Prob-Sheet (Properties of Fluid):

1. $u(y) = \frac{2}{3}y - y^2$. $\quad \frac{du}{dy} = \left(\frac{2}{3} - 2y\right)$

$$\tau_{y=0} = \mu \cdot \frac{du}{dy} = 0.863\left(\frac{2}{3}\right) = 0.576\ N/m^2$$

$$\tau_{y=0.15m} = 0.863\left(\frac{2}{3} - 0.3\right) = 0.317\ N/m^2.$$

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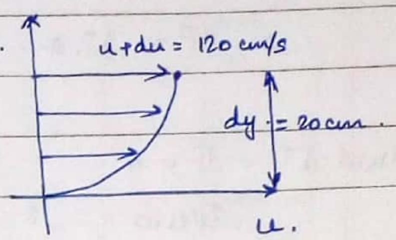
2. At vertex, $\frac{du}{dy} = 0$.



Parabola: $u = Ay^2 + By + C$

at $u=0,\ y=0,\ \Rightarrow C=0$.

$y = 20,\ u = 120$:

$\Rightarrow 120 = 400A + 20B + 0$.

$\Rightarrow 20A + B = 6.$ — (1)

$$\frac{du}{dy} = 2Ay + B.$$

$\Rightarrow 2A(20) + B = 0$.

$\Rightarrow 40A + B = 0. \Rightarrow B = -40A.$

(putting in (1))

$$20A - 40A = 6. \Rightarrow A = -\frac{6}{20} = -0.3$$

$\therefore B = -40 \times (-0.3) = 12.$

$\therefore$ Parabola: $u = -0.3y^2 + 12y$

Vel gradient $= \frac{du}{dy} = -0.6y + 12$

$\cancel{\therefore \left.\frac{du}{dy}\right|_{y=0} = 0 \ (\because du = 0)} \quad \cancel{\left.\frac{du}{dy}\right|_{y=10}}$

$$\therefore \left.\frac{du}{dy}\right|_{y=0} = -0.6(0) + 12 = 12.\ s^{-1}$$

$$\left.\frac{du}{dy}\right|_{y=10} = -0.6(10) + 12 = 6\ s^{-1}$$

$$\left.\frac{du}{dy}\right|_{y=20} = -0.6(20) + 12 = 0\ s^{-1}$$

Shear stress

$y=0$: $= \tau\left(\frac{du}{dy}\right) = 10.2\ N/m^2$

$y=10$: $= \tau \frac{du}{dy} = 5.1\ N/m^2$

$y=0$: $= \tau\ du/dy = 0.\ N/m^2$

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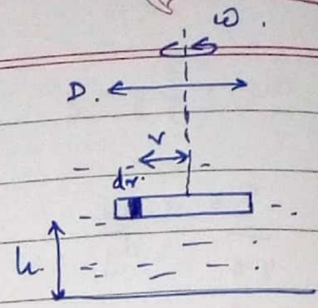
3. For an elemental ring of thickness dr,
at a radius r.



Shear stress

$$\frac{dF}{A} = d\tau = \frac{du}{dy}.\mu = \mu.\frac{(r.\omega)}{h}$$

$$\Rightarrow dF = d\tau.A = \frac{\mu.r.\omega}{h}(2\pi r.dr)$$

Now $dT = dF \times r$

$$= \frac{2\pi\mu\omega}{h}.r^3.dr$$

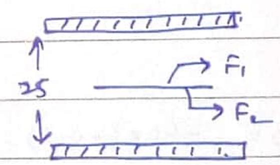
$$\therefore T = \frac{2\pi\mu\omega}{h}\int_0^{D/2} r^3 dr = \frac{2\pi\mu\omega}{h} \times \frac{(D/2)^4}{4} = \frac{\pi\mu.\omega D^4}{32h}$$

4. $F = \tau.A$

$$= \mu.\frac{du}{dy}.A$$

$\mu \rightarrow 0.785\ N\text{-}s/m^2$

$A \rightarrow 0.75\ m^2$



(i) Now

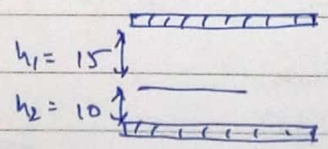
req. $dF = F_1 + F_2$ (∵ they are equal)

$$= 2 \times \mu.\frac{du}{dy} \times A$$

$$= 2 \times 0.785 \times \frac{0.5}{\left(\frac{12.5}{1000}\right)} \times 0.75$$

$$= 47.1\ N$$

(ii)



reqd $F = F_1 + F_2$

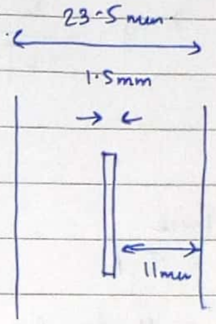
$= \mu \cdot \frac{du}{dy_1} \cdot A + \mu \frac{du}{dy_1} \cdot A$.

