Properties of Fluids

1. Given: glycerin $m = 1200\,kg$
$V = 0.952$ cu.m
weight, W ?

$\boxed{W = M \times g}$
$= 1200\,kg\,(9.81)$
$= 11.77\,kN$

unit weight ?

$\boxed{\gamma = \frac{W}{V}}$

$= \frac{11.77\,kN}{0.952\,cu.m}$

$= 12.366\,kN/m^3$

density ?

$\boxed{\rho = \frac{m}{V}}$

$= \frac{1200}{0.952}$

$= 1260.5\,kg/m^3$

specific gravity ?

$\boxed{S = \frac{\rho_{gly}}{\rho_{water}}}$

$= 1260.5/1$
$= 1.26$

2. specific gravity of an oil is 0.82
specific weight (lb/ft^3) ?

$\boxed{\gamma = \gamma_{water} \times S}$
$= 62.4 \times 0.82$
$= 51.168\,lb/ft^3$

specific weight (kN/m^3) ?
$= 9.81 \times 0.82$
$= 8.044\,kN/m$

density ?

$\boxed{\rho = \rho_{water} \times S}$
$= 1.94 \times 0.82$
$= 1.59\,slugs/ft^3$
$= 1000 \times 0.82$
$= 820\,kg/m^3$

3. A liter of water weighs about 9.75N
Mass (in kg)?

$\boxed{W = mg}$
$9.75\,N = m\,(9.81\,m/s^2)$
$m = 0.994\,kg$

4. An object has a mass of 22 kg at Sea level
Weight at $g = 9.75\,m/s^2$?

$\boxed{W = mg}$
$= 22(9.75) = 214.5\,N$

5. What is the weight of a 45 kg boulder if it is brought to a gravity of 395 m/s per min?

$\boxed{W = mg}$

$$g = \frac{395\ m/s}{min} \times \frac{1\ min}{60\ s}$$

$$= 6.583\ m/s^2$$

$$W = 45(6.583)$$

$$= 296.25\ N$$

6. Specific Volume of a certain gas is $0.7848\ m^3/kg$. What is its specific weight?

Density, Specific Volume

$\boxed{\rho = \frac{m}{V}}$ relationship $\boxed{\forall = \frac{V}{m}}$

$$\rho = \frac{1}{\forall} = \frac{1}{0.7848}$$

$$= 1.2742\ kg/m^3$$

Specific Weight, $\boxed{\gamma = \rho \times g}$

$$= 1.2742 \times 9.81$$

$$= 12.5\ N/m^3$$

7. Specific weight of air at 480 kPa absolute and 21°C?

$\boxed{\gamma = \rho \times g}$

$$\rho = \frac{P}{RT} \quad R = 287\ J/kg\text{-}°k$$

$$= \frac{480 \times 10^3}{287(21+273)}$$

$$= 5.689$$

$$\gamma = 5.689 \times 9.81$$

$$= 55.81\ N/m^3$$

8. Find the mass density of helium at a temp. of 4°C and a pressure of 184 kPa gage, if atmospheric pressure is 101.92 kPa ($R = 2079\ J/kg \cdot °K$)

$\boxed{\rho = \frac{P}{RT}}$

$$P = P_{gage} + P_{atm}$$

$$= 184 + 101.92$$

$$P = 285.92\ kPa$$

$1\ Pa = 1\ \frac{N}{m^2}$

$1\ J = 1\ Nm$

$$= \frac{285.92 \times 10^3\ Pa\ N/m^2}{2079\ J/kg \cdot k\ (4+273)}$$

$$= 0.4965\ kg/m^3$$

9. At 32°C and 205 kPa gage, the specific weight of a certain gas was 13.7 N/m³. What is its gas constant?

R?

$$\boxed{\rho = \frac{P}{RT}}$$

$$\rho = \frac{\gamma}{g} = \frac{13.7 \ N/m^3}{9.81 \ m/s^2} \qquad N = kg \cdot \frac{m}{s^2}$$

$$= 1.397 \ kg/m^3$$

$$1.397 = \frac{(205 + 101.325) \times 10^3}{R(273 + 32)} \qquad P_{atm} = 101.325 \ kPa$$

$$R = 718.93 \ J/kg\text{-}°K$$

10. Air is kept at a pressure of 200 kPa absolute and a temperature of 30°C in a 500 liter container. What is the mass of air?

$$\boxed{\rho = \frac{m}{V}}$$

$$\rho = \frac{P}{RT} \qquad R = 287$$

$$= \frac{(200 + 101.325) \times 10^3}{287(273 + 30)}$$

$$\rho = 2.3 \ kg/m^3$$

$$m = \rho V$$

$$= 2.3 \ \frac{kg}{m^3} \times \left(500 \text{ liters} \times \frac{1 m^3}{1000 \text{ liters}}\right)$$

$$m = 1.15 \ kg$$

11. A cylindrical tank 80 cm in diameter and 90 cm is filled with liquid. The tank and the liquid weighed 420 kg. The weight of the empty tank is 40 kg. What is the unit weight of the liquid in kN/m³.

$$\boxed{\gamma = \rho g}$$

$$\rho = \frac{m}{V} = \frac{(420 - 40)}{\frac{\pi}{4}(0.8)^2(0.9)}$$

$$= 840 \ kg/m^3$$

$$\gamma = 840(9.81)$$

$$\gamma = 8.24 \ kN/m^3$$

12. A lead cube has a total mass of 80 kg. What is the length of its side? Sp.gr. of lead = 11.3

$$\rho = \frac{m}{V} \text{ — } L^3$$

$$G = \frac{\rho_f}{\rho_w} \ ; \quad 11.3(1000) = \gamma_{lead}$$

$$\boxed{\rho = \frac{m}{V}}$$

$$11.3 \times 1000 = \frac{80}{L^3}$$

$L = 0.192\ m$

13. A liquid compressed in a container has a volume of 1 liter at a pressure of 1 MPa and a volume of 0.995 liter at a pressure of 2 MPa. Bulk Modulus of Elasticity?

