

**APPLIED SCIENCE – 1(PHYSICS)**  
**OCTOBER 2010**

PART –A

(Answer the question in one or two sentences. Each question carries 2 mark)

I. a) Give the physical quantities and their units in which SI is based on.

Ans:	Quantity	Unit
	Length	meter
	Mass	kg
	Time	S
	Electric current	ampere
	Temperature	K
	Amount of substance	mol
	Luminous intensity	cd
	Plane angle	rad
	Solid angle	sr

b) State and explain Newton's law of gravitation

Ans: Every body in the 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.

$$F = G \frac{m_1 m_2}{r^2}$$

PART – B

(Answer any two questions. Each question carried 8 mark)

II. a) Deduce that a projectile can have two angles of projection for ranges other than the maximum range. (4)

Ans: The horizontal range,  $R = \frac{u^2 \sin 2\theta}{g}$

Since  $\sin 2\theta = \sin(180 - 2\theta)$ , the range will be the same for angles  $\theta$  and  $90^\circ - \theta$ . But for the maximum range,  $\sin 2\theta = 1$ . that is,  $2\theta = 90^\circ$  and  $\theta = 45^\circ$

Thus, for ranges other than the maximum range, there can be two angles of projection.

b) Analyze the statement – Newton's first law defines force and second law provides a means to measure force. (4)

Ans: Newton's first law defines force because it states that a body continues to be in its state of rest or of uniform motion along a straight line until and unless it is compelled by an external force. From the statement, force can be defined as that which changes or tends to change the state of rest or that of uniform motion.

Second law tells what happens when a force is actually exerted on a body. when a force acts on a body and there occurs a change in its momentum, then according to second law, the rate of change of momentum is proportional to the applied force and in its direction

III. a) A cycle wheel can be set in to rotation easily if force is applied at the rim rather than at a point near to the axis of rotation. (4)

Ans: Ability of a force to rotate a body depends on the magnitude of force and how far it is applied from the axis of rotation.

That is,  $T = r \cdot F$

Torque due to a force is the product of force and perpendicular distance of the line of action of force from the axis of rotation.

b) Differentiate between inertia and moment of inertia. (4)

Ans: Inertia is the inability of a body to change its original state by itself. Inertia is a measure of mass. A body at rest has inertia of rest and a body in motion has inertia of motion.

Moment of inertia is rotational inertia. Moment of inertia is the inability of a body to change its state from uniform rotational motion to rest or vice versa. It is measured as the product of the mass of the particle and the square of the distance of the particle from the axis of rotation.

IV. a) Give reason why a body weighs more at poles. (4)

Ans: Weight of a body is given by the equation  $F = Mg$ . Here  $g$  is the acceleration due to gravity.

$$G = \frac{GM}{R^2}$$

Where  $M$  is the mass and  $R$  the radius of the earth. Since the shape of earth is flattened at poles and bulging out at the equator, radius of the earth is smaller at poles. Since  $g \propto 1/r^2$ ,  $g$  is less at equator and comparatively more at the poles. Hence body weighs more at the poles.

b) A cable is replaced by another of the same length and material but twice the diameter. Analyze how it affects the elongation under a given load.

Ans: Young's modulus  $Y = \frac{FL}{Al} = \frac{FL}{\pi r^2 l}$

Since both cables have same length, load and material, but diameter differs, the eqn for elongation can be given as,

$$l_1 = \frac{FL}{\pi r_1^2 y} \quad \text{and} \quad l_2 = \frac{FL}{\pi r_2^2 y}$$

Since  $r_2 = 2r_1$ ,  $l_1/l_2 = (2r_1)^2/r_1^2 = 4$

i.e.  $l_1 = 4l_2$ . Elongation becomes four times compared to the first cable.

#### PART-C

(Answer two full questions. Each question carries 15 marks)

V. a) Differentiate between dimensional formula and dimensional equation with a suitable example. (3)

Ans: Dimension of a physical quantity is powers to which the fundamental units of mass, length and time must be raised to represent a derived unit of the quantity.

