M.E. (Water Resources & Hydraulic Engineering) Examination, 2024

(1st Year-1st Semester)

GEOPHYSICAL FLUID DYNAMICS

Time : Three Hours Full Marks : 100

Answer any ***four*** questions.

1. (a) Explain how you justify "Importance of Rotation" and "Importance of Stratification" which effects in Geophysical Fluid Dynamics.

   (b) Prove the relationship between length (L) and height (H) on a planet rotating at rate Ω

   $$L \sim \frac{1}{\Omega}\sqrt{\frac{\Delta\rho}{\rho_0}gH}$$

   (c) On Jupiter, a day lasts 10.8 earth hours and the equatorial circumference is 642,500 km. Knowing that the measured gravitational acceleration of the equator is 30.1 m/s^2, what is the value of true gravitational acceleration.

   8+8+7=25

2. (a) State the scale analysis of forward and backward difference of third order truncation error.

   (b) Show that the fourth-order centred finite difference approximation of the first derivative is two centred difference one across 2Δt and other across 4Δt.

   (c) Using scaling, find out the dynamic pressure induced by a stream (speed= 1.5 m/s) width 60 km and depth 1000 m and also estimate the hydrostatic pressure due to the weight of the water depth.

   Also convert dynamic pressure scale to its equivalent height of hydrostatic pressure head. What will be the possible depth for measuring oceanic dynamic pressure by pressure gauge? Assume rotation rate =7.229 $x10^{-5}$ /s

   10+9+6=25

3. (a) Prove that the absolute velocity is equal to the relative velocity and entraining velocity due to the rotation of the reference framework in case of 2-D rotating frame.

   (b) Prove that the centrifugal acceleration is proportional to the square of angular rate and the coordinates in case of 2-D rotating frame.

   (c) What is Coriolis Force? Differentiate between temporal Rossby number and Rossby number. Define Ekman Number.

(d) A laboratory tank consists of a cylindrical container 35 cm in diameter, filled while at rest with 25 cm of fresh water and then spun at 32 rpm. After a state of solid-body rotation is achieved, what is the difference in water level between the rim & the centre? How this difference does compares with the minimum depth at the centre?

6+8+6+5=25

4. (a) What Integral Transform (IT)? Classify different types of IT. Differentiate between Laplace Transform & Fourier Transform.

(b) Solve Laplace Transforms of $\cos^2(2t)$ and Inverse Transforms of

$$\frac{2s+3}{s^2+4s+13}$$

(c) State the difference between ordinary differential equation & partial differential equation.

(d) The bullet train zips from one station to another (both at approx 36^0N) at a speed of 180 km/hr. In the design of the train and tracks, what is the value of the coriolis acceleration and the tilt of the net acceleration? Assume rotation rate =7.229 x 10^{-5}/s

7+8+3+7=25

5. (a) Differentiate between round jet and plane jet.

(b) Show that the velocity fluctuations and the contaminant concentration at any location are proportional to the centre line velocity and initial concentration of the plane jet at that location.

(c) A laboratory experiment is conducted in a cylindrical tank 35 cm diameter filled with homogenous (25 cm deep at the centre) water and rotating at 30 rpm. A steady flow liquid with maximum velocity of 1cm/s is generated by source-sink device. The water viscosity is 10^{-6} m^2/s. Estimate temporal Rossby number, Rossby number and Ekman number. Verify whether this flow field fulfils the condition of geostrophy.

4+12+9=25

6. (a) Briefly describe the different applications of GFD.

(b) What is geostrophic motion?

Derive the equation for geostrophic motion considering steady flow with a pressure gradient.

6+19=25