$$\boxed{E_B = -\frac{dP}{dV/V}}$$

$$= -\frac{2-1}{(0.995-1)/1}$$

$E_B = 200\ MPa$

13. What pressure is required to reduce the volume of water by 0.6% Bulk Modulus of Elasticity of Water, $E_B = 2.2$ GPa

$$\boxed{E_B = -\frac{dP}{dV/V}} \quad ; \ P_1 = 0$$

$$2.2 = -\frac{P_2}{0.006\,V/V}$$

$P_2 = 0.0132\ GPa = 13.2\ MPa$

15. Water in a hydraulic press, initially at 137 kPa absolute, is subjected to a pressure of 116,280 kPa absolute. Using $E_B = 2.5$ GPa, determine the percentage decrease in the volume of water.

$$\boxed{E_B = -\frac{dP}{dV/V}}$$

$$2.5 \times 10^9 = \frac{(116,280 - 137) \times 10^3}{dV/V}$$

$dV/V = -0.0465 = 4.65\%$ decrease

16. If $9\ m^3$ of an ideal gas at 24°C and 150 kPa is compressed to $2m^3$, a) what is the resulting pressure assuming isothermal conditions. b) what would have been the pressure and temperature if the process is isentropic. Use $k = 1.3$

a. Isothermal Condition:

$$\boxed{P_1V_1 = P_2V_2}$$

$$150(9) = P_2(2)$$

$P_2 = 675$ kPa abs

b. Isentropic process:

$$\boxed{P_1V_1^k = P_2V_2^k}$$

$$150(9)^{1.3} = P_2(2)^{1.3}$$

$P_2 = 1060$ kPa abs

17. A gas at 40°C under a pressure of 21.868 bars abs has a unit weight of 362 N/m³. What is the value of R for this gas? What gas might this be?

$$\boxed{\gamma = \frac{P}{RT}}$$

bars = $\times 10^5$

$$362\ N/m^2 = \frac{21.868 \times 10^5}{R(40+273)}$$

$R = 19.3\ m/K$

18. Calculate the density, specific weight, and volume of chloride gas 25°C and pressure of 600,000 N/m² abs.

density, ρ

$$\boxed{\rho = \frac{P}{RT}}$$

$$= \frac{600{,}000}{118(25+273)}$$

$= 17.1\ kg/m^3$

specific weight, γ

$$\boxed{\gamma = \rho g}$$

$= 17.1\ kg/m^3 (9.81\ m/s^2)$

$= 168\ N/m^3$

Volume, V

$$V = \frac{1}{\rho} = \frac{1}{17.1}$$

$= 0.0585\ m^3/kg$

VISCOSITIES

Dynamic or Absolute

$$\boxed{\frac{F}{A} = \tau = \mu \frac{du}{dy} = \mu \frac{u}{y}}$$

$$\boxed{\mu = \frac{\tau}{du/dy}}$$ (Pa. sec)

Kinematic

$$\frac{m^2}{s} \quad \boxed{\nu = \frac{\mu}{\rho}} \qquad \frac{\frac{Ns}{m}}{\frac{kg}{m^3}} = \frac{N\cancel{s}}{\cancel{m^2}} \cdot \frac{\cancel{m^3}}{\cancel{kg}} = \frac{m^2}{s}$$

$kg\ m/s^2$ $\quad m^{3}$ $\ ^1$

CONVERSIONS

1 Pa-s	1 Ns/m²
1 Pa	1 N/m²
1 N	1 kg·m/s²
1 poise	0.1 Pa-s
1 stoke	0.0001 m²/s

19. If the viscosity of water at 70°C is 0.00402 poise and its specific gravity is 0.978 determine its absolute viscosity in Pa-s and its kinematic viscosity in m^2/s and in stokes.