Dimensional formula is an expression which tells us which and how the physical quantity depends on the fundamental units.

Dimensional equation is the equation obtained when a physical quantity is equated to its dimensional formula.

E.g.: velocity: dimension is zero in mass, +1 in length and -1 in time. Dimensional formula is  $LT^{-1}$ .

Dimensional equation:  $V = [M^0 L^1 T^{-1}]$

b) A body covers 120m in the 4<sup>th</sup> second. If it travels 240m in 8s, calculate its acceleration, initial velocity and velocity at the end of 8<sup>th</sup> second. (6)

Ans:  $S_n = u + a(n - \frac{1}{2})$

$$120 = u + a(4 - \frac{1}{2})$$

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

$$240 = 8u + \frac{1}{2} a(8)^2$$

The equations get simplified as,  $240 = 2u + 7a$  and  $480 = 16u + 64a$

Solving, we get  $a = -180 \text{ m/s}^2$ ,  $u = 750 \text{ m/s}$ .

By 8 seconds, the distance covered by the body be  $S = ut + \frac{1}{2} at^2$

$$S = 750 \cdot 8 + \frac{1}{2} (-180) \cdot 8^2 = 240 \text{m.}$$

$$\text{Using } v^2 = u^2 + 2as = 750^2 - 2 \cdot 180 \cdot 240 = 476100.$$

Therefore  $v = 690 \text{ m/s.}$

i.e. by the end of 8 seconds, the body will have a velocity 690m/s.

c) A stone of mass 0.3kg is tied at the end of a string and whirled in a horizontal plane forming a circle of radius 1m with a speed of 40 revolutions per minute. What is the tension on the string? What is the linear velocity of string? (6)

Ans:  $M = 0.3 \text{kg}$

$R = 1 \text{m}$

$\omega = 40 \text{ rev/min} = 40 \cdot 2\pi \text{ rad/sec} = 4.2 \text{ rad/sec}$

Tension in the string = Centripetal force =  $m r \omega^2$

Therefore Tension =  $0.3 \cdot 1 \cdot 4.2^2 = 5.29 \text{N}$

We have,  $m v^2 / r = T$

$$\text{Therefore } v = \sqrt{\frac{T \cdot r}{m}} = \sqrt{\frac{5.29 \cdot 1}{0.3}} = 4.2 \text{m/s}$$

VI. a) When projected from horizontal at certain angle, a ball just passes over a pole at 10m height. Find the time taken by the ball to hit the ground. (3)

Ans: Here, the maximum height,  $H = \frac{u^2 \sin^2 \theta}{2g} = 10 \text{m}$

$$u \sin \theta = \sqrt{10 \cdot 2g} = \sqrt{10 \cdot 19.6} = \sqrt{196} = 14$$

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

Substituting the value of  $u \sin \theta$ .

$$T = \frac{2 \cdot 14}{g} = \frac{2 \cdot 14}{9.8}$$

$$T = 2.86 \text{ s.}$$

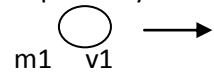
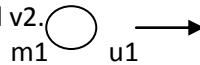
b) Demonstrate the conservation of linear momentum in collision of two bodies. If two masses 12kg and 8kg with velocities 10m/s and 5m/s move together after collision. Find their common velocity. (6)

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  $m_1$  and  $m_2$  moving along a line with velocities  $u_1$  &  $u_2$  respectively.

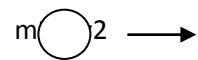
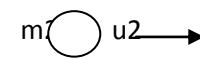
After colliding for a time  $t$ , their velocities are  $v_1$  and  $v_2$ .

Momentum of  $m_2$  before Collision =  $m_2 u_2$  .



Momentum of  $m_2$  after Collision =  $m_2 v_2$  .

Changes of momentum in  $t$  seconds =  $m_2 v_2 - m_2 u_2$  .



Rate of change of momentum  $m_2 = \frac{m_2 v_2 - m_2 u_2}{t}$ .

