17.5/20

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Fluid Mechanics – First Exam   November 6th, 2012

Answer All Questions on same sheets

Question 1:

The mass-less, *4 m* wide gate shown in the figure below pivots about the frictionless hinge *O*. It is held in place by the *1000 N* counterweight, *W*.

For such configuration, determine the water depth, *h*?

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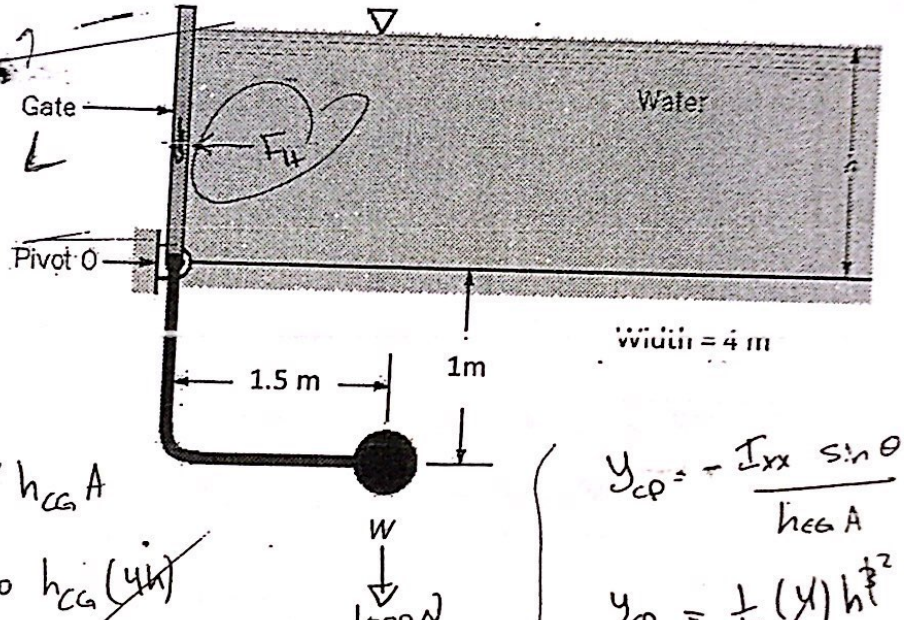


$h_{CG} = \frac{h}{2}$

$F_H = \gamma h_{CG} A$

$F_H = 9790\ h_{CG}(4h)$

$F_H = 39160\ h_{CG} h$

$F_H = 39160\left(\frac{h}{2}\right)h \Rightarrow F_H = 19580 h^2$

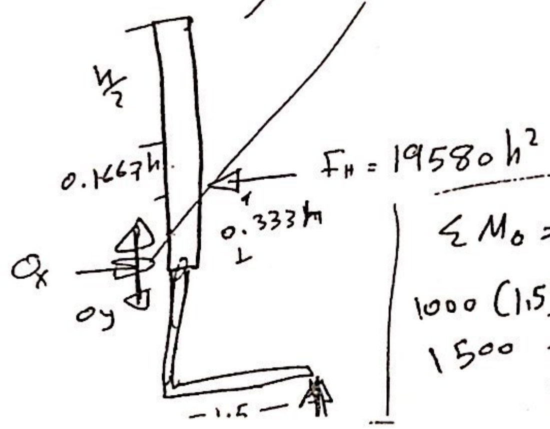
$y_{cp} = -\frac{I_{xx}\sin\theta}{h_{CG} A}$

$y_{cp} = -\frac{\frac{1}{12}(4)h^3 \sin 90}{h_{CG}(4h)}$

$y_{cp} = \frac{-0.0833\ h^2}{h_{CG}}$

$y_{cp} = \frac{-0.0833\ h^2}{\frac{h}{2}}$

$y_{cp} = -0.1667h$



$\Sigma M_O = 0$

$1000(1.5) = 19580 h^2 (0.333h)$

$1500 = 6520.14 h^3$

$h = 0.613$ m

Question 2:

Two spheres, one heavier and weighing ***12000 N*** and of diameter ***1.2 m*** and the other lighter and weighing ***4000 N***, are tied with a rope and placed in water. It was found that the spheres floated vertically with the lighter sphere just submerging.

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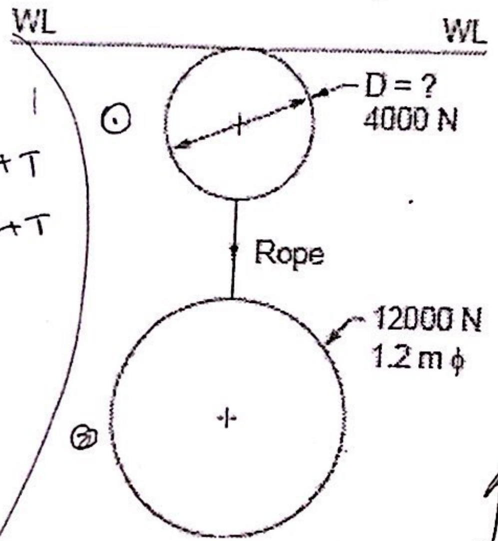
Determine:

a) The diameter of the lighter sphere?
b) The tension in the rope?