$= 0.785 \times \frac{0.5}{\left(\frac{10}{1000}\right)} \times 0.75 + 0.785 \times \frac{0.5}{\left(\frac{15}{1000}\right)} \times 0.75$

$= 49.06$ N.

5. $\rho = 0.95$ $\quad \mu = 2.45$ N-s/m^2

$W = 49$ N. $\quad V = 0.1$ m/s.



Nett downward force = wt + Shearing forces on both sides of plate. − Buoyant force.

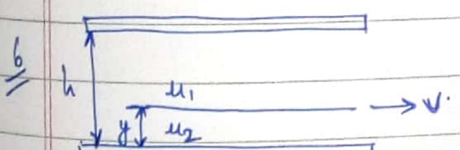
$= 49N + 2 \times \mu \times \frac{du}{dy} \times A$.

$= 49N + 2 \times 2.45 \times \frac{0.1}{\left(\frac{11}{1000}\right)} \times (1.5)^2 - \left(\frac{1.5 \times 1.5 \times 1.5}{1000}\right) \times 9500 \times 9.81$

vol. of liq displaced $\times \rho$ (liquid) (SI units). $\times g$.

$= 149.28$ N − 31.45.

~~146.07 N~~. $= 117.83$ N.

6. 

$F = \tau \cdot A$.

$= (\tau_1 + \tau_2) \cdot A$

$= \left(\mu_1 \frac{du}{dy_1} + \mu_2 \frac{du}{dy_2}\right) A$.

$= \left(\mu_1 \frac{V}{h-y} + \mu_2 \frac{V}{y}\right) \cdot A$.

For minimum drag force.

$\frac{dF}{dy} = 0 \Rightarrow -\frac{\mu_1 . V . A\ (-1)}{(h-y)^2} + (-)\frac{\mu_2 . V . A}{y^2} = 0$.

$\Rightarrow \frac{\mu_1 \cancel{V A}}{(h-y)^2} = \frac{\mu_2 \cancel{V . A}}{y^2}$

$$\Rightarrow \frac{\mu_1}{\mu_2} = \frac{(h-y)^2}{y^2} \quad \Rightarrow \sqrt{\frac{\mu_1}{\mu_2}} = \frac{h-y}{y}$$

$$= \frac{h}{y} - 1$$

$$\Rightarrow \frac{h}{y} = 1 + \sqrt{\mu_1/\mu_2}\,.$$

$$\Rightarrow y = \frac{h}{1+\sqrt{\mu_1/\mu_2}}$$

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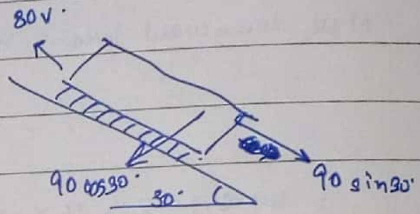
7. Force



$= \tau . A .$

$= \mu \cdot \frac{du}{dy} A .$

$= 0.8 \times \frac{v}{\left(3/1000\right)} \times 0.3$

$= 80v .$

$80v = 90 \sin 30°$

$\Rightarrow v = 0.5625 \ m/s.$

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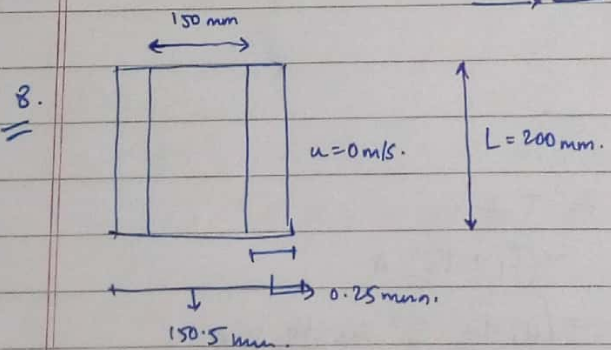
8.



$\mu = 0.8$

$\text{Force} = A\left(\mu \cdot \frac{du}{dy}\right).$

Now, 0.8 Poise

$= 0.08 \ kg \ m^{-1} s^{-1}$

$v = du = \frac{\pi D N}{60}$

$v = r\omega . \quad \omega = \frac{2N\pi}{60}.$

$\Rightarrow v = \frac{\pi D N}{60}.$

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$\therefore F = A \times \mu \times \frac{du}{dy}$.

$= (\pi D L) \times 0.08 \times \frac{\pi D N}{60} \times \frac{1}{\left(\frac{0.25}{1000}\right)}$

D → 150 mm. → metre
L → 200 mm → "
N → 1500

$= 355.305$ N

$\therefore$ Power req.d $= F.v$

$= 355.305 \times \frac{\pi D N}{60}$

$= 4185.8$ W.

≈ 4186 W $= 4.186$ kW.