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

$$\text{Action} = \frac{m_2 v_2 - m_2 u_2}{t}$$

Change of momentum of first body in  $t$  seconds =  $m_1 v_1 - m_1 u_1$ .

Rate of change of momentum of the first body =  $\frac{m_1 v_1 - m_1 u_1}{t}$ .

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

$$m_2 v_2 - m_2 u_2 / t = - (m_1 v_1 - m_1 u_1 / t)$$

$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$

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

Here,  $m_1 = 12 \text{kg}$ ,  $m_2 = 8 \text{kg}$ ,  $u_1 = 10 \text{m/s}$ ,  $u_2 = 5 \text{m/s}$ .

After collision,  $m = m_1 + m_2 = 20 \text{kg}$ .

Using law of conservation of momentum,  $m_1 u_1 + m_2 u_2 = M V$

i.e.  $V = (m_1u_1 + m_2u_2)/M = ((12 \times 10) + (8 \times 5))/20 = 8 \text{ m/s}$ .

c) What is centripetal force? What is its relevance in the banking of a track? (6)

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 frictional 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  $r$  is the radius of the curve, the angle of banking ' $\theta$ ' is given by,

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

b) Derive an expression for orbital velocity of a satellite

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,

$$\text{Centripetal force} = \frac{Mv^2}{R+h} \rightarrow (1)$$

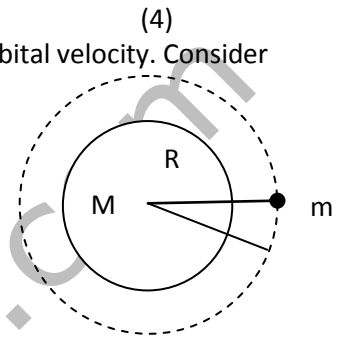
$$\text{Gravitational force} = \frac{GMM}{(R+h)^2} \rightarrow (2)$$

Equating (1)&(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<sup>n</sup> (4) gives the eq<sup>n</sup> for orbital velocity



VII. a) Define radius of gyration. Determine the radius of gyration of a circular disc of radius  $R$  rotating about an axis passing through its center and perpendicular to its plane. (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

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

Let  $M$  be the mass and  $R$  the radius of the disc. The disc  $R$  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 =  $M$ .

$$\text{Mass per unit area of the disc} = \frac{M}{\pi R^2}$$

$$\text{Area of the ring of radius } x \text{ and width } dx = 2\pi x dx$$

$$\text{Mass of the ring} = 2\pi x dx \left(\frac{M}{\pi R^2}\right) = 2x dx \frac{M}{R^2}$$

Moment of inertia of this ring about the axis passing through the center and perpendicular to its plane is therefore  $2Mx^3 dx / R^2$ . Therefore the moment of inertia of the disc can be obtained by integrating between the limits  $x=0$  to  $x=R$ . Thus,

$$I = \int_0^R (2M/R^2) x^3 dx$$

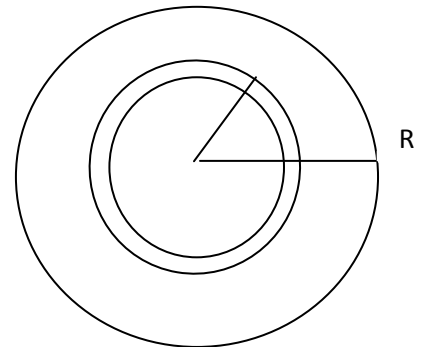
$$I = 2M/R^2 \int_0^R x^3 dx$$

$$I = 2M/R^2 [x^4/4]_0^R$$

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

Since  $I = MK^2$  and for a circular disc, about an axis perpendicular to its plane the moment of inertia is  $\frac{1}{2} MR^2$ , we have

$$MK^2 = \frac{1}{2} MR^2$$



$$K = R/\sqrt{2}$$

b) A disc of mass 1 kg with radius 0.5m is set to rotation in a horizontal plane about an axis passing vertically through its centre. If it makes 10 revolutions in 5 seconds. Determine the torque and rotational kinetic energy.

