APPLIED SCIENCE –I (PHYSICS)
OCTOBER 2011

PART A

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

I. a) What are peta and Pico?

Ans: Both are two prefixes used to indicate multiples and submultiples. Peta stands for 10^{15} and Pico stands for 10^{-12}.

b) Why are springs made of steel and not of copper?

Ans: Since Young's modulus of steel is more than that of copper, a larger restoring force is set up in on being deformed. This elastic quality is preferred for spring, so that steel is used for making spring.

PART B

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

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

$0 = u - gt_1 \quad or\ t_1 = u/g \rightarrow$ (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, $h = 0 + ½ gt_2^{\ 2}$

Sub (1) in the above eq^n

$$\frac{u^2}{2g} = ½ gt_2^{\ 2}$$

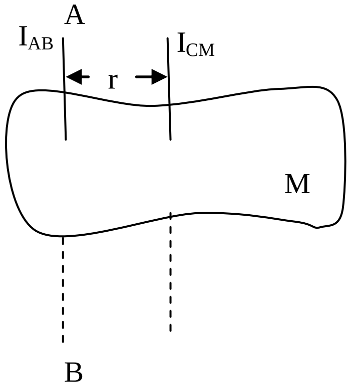
$$\Rightarrow \quad t_2^{\ 2} = \frac{u^2}{g^2}$$

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

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

ie, time of ascent =time of descent

b) State and explain parallel and perpendicular axes theorem. (4)

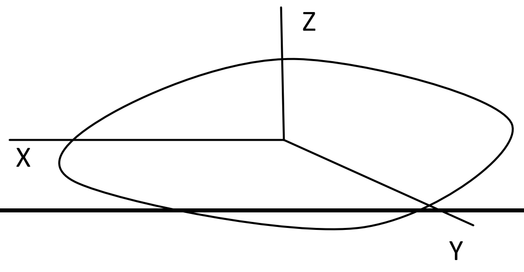


Ans: <u>Theorem of Parallel axes</u>: -

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>:-



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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

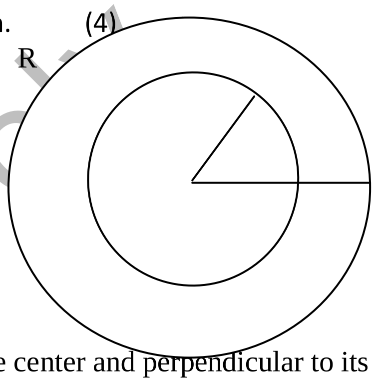
$$I_x + I_y = I_z$$

III. a) Derive the equation for the displacement of a body during the nth second of its motion. (4)

Ans: Consider a particle having an initial velocity u and acceleration a .To calculate the distance travelled in nth 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 nth 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 the moment of inertia of a uniform circular disc about an axis passing through its center and perpendicular to its plan. (4)



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^{3}dx/R^2.Therefore the moment of inertia of the disc can be obtained by integrating between the limits x=0 to x=R. Thus,

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

IV. a) Explain why the outer edge of the road bed is raised over the inner on the curved portion of the 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) When the diameter of the earth reduced to half, its mass will become 1/8th of its present value. What will be the value of ‘g’ for the new earth? (4)

Ans: g=GM/R^2

Here, R=R/2, M=M/8

Therefore g=G(M/8) / (R/2)^2 = 1/8*4GM/ R^2

i.e. g will get reduced to half.

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PART C

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

UNIT 1

V. a) Obtain the dimensional formula for Planck's constant from the equation E=hʋ. (3)

Ans: h= E/ʋ

Taking dimensional formula for R.H.S, h= $ML^2T^{-2}/T^{-1} = ML^2T^{-1}$

b) A boy can throw a ball 40m vertically upwards, find the greatest horizontal distance he can throw. (6)

Ans: H=40m

H= $u^2Sin^2\Theta/ 2g$

When throwing vertically upwards, $\Theta=90^0$.

Therefore $u^2/2g = 40$

$U^2=40*2g = 784$

U = 28

Maximum range, $R_{max} = u^2/g = 784/9.8 = 80$m.

c) If a gun of mass 20kg fires 4 bullets per second each of mass $35*10^{-3}$kg with a velocity of 400m/s, calculate the force required to stop the recoil of the gun. (6)

Ans: Mass of a bullet, m = $35*10^{-3}$kg.

Velocity of bullet, ʋ = 400m/s.

Mass of the gun, M = 20kg.

