## Subject Name & Code:

# FLUID MECHANICS - BE04000161

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## Assignment – 1

**Q-1: Fluid Properties (Viscosity): A flat plate with an area of 0.2 m2 is pulled at a velocity of 0.5 m/s over a stationary base plate. The gap between the plates is 0.8 mm and is filled with a biodiesel blend acting as a lubricant. If the force required to maintain the motion is 15 N, determine the dynamic viscosity and kinematic viscosity of the biodiesel blend. (Assume the specific gravity of the blend is 0.88).**

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**Answer:**

**Given:**
Area $A = 0.2\ \text{m}^2$
Velocity $u = 0.5\ \text{m/s}$
Gap $dy = 0.8\ \text{mm} = 0.0008\ \text{m}$
Force $F = 15\ \text{N}$
Specific gravity $SG = 0.88$
Density of water $\rho_w = 1000\ \text{kg/m}^3$

**To Find:**
Dynamic viscosity $\mu$ (Pa·s or N·s/m²)
Kinematic viscosity $\nu$ (m²/s)

**Formula:**
Shear stress $\tau = \frac{F}{A} = \mu \frac{du}{dy}$

**Solution:**

$$\tau = \frac{15}{0.2} = 75\ \text{Pa}$$
$$\frac{du}{dy} = \frac{0.5}{0.0008} = 625\ \text{s}^{-1}$$
$$\mu = \frac{\tau}{du/dy} = \frac{75}{625} = 0.12\ \text{Pa} \cdot \text{s}$$

Density of biodiesel $\rho = 0.88 \times 1000 = 880\ \text{kg/m}^3$

$$\nu = \frac{\mu}{\rho} = \frac{0.12}{880} = 1.364 \times 10^{-4}\ \text{m}^2/\text{s}$$

**Final Answer:**

$$\boxed{\mu = 0.12\ \text{Pa} \cdot \text{s}, \nu = 1.364 \times 10^{-4}\ \text{m}^2/\text{s}}$$

**Q-2: Capillarity: Calculate the capillary rise of water in a glass tube of 2.5 mm diameter when submerged vertically in water. Take the surface tension of water as 0.0725 N/m and the angle of contact as 0°. How would this value change if the fluid was an automotive brake fluid with a higher surface tension?**

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**Answer:**

**Given:**
Diameter $d = 2.5\ \text{mm} = 0.0025\ \text{m} \rightarrow$ radius $r = 0.00125\ \text{m}$
Surface tension $\sigma = 0.0725\ \text{N/m}$
Contact angle $\theta = 0°$
Density of water $\rho = 1000\ \text{kg/m}^3$, $g = 9.81\ \text{m/s}^2$

**To Find:** Capillary rise $h$

**Formula:**

$$h = \frac{2\sigma \cos\ \theta}{\rho g r}$$

**Solution:**

$$h = \frac{2 \times 0.0725 \times \cos\ 0°}{1000 \times 9.81 \times 0.00125}$$
$$h = \frac{0.145}{12.2625} = 0.01182\ \text{m} = 11.82\ \text{mm}$$

**Effect of higher surface tension:**
If the brake fluid has higher surface tension, capillary rise increases proportionally, assuming similar density and contact angle. Higher $\sigma \rightarrow$ stronger cohesive forces $\rightarrow$ greater meniscus curvature $\rightarrow$ higher rise.

**Final Answer:**

$$\boxed{h = 11.82\ \text{mm}}$$

**Q-3: Pressure Measurement: A U-tube differential manometer connects two pressure pipes, A and B. Pipe A contains a coolant fluid (Specific Gravity = 1.05) at a pressure of 1.2 x 105 N/m2, and Pipe B contains oil (Specific Gravity = 0.9) at a pressure of 2.0 x 105 N/m2. The manometer liquid is mercury. Find the difference in the mercury level if pipe B is positioned 0.5 m higher than pipe A.**

**Answer:**

**Given:**
Pipe A: Coolant $SG_1 = 1.05$, $P_A = 1.2 \times 10^5$ Pa
Pipe B: Oil $SG_2 = 0.9$, $P_B = 2.0 \times 10^5$ Pa
Manometer liquid: Mercury $SG_m = 13.6$
$z_B = z_A + 0.5$ m (B is higher)

**To Find:** Difference in mercury level $h$ (in m)

**Formula:**
Equality of pressures at same horizontal level in the manometer.

**Solution:**
Let level of mercury in limb A be reference.
Pressure at A + pressure due to coolant column above mercury on left = Pressure at B + pressure due to oil column + pressure due to mercury difference.