Absolute Viscosity,

$$\mu = 0.00402 \text{ poise} \times \frac{0.1 \text{ Pa-s}}{1 \text{ poise}}$$

$$\mu = 0.000402 \text{ Pa-s}$$

Dynamic Viscosity,

$$\boxed{v = \frac{\mu}{\rho}}$$

$$= \frac{0.000402 \text{ Pa-s}}{(0.978 \times 1000)}$$

$$P_a = \frac{N}{m^2} = \frac{kg}{m \times s^2}$$

$$v = 4.11 \times 10^{-7} \, m^2/s$$

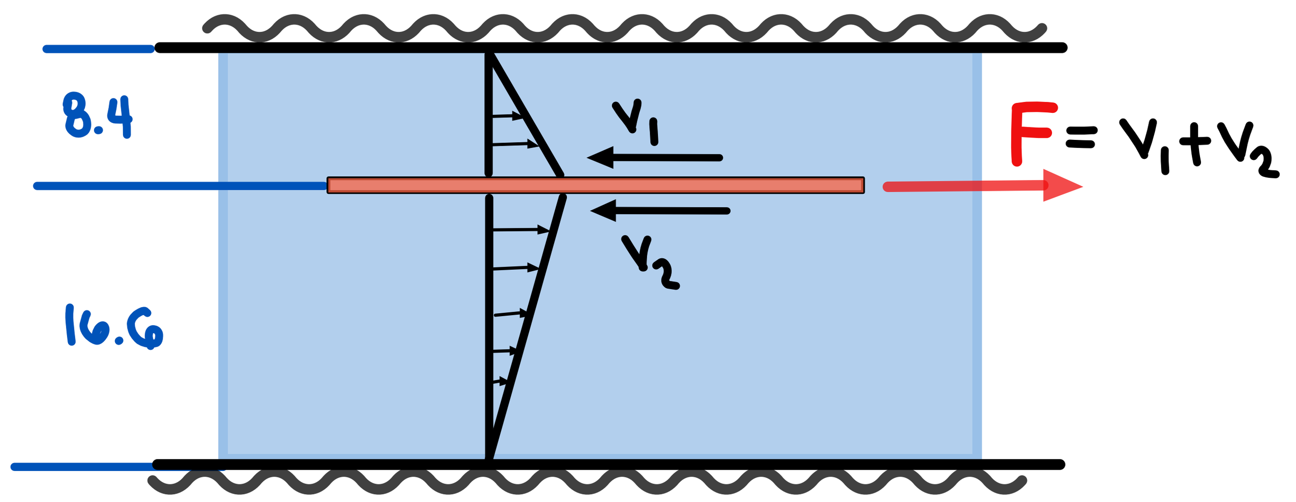
$$= 4.11 \times 10^{-7} \, m^2/s \times \frac{1 \text{ stoke}}{0.0001 \, m^2/s}$$

$$= 4.11 \times 10^{-3} \, m^2/s$$

20. Two large plane surfaces are 25 mm apart and the space between them is filled with a liquid of of viscosity $\mu = 0.958$ Pa-s. Assuming the velocity gradient to be a straight line, what force is required to pull a very thin plate of 0.37 m^2 area at a constant speed of 0.3 m/s if the plate is 8.4 mm from one of the surfaces?

$$\boxed{\mu = \frac{\tau}{du/dy}}$$

$$\mu = \frac{F/A}{du/dy}$$



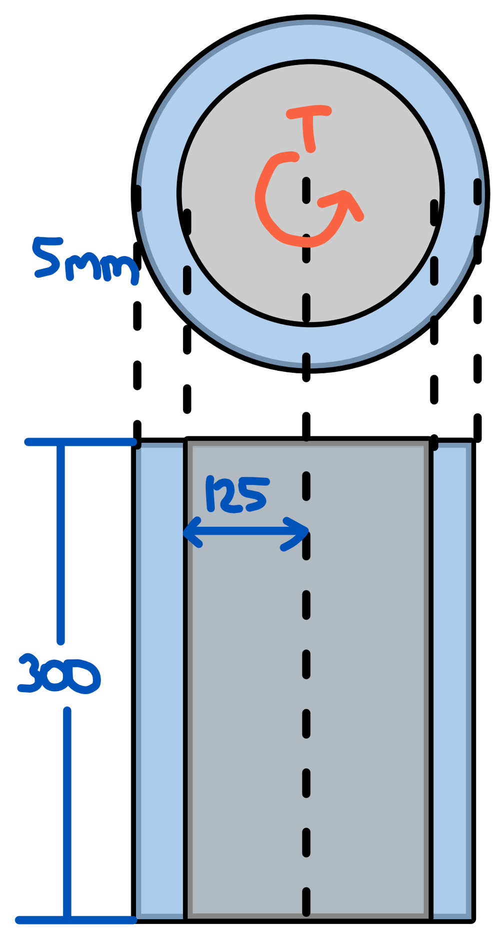
$$F = \frac{\mu U A}{y}$$

$$F_1 = \frac{0.958(0.3)(0.37)}{0.0084} = 12.6 \text{ N}$$

$$F_2 = \frac{0.958(0.3)(0.37)}{0.0166} = 6.4 \text{ N}$$

$$F = 12.6 + 6.4 = 19 \text{ N}$$

21. A cylinder of 125mm radius rotates concentrically inside a fix cylinder of 130 mm radius. Both cylinders are 300 mm long. Determine the viscosity of the liquid which fills the space between the cylinders. If a torque of 0.88 N-m is required to maintain an angular velocity of 2π rad/sec. Assume the velocity gradient to be straight line.