Ans:  $m=1$  kg

$r=0.5$ m

$\omega_2=10$  rev/5 sec =  $2\pi$  rad/sec = 12.57 rad/sec

$\omega_1=0$  rad/sec

torque =  $I\alpha$

For a disc,  $I = \frac{1}{2}mr^2 = \frac{1}{2} * 1 * 0.5^2 = 0.1250 \text{kgm}^2$

c) Deduce an expression for the orbital velocity of a satellite. What will be the velocity of the satellite if its orbit is close to the surface of earth? (6)

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,

$$\text{Centripetal force} = \frac{Mv^2}{R+h} \rightarrow (1)$$

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

Equating (1)&(2)

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

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

Eq<sup>n</sup> (4) gives the eq<sup>n</sup> for orbital velocity

When the satellite is revolving close to the earth,  $h=0$ . Then,  $v_0 = \sqrt{\frac{GM}{R}} = \sqrt{gR}$

$$\text{i.e. } v_0 = \sqrt{9.8 * 6400 * 10^3} = 7919.6 \frac{\text{m}}{\text{s}} = 7.92 \text{km/s}$$

VIII. a) Calculate the height at which geostationary satellite revolve above earth.  $g=9.8\text{m/s}^2$ ,  $R=6400$  km. (3)

$$\text{Ans: For a geostationary satellite, } T = 2\pi \sqrt{\frac{(R+h)^3}{gR^2}}$$

$$T=24 \text{ hrs} = 864400\text{s}, g=9.8\text{m/s}^2, R=6400 * 10^3 \text{m}$$

$$\text{Therefore } 864400 = 2\pi \sqrt{\frac{((6400 * 10^3) + h)^3}{9.8 * (6400 * 10^3)^2}}$$

Solving we get,  $h=35954$  km.

b) Deduce expressions for Young's modulus, rigidity modulus and bulk modulus. (6)

Ans: Young's modulus : It is ratio of the longitudinal stress to the longitudinal strain

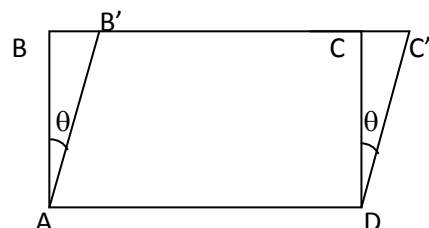
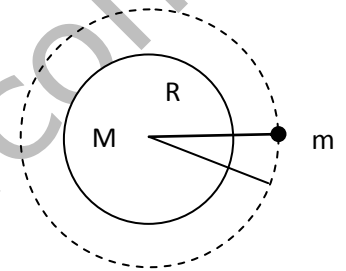
$$Y = \frac{\text{Longitudinal stress}}{\text{Longitudinal strain}} = \frac{(F/A)}{(l/L)} = \frac{FL}{Al}$$

Rigidity modulus : It is the ratio of shearing stress to shearing strain

$$\eta = \frac{F}{A} = \frac{F}{A\theta}$$

Bulk Modulus : It is the ratio of the bulk stress to the strain

$$K = \frac{P}{\frac{\Delta V}{V}} = \frac{PV}{\Delta V}$$



c) A steel wire of length 4.m and cross-section  $3 \times 10^{-5} \text{m}^2$  stretches by the same amount as a copper wire of length 3.5m and cross-section  $4 \times 10^{-5} \text{m}^2$  under a given load. What is the ratio of Young's modulus of steel to that of copper? (6)

Ans:  $L_s = 4.7 \text{m}$  for steel

$A_s = 3 \times 10^{-5} \text{m}^2$

$L_c = 3.5 \text{m}$  for copper

$A_c = 4 \times 10^{-5} \text{m}^2$

L and F are the same for both. We know that  $Y = FL/AI$ .

$Y_s / Y_c = (FL_s / A_s I) * (A_c I / FL_c) = L_s A_c / A_s L_c = 1.79$

www.madinpoly.com