{R+h}}$.

$v_0 = [6.67*10^{-11}*6*10^{24}/ (6400000+36000000)]^{½} = 3072.24$m/s.

Orbital velocity, $v_0 = 3072.24$m/s.

c) A brass wire of young's modulus 90GPa of length 3.14 and a diameter 0.4mm is stretched. Find the mass to be suspended to produce an elongation of 0.98cm. (6)

Ans: Y=90GPa = $90*10^9$Pa

L= 3.14m

Diameter = 0.4mm, Radius=0.2mm.

l=0.98cm = $0.98*10^{-2}$m.

Y=FL/Al

F= YAl/L=$90*10^9*0.98*10^{-2}*(0.2*10^{-3})^2*$/ 3.14

F=mg=35.298N

Therefore mass to be suspended, m=35.298/9.8=3.6kg.