$$\boxed{\tau = \mu \frac{V}{Y}}$$

$$\boxed{\frac{F}{A} = \mu \frac{V}{Y}}$$

$$V = \omega r$$
$$= 2\pi(0.125) = \frac{\pi}{4}$$

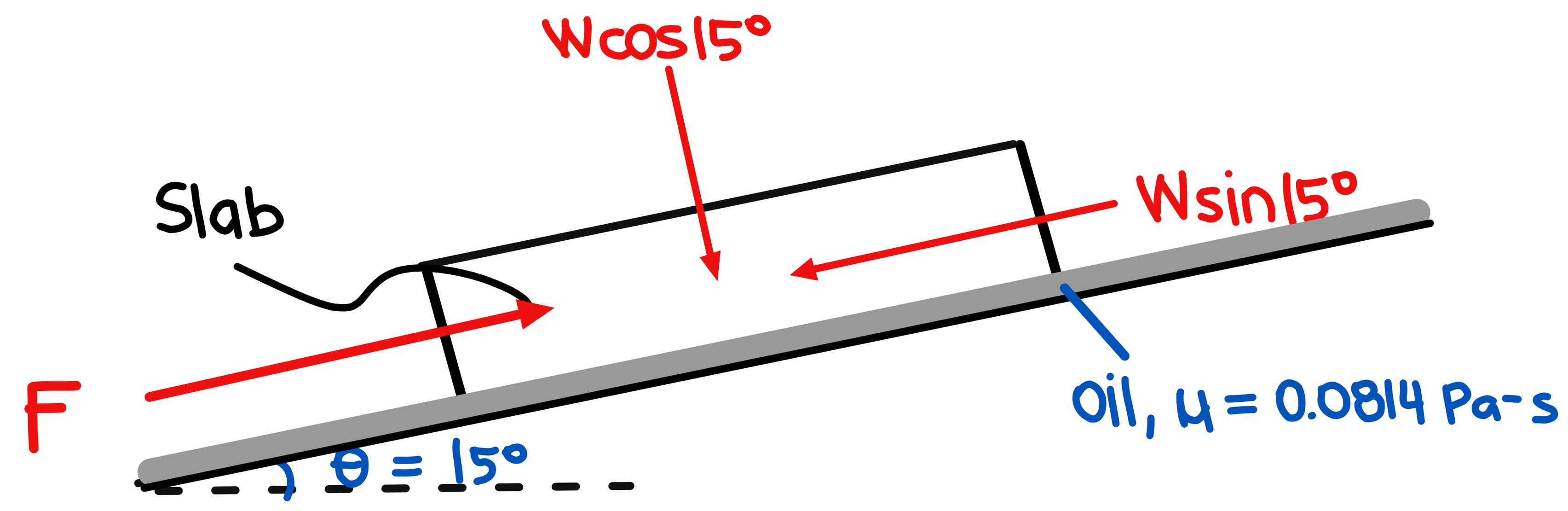
$$A = 2\pi r l$$
$$= 2\pi(0.125)(0.3)$$
$$= 0.236\ m^2$$

$$T = Fr$$
$$0.88\,N\cdot m = F(0.125)$$
$$F = 7.04\,N$$

$$\frac{7.04}{0.236} = \mu \frac{\pi/4}{0.005}$$

$\mu = 0.19$ Pa-s

22. An 18 kg slab slides down a 15° inclined plane on a 3 mm thick film of oil with viscosity $\mu = 0.0814$ Pa-s. If the contact area is $0.3\,m^2$, find the terminal velocity of the slab.



$$\tau = \mu \frac{V}{Y}$$ Looking for

$$\frac{F}{A} = \mu \frac{V}{Y}$$

$$F = W\sin\theta$$
$$= 18(9.81)\sin 15°$$
$$= 45.702\,N$$

$$\frac{45.702}{0.3} = 0.0814 \frac{V}{0.003}$$

$V = 5.614$

23. Estimate the height to which water will rise in a capillary tube of diameter 3 mm. Use σ = 0.0728 N/m and γ = 9810 N/m³ for water.

Capillary rise, h

$$\boxed{h = \frac{4\sigma}{\gamma d}}$$

$$= \frac{4(0.0728)}{9810(0.003)}$$

$$h = 0.0099 \text{ m} = 9.9 \text{ mm}$$

24. Estimate the capillary depression for mercury in a glass capillary tube 2mm in diameter. Use σ = 0.514 N/m and θ = 140°

Capillary rise, h

$$h = \frac{4\sigma\cos\theta}{\gamma d}$$

$$= \frac{4(0.514 \cos 140)}{(9810 \times 13.6)(0.002)}$$

$$= \ominus\ 0.0059$$

(−) capillary depression

$$h = 5.9 \text{ mm}$$

25. What is the value of the surface tension (σ) of a small drop of water 0.3 mm in diameter which is in contact with air if the pressure within the droplet is 561 Pa?

$$\boxed{P = \frac{4\sigma}{d}}$$

$$561 = \frac{4\sigma}{0.0003}$$

$$\sigma = 0.042 \text{ N/m}$$

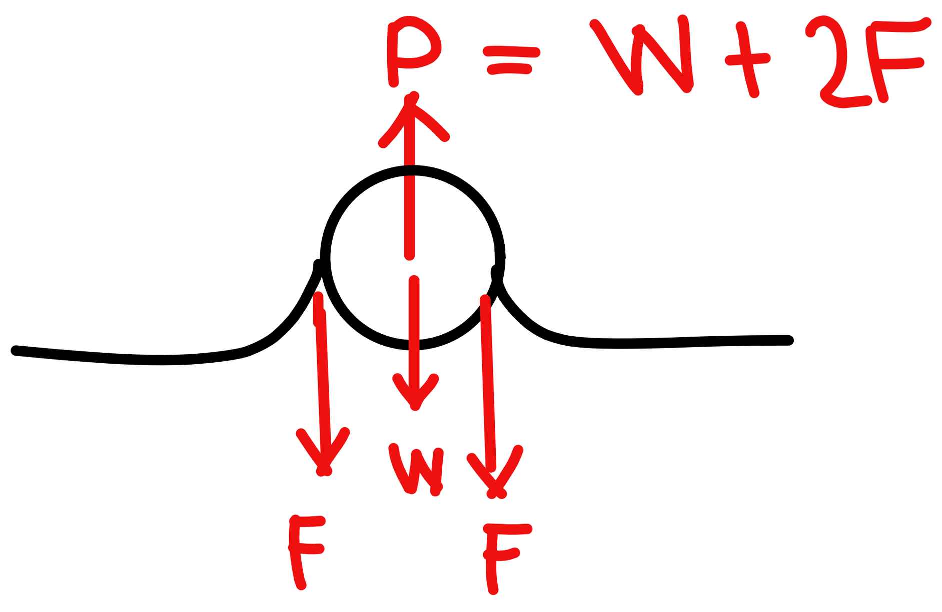
26. An atomizer forms water droplets 45 μm in diameter. Determine the excess pressure within these droplets using σ = 0.0712 N/m.