$d = 1.2$
$r = 0.6$

~~$F_B = W + T$~~

~~$\rho g\,\text{Volume} = 4000 + T$~~

~~$9790\,(V_{\text{volume displaced}}) = 4000 + T$~~

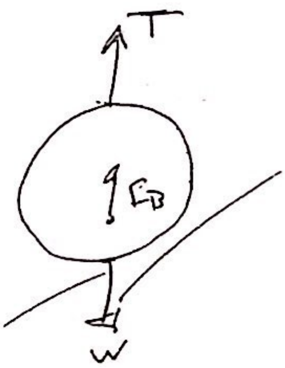
~~Volume = 0.408~~

~~$\frac{4}{3} r^3 \pi = 0.408$~~

~~$r = 0.46$ m~~

~~$d = 2 * r$~~

~~$d = 0.921$ m~~



for heavier

$W = F_B + \text{Tension}$

$12000 = \gamma\,(\text{Volume displaced}) + \text{Tension}$

$12000 = 9790\left(\frac{4}{3}\pi r^3\right) + \text{Tension}$

$12000 = 8853.3 + \text{Tension}$

b) $\boxed{\text{Tension} = 3146.7\ N}$

$F_B = W + \text{Tension}$

$9790\,(\text{Volume disp.}) = 4000 + 3146.7$

$V = 0.73$

$\frac{4}{3}\pi r^3 = 0.73 \Rightarrow r = 0.558$

$2 \times r \Rightarrow d = 1.12$ m

1 bar = 100 000 Pa

Question 3: Volume = $\frac{4}{3} r^3 \pi$

Pressure

i. A balloon is filled with ~~6 kg~~ of hydrogen at ***2 bar*** and ***20°C***. **What will be the diameter of the balloon** when it reaches an altitude where the pressure and temperature are ***0.2 bar*** and ***–60° C***. Assume that the pressure and temperature inside are the same as that at the outside at this altitude.
Take $R_{hydrogen}$= *4157 J/kg.K*, and assume it an ideal gas.

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$\boxed{P = \rho R T}$ $\rho = \frac{m}{V}$

~~mass 6kg~~

$2 \times 10^5 = \rho \times 4157 \times 293$

$\rho = 0.1642$

$\rho = \frac{m}{Volume} \Rightarrow Volume = \frac{m}{\rho}$

$Volume = \frac{6}{0.164}$

$Volume = 36.54\ m^3$

and when the temp. –60° C.
and the Pressure = 0.2 bar
it is diameter will be

Temp. = 273 – 60 = 213 Kelvin
Pressure = 0.2 (10^5) = 20 000 Pa

$P = \rho R T$

$\rho = \frac{P}{RT} \Rightarrow \frac{20\ 000}{4157 \times 213}$

$\rho = 0.0225$

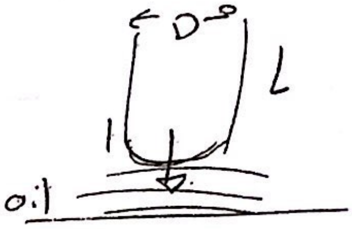
$\rho = \frac{m}{V} \Rightarrow V = \frac{m}{\rho} = \frac{6}{0.022}$

$V = 265.63\ m^3$

$V_{ballon} = \frac{4}{3} r^3 \pi$

$\frac{(265.63)\,3}{4\pi} = r^3$

$r = 3.988$



ii. **Determine the resistance offered to the downward sliding of a shaft of** ***400 mm*** **diameter and** ***0.1 m*** **length by the oil film between the shaft and a bearing of internal diameter** ***402 mm.*** The kinematic viscosity is $2.4 \times 10^{-4}\ m^2/s$ and density is $900\ kg/m^3$. The shaft is to move centrally and axially at a constant velocity of $0.1\ m/s$.

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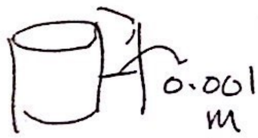
$$\tau = \mu \frac{du}{dh}$$

$$A = \pi D h$$
$$A = \pi (400 \times 10^{-3})(0.1)$$
$$A = 0.1256\ m^2$$

$$\frac{F_{shear}}{A} = \mu \frac{du}{dh}$$

$$\cancel{\frac{F}{0.1256} = 2.4 \times 10^{-4} \times \frac{0.1}{0.402}}$$



$$\tau = \mu \frac{u}{h}$$

$$= 2.4 \times 10^{-4} \times \frac{0.1}{0.402}$$

$$\tau\ \frac{F}{A} = 5.97 \times 10^{-5}$$

$$\frac{F}{0.1256} = 5.97 \times 10^{-5}$$

$$F = 7.498 \times 10^{-6}\ N$$