But careful: Pipe B is higher by 0.5 m. Let's define:
Mercury level difference $h$ (higher in limb A? We'll solve).

Equate pressures at mercury level in limb A:

$$P_A + \rho_1 g(0.5 + h) = P_B + \rho_2 g(0.5) + \rho_m g h$$

Where $\rho_1 = 1.05 \times 1000 = 1050$ kg/m$^3$
$\rho_2 = 900$ kg/m$^3$
$\rho_m = 13600$ kg/m$^3$

Substitute:

$$1.2 \times 10^5 + (1050)(9.81)(0.5 + h) = 2.0 \times 10^5 + (900)(9.81)(0.5) + (13600)(9.81)h$$
$$1.2 \times 10^5 + 5150.25 + 10300.5h = 2.0 \times 10^5 + 4414.5 + 133416h$$
$$125150.25 + 10300.5h = 204414.5 + 133416h$$
$$125150.25 - 204414.5 = (133416 - 10300.5)h$$
$$-79264.25 = 123115.5h$$

Negative $h$ means mercury level higher in limb B.

$$h = -\frac{79264.25}{123115.5} = -0.6437 \text{ m}$$

Magnitude $h = 0.644$ m (mercury higher in limb B)

**Final Answer:**

$$\boxed{h = 0.644 \text{ m}}$$

**Q-4: Hydrostatic Forces: A circular plate of 2 m diameter is submerged vertically in a liquid of specific gravity 0.95 such that its top edge is 1 m below the free surface. Calculate the total hydrostatic pressure force on the plate and the depth of the center of pressure.**

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**Answer:**

**Given:**
Diameter $D = 2$ m $\rightarrow$ radius $R = 1$ m
Specific gravity $SG = 0.95 \rightarrow \rho = 950$ kg/m$^3$
Top edge is 1 m below free surface: $h_c = 1 + R = 2$ m (center of circular plate from surface)

**To Find:** Total hydrostatic force $F$ and depth of center of pressure $h_p$

**Formula:**

$$F = \rho g h_c A$$
$$A = \pi R^2 = \pi(1)^2 = \pi \text{ m}^2$$

$I_G = \frac{\pi R^4}{4} = \frac{\pi(1)^4}{4} = \frac{\pi}{4}$ m$^4$ for circle

$$h_p = h_c + \frac{I_G}{h_c A}$$

**Solution:**

$$F = 950 \times 9.81 \times 2 \times \pi = 950 \times 9.81 \times 2 \times 3.1416$$
$$F = 950 \times 61.68 = 58596 \text{ N} \approx 58.6 \text{ kN}$$
$$h_p = 2 + \frac{\pi/4}{2 \times \pi} = 2 + \frac{1/4}{2} = 2 + 0.125 = 2.125 \text{ m}$$

**Final Answer:**

$$\boxed{F = 58.6 \text{ kN}, h_p = 2.125 \text{ m}}$$

**Q-5: Buoyancy: A solid cylinder of diameter 3 m and height 2 m floats in water with its vertical axis perpendicular to the surface. If the specific gravity of the cylinder material is 0.65, determine its metacentric height and state whether its equilibrium is stable.**

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**Answer:**

**Given:**
Cylinder: $D = 3$ m, $H = 2$ m

SG = 0.65 → $\rho_{cyl} = 650$ kg/m$^3$
Floats in water ($\rho = 1000$)

**To Find:** Metacentric height $GM$ and stability

**Solution:**
Let submerged depth = $d$.
Weight = Buoyancy:

$$650 \times 9.81 \times \frac{\pi D^2}{4} \times H = 1000 \times 9.81 \times \frac{\pi D^2}{4} \times d$$

Cancel common terms:

$$650 \times 2 = 1000 \times d \Rightarrow d = 1.3 \text{ m}$$

Center of buoyancy $OB = d/2 = 0.65$ m from bottom.
Center of gravity $OG = H/2 = 1.0$ m from bottom.
So $BG = 1.0 - 0.65 = 0.35$ m.

Metacentric radius $BM = \frac{I}{V_{sub}}$

$$I = \frac{\pi D^4}{64} = \frac{\pi(81)}{64} = 3.976 \text{ m}^4$$

$$V_{sub} = \frac{\pi D^2}{4} \times d = \frac{\pi \times 9}{4} \times 1.3 = 9.186 \text{ m}^3$$

$$BM = \frac{3.976}{9.186} = 0.433 \text{ m}$$

$$GM = BM - BG = 0.433 - 0.35 = 0.083 \text{ m} > 0$$

**Stability:** Positive GM → stable equilibrium.

**Final Answer:**

$$\boxed{GM = 0.083 \text{ m,Stable}}$$

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