$$\boxed{P = \frac{4\sigma}{d}}$$

$$= \frac{4(0.0712)}{45 \times 10^{-6}}$$

$$P = 6{,}329 \text{ Pa}$$

27. The length of a needle floating on water is 2.5 cm. The minimum force in addition to its weight needed to lift the needle above the surface of water will be $\sigma = 0.072\ N/m$



$$\boxed{P = W + 2F}$$

$= 2\sigma L$

$= 2(0.072)(0.025)$

$= 3.6 \times 10^{-3}\ N$

28. A 10 cm long wire is pulled horizontally on the surface of water and is gently pulled up with a force of 2×10^{-2} N. To keep the wire in equilibrium, the surface tension of water N/m?

Assume mass is negligable

$P = \overset{0}{\cancel{W}} + 2F$

$2\times10^{-2} = 2\sigma\ell$

$2\times10^{-2} = 2\sigma(0.1\,m)$

$\sigma = 0.1\ N/m$

30. A force of 3.6×10^{-3} N is required to pull a 5cm long wire attached to a thin film of liquid shown below.

a. Calculate the surface tension.

b. How much work is required to increase the area of this fluid by $2.8 \times 10^{-4}\ m^2$.

a $\boxed{P = \overset{0}{\cancel{W}} + 2F_\sigma}$

$3.6 \times 10^{-3}\ N = 2\sigma(0.05)$

$\sigma = 0.036\ N/m$

b $W = Fd$

$= \sigma Ld$ A

$= 0.036 \frac{N}{\cancel{m}} (2.8\times10^{-4}\ m^{\cancel{2}})$

$= 1.008 \times 10^{-5}\ N\cdot m$ or J

31. Under standard conditions a certain gas weighs $0.14\ lb/ft^3$. Calculate its density, specific volume and specific gravity relative to air weighing $0.075\ lb/ft^3$.

density, ρ

$$\boxed{\rho = \frac{\gamma}{g}} = \frac{0.14\ lb/ft^3}{32.2} = 4.34 \times 10^{-3}\ slug/ft^3$$

specific volume, V_s

$$\boxed{V_s = \frac{1}{\rho}} = \frac{1}{4.34 \times 10^{-3}} = 230\ ft^3/slug$$

specific gravity relative to air

$$S = \frac{0.14}{0.075} = 1.87$$

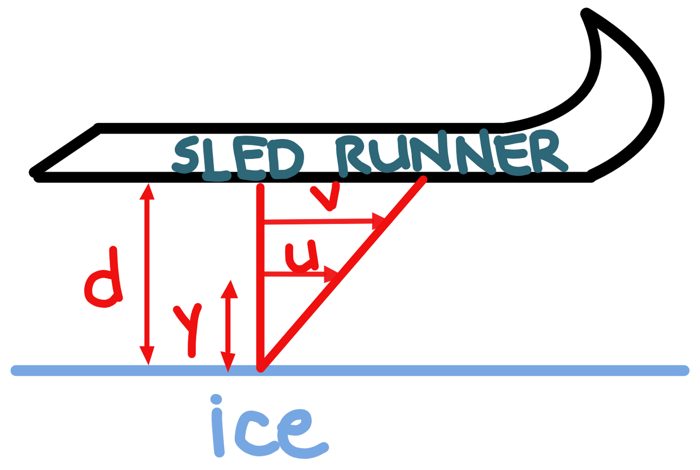
32. If $E = 2.2$ GPa is the bulk modulus of elasticity for water, what pressure is required to reduce a volume by 0.6 percent?

$$\boxed{E = -\frac{\Delta P}{\Delta V / V}}$$

$$2.2 = -\frac{P_2 - 0}{-0.006}$$

$$P_2 = 0.0132\ GPa = 13.2\ MPa$$

33.



$F = 1.2\ lb$

$V = 50\ ft/s$

$A = 0.08\ ft^2$

$\mu = 3.5 \times 10^{-5}\ \frac{lb \cdot s}{ft^2}$

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

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

$$\frac{1.2\ lb}{0.08\ ft^2} = \left(3.5 \times 10^{-5}\ \frac{lb \cdot s}{ft^2}\right)\left(\frac{50\ \cancel{ft}/s}{d\ \cancel{ft}}\right)$$

$$d = 11.7 \times 10^{-4}\ ft$$

Principles of Hydrosstatics

1. If a depth of liquid of 1m causes a pressure of 7 kPa, what is the specific gravity of the liquid?

$$\boxed{P = \gamma h}$$

$$7 = (9.81 \times s)(1)$$

$$s = 0.714$$

2. What is the pressure 12.5 below the ocean? Use sp.gr. = 1.03 for salt water.

$$\boxed{P = \gamma h}$$

$$= (9.81 \times 1.03)(12.5)$$

$$P = 126.31 \text{ kPa}$$

3. If the pressure 23 m below a liquid is 338.445 kPa, determine its unit weight γ, mass density and specific gravity, s.