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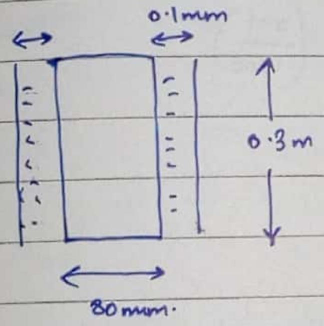
9.



$\mu = 0.1$ kg/m.s $\rho = 0.9$.

~~D = 80 mm~~ ~~L = 0.3m~~ (N → 1800 rpm)

~~= 0.08m~~

a $A = \pi D L$. $du = 0.8$ m/s (given). $dy = 0.1$ mm.

$\therefore$ Resistive force

$= A \cdot \tau$.

$= A \cdot \mu \cdot \frac{du}{dy} = \pi D L \times 0.1 \times \frac{0.8}{\left(\frac{0.1}{1000}\right)}$

$= 60.318$ N.

b $du = \frac{\pi D N}{60}$

$\therefore$ Resistive force (F) $= A \cdot \mu \cdot \frac{du}{dy}$.

$= (\pi D L) \times 0.1 \times \frac{\pi D N}{60} \times \frac{1}{\left(\frac{0.1}{1000}\right)}$

$= 568.49$

$\therefore$ Torque exerted $= F \times \frac{D}{2} = 22.74$ N-m.

$\therefore$ Power req.d $= F \times v = F \times \frac{\pi D N}{60} = 4286.3$ W

$= 4.286$ kW.

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$\rho = 850\ kg/m^3$

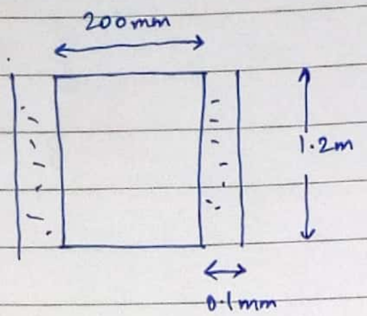
$D = 200\ mm = 0.2m$

$L = 1.2m$

10. $\nu = \mu/\rho \Rightarrow \mu = \nu . \rho$

$= \frac{400\ m^2}{(1000)^2\ s} \times 850\ \frac{kg}{m^3}$

$= 0.34\ kg/m.s$



$V = du = \frac{120\ mm}{s} = 0.12\ m/s$

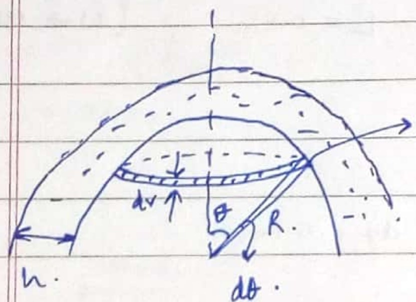
Now, resistive force

$= A . \mu . \frac{du}{dy}$

$= (\pi D L) \times 0.34 \times \frac{0.12}{\left(\frac{0.1}{1000}\right)}$

$= 307.62\ N.$

11.



radius, $r = R \sin\theta$.

Area of ring $= 2\pi r . dr$.

$= 2\pi (R\sin\theta)(R d\theta)$

$(dA) = 2\pi R^2 \sin\theta\, d\theta$.

$du = r.\omega$.

$= R\sin\theta . \omega$.

$df = dA \times \mu \times du/dy$.

$= (2\pi R^2 \sin\theta\, d\theta) . \mu \times \frac{R\sin\theta . \omega}{h}$.

$= \frac{2\pi R^3 \mu \omega}{h} \sin^2\theta . d\theta$.

Now $dT = dF \times r. = dF \times R\sin\theta$.

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$$\Rightarrow dT = \frac{2\pi\omega\mu R^4}{h}\sin^3\theta\, d\theta.$$

$$\therefore T = \frac{2\pi\omega\mu R^4}{h}\int_0^{\pi/2}\sin^3\theta . d\theta. \qquad = \frac{2\pi\omega\mu . R^4}{h}\times\left(\frac{2}{3}.1\right)$$

$$= \frac{2\pi\omega\mu R^4}{h}\int_0^{\pi/2}\left(\frac{3}{4}\sin\theta - \frac{\sin 3\theta}{4}\right)d\theta. \qquad = \boxed{\frac{4\pi\omega\mu R^4}{3h}}$$

$$= \frac{2\pi\omega\mu R^4}{h}\left[-\frac{3\cos\theta}{4} + \frac{\cos 3\theta}{12}\right]_0^{\pi/2}.$$

$$= \frac{2\pi\omega\mu . R^4}{h}$$

12. $dP = 17 MPa - 8 MPa$ $\qquad \frac{dV}{V} = -0.3\%$

$= 9 MPa$ $\qquad = -0.003$

Mod. of compressibility.

Now, $K = \frac{-dP}{dV/V} = \frac{-9 MPa}{-0.003} = 3000 MPa.$

$\therefore$ Coefficient of compressibility $= \frac{1}{3000\times10^6 \; Pa}$

$= 3.33\times10^{-10} \; \frac{m^2}{N}$

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