

2020

MATHEMATICS — HONOURS

Sixth Paper

(Module - XII)

Full Marks : 50

*The figures in the margin indicate full marks.*

*Candidates are required to give their answers in their own words  
as far as practicable.*

*Symbols have their usual meanings.*

Group - A

[Hydrostatics]

(Marks : 25)

Answer *any one* question.

1. (a) A hollow sphere of radius 'a', half filled with liquid, is made to rotate with angular velocity  $\omega$  about its vertical diameter. If the lower point of the sphere is just exposed, show that

$$2g = a\omega^2 \left(2 - \sqrt[3]{4}\right)$$

- (b) Prove that the pressure at a point in a perfect fluid in motion is same in every direction. 25

2. (a) A tube in the form of a parabola held with its vertex downwards and axis vertical, is filled with different liquids of densities  $\delta$  and  $\delta'$ . If the distance of the free surface of the liquids from the focus of parabola be  $r$  and  $r'$  respectively, show that the distance of their common surface from the focus

is  $\frac{r\delta - r'\delta'}{\delta - \delta'}$ .

- (b) One end of a horizontal pipe of circular section is closed by a vertical door hinged to the pipe at the top. Show that the moment about the hinge of the liquid pressure is (i)  $\frac{5}{4}g\rho\pi a^4$  when full and

(ii)  $g\rho a^4 \left(\frac{2}{3} + \frac{\pi}{8}\right)$  when half-full of liquid, where 'a' is the radius of the section. 25

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3. (a) If the floating solid be a cylinder, with its axis vertical, the ratio of whose specific gravity to that of the fluid is  $\sigma$ , prove that the equilibrium will be stable if the ratio of the radius of the base to the height be greater than  $[2\sigma(1-\sigma)]^{1/2}$ .
- (b) A given volume  $V$  of liquid is acted upon by forces  $X = \frac{-\mu x}{a^2}$ ,  $Y = \frac{-\mu y}{b^2}$ ,  $Z = \frac{-\mu z}{c^2}$ . Find the equation of the free surface. ( $a, b, c$  are constants &  $x, y, z$  have their usual meanings) 25
4. (a) Write down the general equation of equilibrium for a mass of homogeneous liquid contained in a vessel, revolving about a vertical axis. Find the equation of the surface of equi-pressure when the gravity is the only external force.
- (b) If near the earth's surface gravity be assumed to be constant and the absolute temperature in the atmosphere be given by  $T = T_0 \left(1 - \frac{Z}{nH}\right)$ , [where  $H$  is the height of the homogeneous atmosphere], show that the pressure in the atmosphere will be given by  $P = P_0 \left(1 - \frac{Z}{nH}\right)^n$ .  
( $n$  is a constant integer) 25

**Group - B**

**[Rigid Dynamics]**

**(Marks : 25)**

Answer *any two* questions, taking *one* from each *Section*.

**Section - I**

5. (a) Explain motion of a rigid body in two dimensions, defining properly the variables used, which determine the motion. Find the moment of momentum of a rigid body moving in two dimensions about the centre of inertia.
- (b)  $ABC$  is a triangular area where  $AD$  is perpendicular to  $BC$ ,  $AE$  is a median and  $O$  is the middle point of  $DE$ . Show that  $BC$  is a principal axis of the triangle at  $O$ . 20
6. (a) Prove that the time of a small oscillation of a compound pendulum is minimum when the axis of suspension is parallel to the maximum radius vector of the momental ellipsoid at the centre of inertia and the point of suspension is taken such that the centre of inertia bisects the join of the point of suspension and the centre of oscillation.
- (b) A solid circular disc of radius ' $a$ ' is rolling up a rough plane (along the line of greatest slope) inclined at an angle ' $\alpha$ ' to the horizontal. If  $V$  be the magnitude of velocity of the centre of the disc at an instant, show that the disc ascends a further distance  $\frac{3V^2}{4g \sin \alpha}$  along the plane, before coming to rest. 20

**Section - II**

7. An elliptic lamina can rotate about a horizontal axis passing through a focus and perpendicular to its plane. If the eccentricity of the ellipse be  $\sqrt{\frac{2}{5}}$ , prove that the centre of oscillation will be at the other focus. 5
8. A uniform rod of length  $2a$  is placed with one end in contact with a small horizontal table and is then allowed to fall; if  $\alpha$  be its initial inclination to the vertical, show that its angular velocity when it is inclined at an angle  $\theta$ , is  $\left\{ \frac{6g}{a} \left( \frac{\cos \alpha - \cos \theta}{1 + 3 \sin^2 \theta} \right) \right\}^{\frac{1}{2}}$ . 5
9. A uniform solid cylinder is placed with its axis horizontal on a plane, whose inclination to the horizon is  $\alpha$ . Show that the least coefficient of friction between it and the plane so that it may roll without sliding, is  $\frac{1}{3} \tan \alpha$ . 5
10.  $AB, BC$  are two equal similar rods freely hinged at  $B$  and lie in a straight line on a smooth table. The end  $A$  is struck by a blow perpendicular to  $AB$ . Show that the resulting velocity of  $A$  is  $\frac{7}{2}$  times the velocity that of  $B$ . 5
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