Unit weight,

$$p = \gamma h$$

$$338.445 = \gamma(23)$$

$$\gamma = 14.715 \text{ kN/m}^3$$

mass density,

$$\boxed{\rho = \frac{\gamma}{g}}$$

$$= \frac{14.715 \times 10^3}{9.81}$$

$$\rho = 1500 \text{ kg/m}^3$$

specific gravity, s

$$\boxed{s = \frac{\rho_{fluid}}{\rho_{water}}}$$

$$= \frac{1500}{1000}$$

$$s = 1.5$$

4. If the pressure point in the ocean is 60 kPa, what is the pressure 27 m below this point?

$$\boxed{P_2 - P_1 = \gamma h}$$

$$P_2 = 60 + (9.81 \times 1.03)(27)$$ $s = 1.03$ seawater

$$P_2 = 332.82 \text{ kPa}$$

5. If the pressure in the air space above an oil ($s = 0.75$) surface in a closed tank is 115 kPa absolute, what is the gage pressure 2m below the surface?

$$\boxed{P = P_{surface} + \gamma h}$$

$$P_{surface} = 115 \text{ kPa} - 101.325$$

$$P_{surface} = 13.675 \text{ kPa gage}$$

$$13.675 + (9.81 \times 0.75)(2)$$

$$P = 28.39 \text{ kPa}$$

6. Find the absolute pressure in kPa at a depth of 10 m below the free surface of oil of sp.gr. 0.75 if the barometric reading is 752 mmHg.

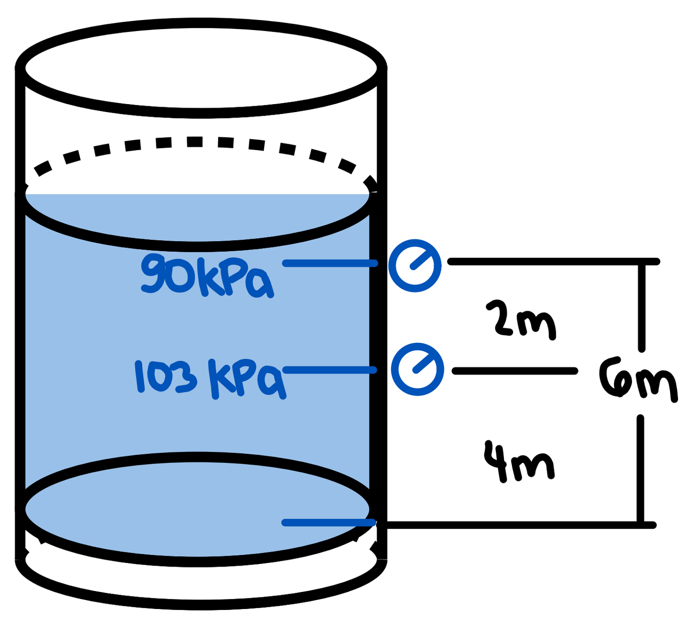
$$\boxed{P_{abs} = P_{gage} + P_{atm}}$$

$$P_{atm} = \gamma_m h_m \quad \text{mercury density}$$
$$= (9.81 \times 13.6)(0.752)$$
$$= 100.329 \text{ kPa}$$

$$= (9.81 \times 0.75)(10) + 100.329$$

$$P_{abs} = 173.9 \text{ kPa}$$

7. A pressure gage 6 m above the bottom of the tank containing a liquid reads 90 kPa. Another gage height 4m reads 103 kPa. Determine the specific weight of the liquid.

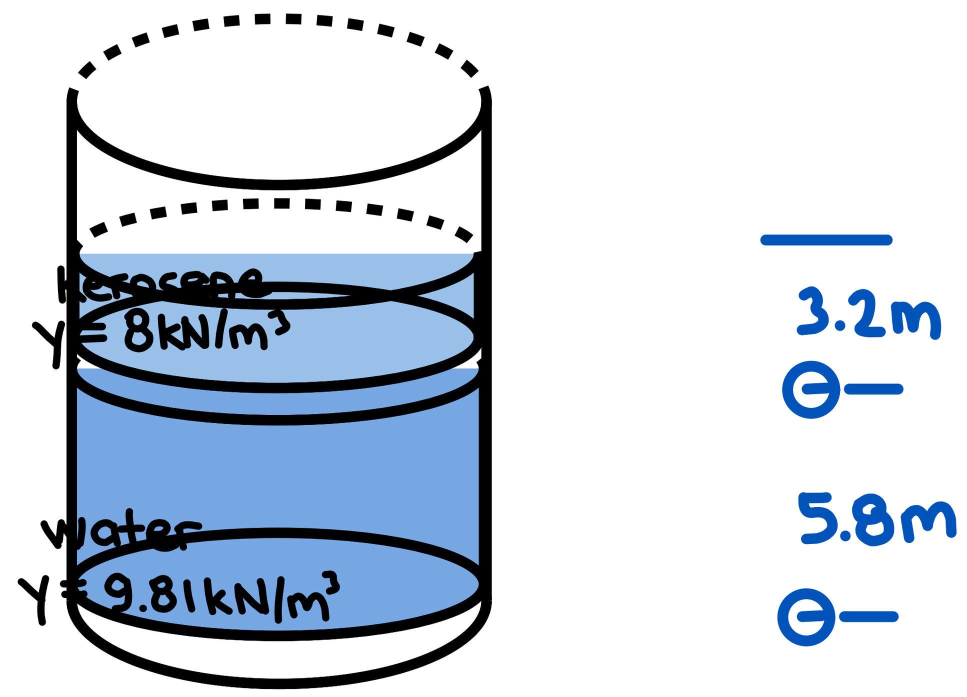


$$\boxed{P_2 - P_1 = \gamma h}$$
$$103 - 90 = \gamma(2)$$
$$\gamma = 6.5 \text{ kN/m}^3$$

8. An open tank contains 5.8 m of water covered with 3.2 m of kerosene ($\gamma = 8$ kN/m³). Find the pressure at the interface and at the bottom.