If v is the velocity of the recoil, v= -m ʋ/ M = $-(400*35*10^{-3}/ 20)$ = -0.7m/s.

As 4 bullets are fired per seconds, the change in velocity of the gun is produced in ¼ second.

Hence the force acting on the gun is,

F= M* rate of change of velocity.

=20*(-0.7- 0)/ (1/4) = -56N.

Therefore a forward force of 56N is required to hold the gun in position.

VI. a) What are the causes of friction? Why is it difficult to move a cycle with its brake on?

Ans: Friction is due to irregularities of surface at molecular level. As one surface slides over another, the contact points are destroyed and recreated. When brakes are applied, there is actually the application of friction on the wheels. Due to the friction, it is difficult to move the cycle.

b) Assuming that the moon completes one revolution in a circular orbit around the earth in 27.3 days, calculate the centripetal acceleration of the moon towards the earth .Radius of the orbit= $3.85*10^5$km.

Ans: T=27.3 days =27.3*24*60*60

r= $3.85*10^5$km= $3.85*10^8$m

Velocity, v=2πr/T = $2\pi*3.85*10^8/(27.3*24*60*60)$ = 1025.57m/s.

Centripetal acceleration, a= $V^2/r = (1025.57)^2/3.85*10^8$

A= $2.7*10^{-3}m/s^2$

c) A stone is dropped to a well and the sound of the splash is heard after 3.91s. If the depth of the well is 67.6m, find the velocity of sound.

Ans: Let the time taken by stone to reach the surface be t1. Distance covered during this time is,

S= ut + ½ at^2.

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67.6 = 0 + ½ *9.8*$t1^2$

Therefore t1 = $(67.6*2/9.8)^{1/2}$ = 3.7143s

Time taken for sound to travel from the water surface to the top will be t2.

t2= Total time – t1

=3.91-3.7143

= 0.1976s

Velocity = distance traveled / time taken

= 67.6/0.1976

= 342.1 m/s

VII. a) Define moment of inertia of a rigid body and radius of gyration. (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

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

Moment of inertia of a particle about an axis of rotation is defined as the product of the mass of the particle and the square of the distance of the particle from the axis of rotation.

b) A stone of mass 5kg is tied to one end of a string of length 1m and is rotated in a horizontal circle at the rate of 5 revolutions per seconds. What are the moment of inertia and kinetic energy of rotation?

Ans: M=5kg

Length, r=1m

ω = 5 revolutions/ seconds = 5*2π rad/sec.

Moment of inertia, I=Mr^2= 5*1^2=5kgm^2

Kinetic energy of rotation= ½ I ω^z

= ½ *5*$(5*2\pi)^2$ = 2467 J

c) An artificial satellite is moving in a definite circular orbit near earth. Prove that its time period is given by $T = \sqrt{3\pi/G\rho}$ where ρ is the density of earth and G the gravitation constant.

Ans: if an artificial satellite is revolving near earth, T= 2πR.

Velocity, V= 2πR/T where, V= $\sqrt{GM/R}$ (Orbital velocity)

Therefore T=$2\pi R/\sqrt{GM/R}$=$2\pi\sqrt{\frac{R^3}{GM}}$

If the ρ is the density, ρ =mass/volume = $\frac{M}{\frac{4}{3}R^3\pi}$

Therefore R^3/M = 3/4πρ

Substituting in the equation for T, $T = 2\pi\sqrt{\frac{3}{4\pi G\rho}} = \sqrt{\frac{3*4\pi^2}{4\pi G\rho}} = \sqrt{\frac{3\pi}{G\rho}}$

I.e. $T = \sqrt{\frac{3\pi}{G\rho}}$

VIII. a) Where should the force be applied on a wrench to produce the best screaming effect? (3)

Ans: The force should be applied at the farthest distance, since the length of the arm(r) is long the force(f) required to produce a given turning effect(r*f) is smaller.

b) What are geostationary satellites? Deduce its orbital velocity. (6)

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

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

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

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

c) A metal wire of length 4m and diameter 2mm is stretched by a mass of 8kg. Find the extension produced if $Y=11*10^{10}\ Nm^{-2}$. (6)

Ans: Y=FL/Al.

Here, L=4m

Diameter=2mm, Radius=1mm.

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

Mass = 8kg

F = mg = 8*9.8=78.4N.

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

Extension produced, l = FL/AY

$l = 78.4*4/3.14*10^{-6}*11*10^{10} = 0.9*10^{-3}m$

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