a. Pressure at the interface

$$\boxed{P_A = \gamma_k h_k}$$
$$= 8(3.2)$$
$$= 25.6 \text{ kPa}$$



b. Pressure at the bottom

$$\boxed{P_B = \Sigma \gamma h}$$
$$= 9.81(5.8) + 8(3.2)$$
$$= 82.498 \text{ kPa}$$

9. If atmospheric pressure is 95.7 kPa and the gage attached to the tank reads 188 mmHg vacuum, find the absolute pressure within the tank.

$$\boxed{P_{abs} = P_{atm} + P_{gage}}$$

$$P_{gage} = \gamma_{mercury} h_{mercury}$$
$$= (9.81 \times 13.6)(0.188)$$
$$= 25.08 \text{ kPa vacuum}$$

$$P_{abs} = 95.7 + (-25.08)$$
$$= 70.62 \text{ kPa abs.}$$

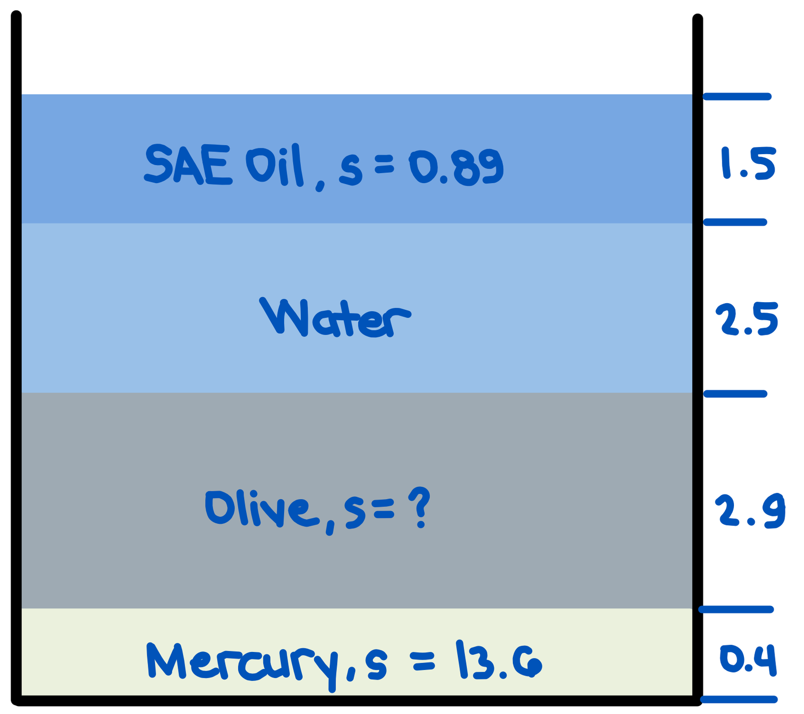
10. The weight density of a mud is given by $\gamma = 10 + 0.5h$, where γ is in kN/m^3 and is in meters. Determine the pressure, in kPa, at a depth of 5m.

$$d_p = \gamma \, dh$$

$$\int_0^p d_p = \int_0^5 (10 + 0.5h)\, dh$$

$p = 56.25$ kPa

11. If the atmospheric pressure is 101 03 kPa and the absolute pressure at the bottom of the tank is 231.3 kPa, what is the specific gravity of olive oil?



Gage pressure at the bottom of the tank:

$$P_{gage} = 231.3 - 101.3$$
$$= 130.27 \text{ kPa}$$

$$\boxed{P = \Sigma \gamma h}$$

$$130.27 = (9.81 \times 13.6)(0.4) + (9.81 \times s)(2.9) + (9.81 \times 1)(2.5) + (9.81 \times 0.89)(1.5)$$

$s = 1.38$

12. If air had a constant specific weight of $12.2 \, N/m^3$ and were incompressible, what would be the height of the atmosphere if the atmospheric pressure (sea level) is 102 kPa.

$$\boxed{P = \gamma h}$$

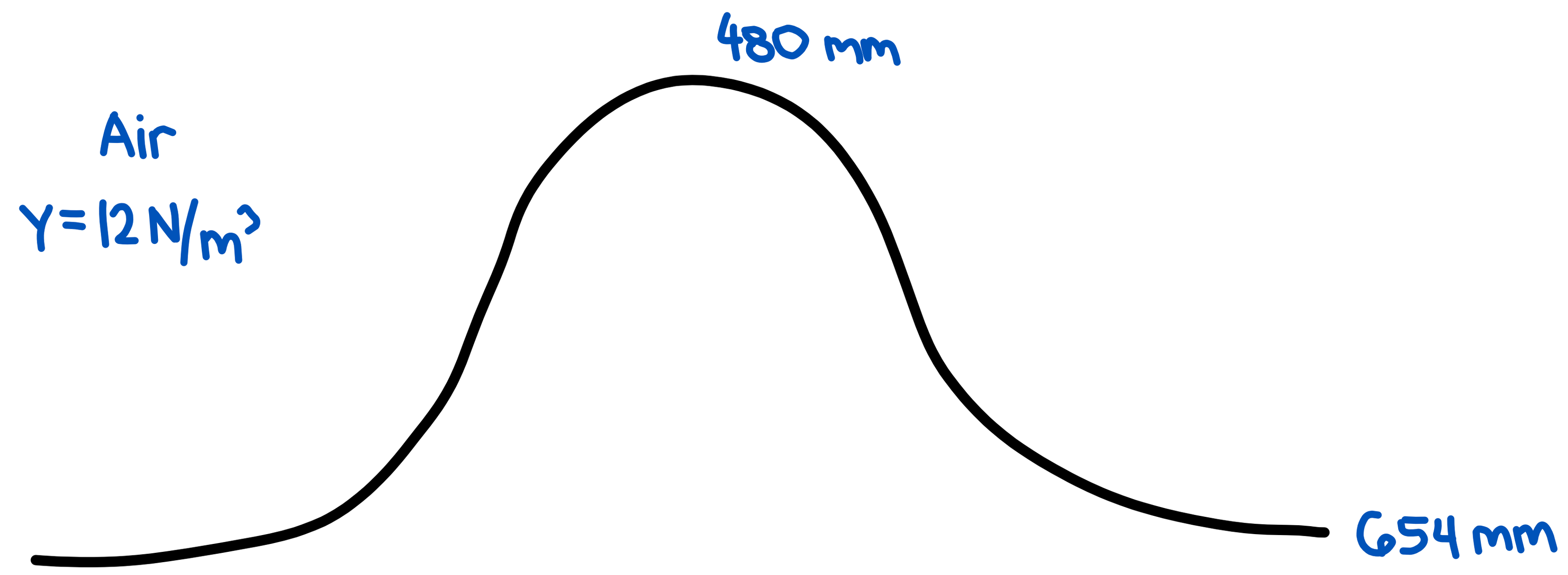
$$102 \times 10^3 = 12.2(h)$$

$h = 8,360.6$ m

13. What is the height of the mountain? Specific weight of air is $12 \, N/m^3$. Mercury barometer reads

bottom = 654 mm

top = 480 mm



$$\boxed{P_{bot} - P_{top} = \gamma h}$$

$$(9.81 \times 13.6)(0.654) - (9.81 \times 13.6)(0.48) = (12)h$$

$h = 1,934.53$ m

14. Convert 760 mm of mercury to oil of sp.gr. 0.82 and water.

a. $\boxed{h_{oil} = h_{mercury} \dfrac{S_{mercury}}{S_{oil}}}$

$$h_{oil} = 0.76 \frac{13.6}{0.82}$$

$h_{oil} = 12.605$ m

b. $\boxed{h_{water} = h_{mercury} S_{mercury}}$

$$= 0.76(13.6)$$

$h_{water} = 10.34$ m

15. A barometer reads 760 mmHg and a pressure gage attached to a tank reads 850 cm of oil (sp.gr. 0.80). What is the absolute pressure in the tank in kPa?

$\boxed{P_{abs} = P_{atm} + P_{gage}}$

$$= (9.81 \times 13.6)(0.76) + (9.81 \times 0.8)(8.5)$$

$P_{abs} = 168.1$ kPa abs

16. A hydraulic press is used to raise an 80-kN cargo truck. If oil of sp.gr. 0.82 acts on the piston under a pressure of 10 MPa, what diameter of piston is required?

$\boxed{F = PA}$

$$80{,}000\text{ N} = 10 \times 10^3\text{ N/m}^2 \left(\frac{\pi}{4} D^2\right)$$

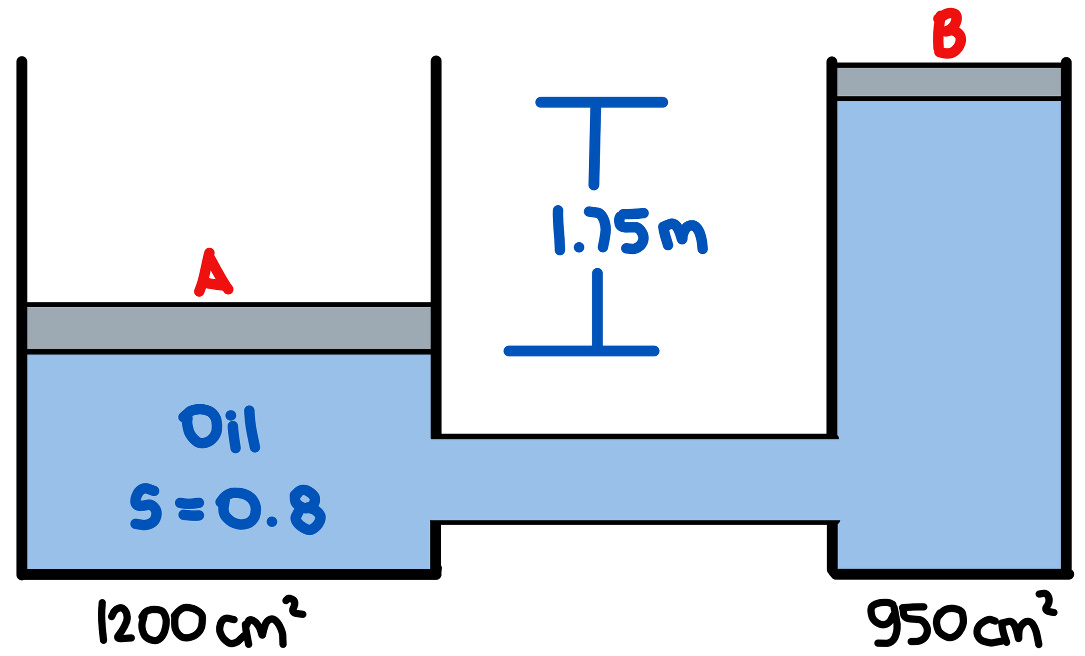
$D = 0.1$ m $= 100$ mm

17. What is the difference in pressure between A and B.

$\boxed{P_A - P_B = \gamma h}$

$$= (9.81 \times 0.8)(1.75)$$

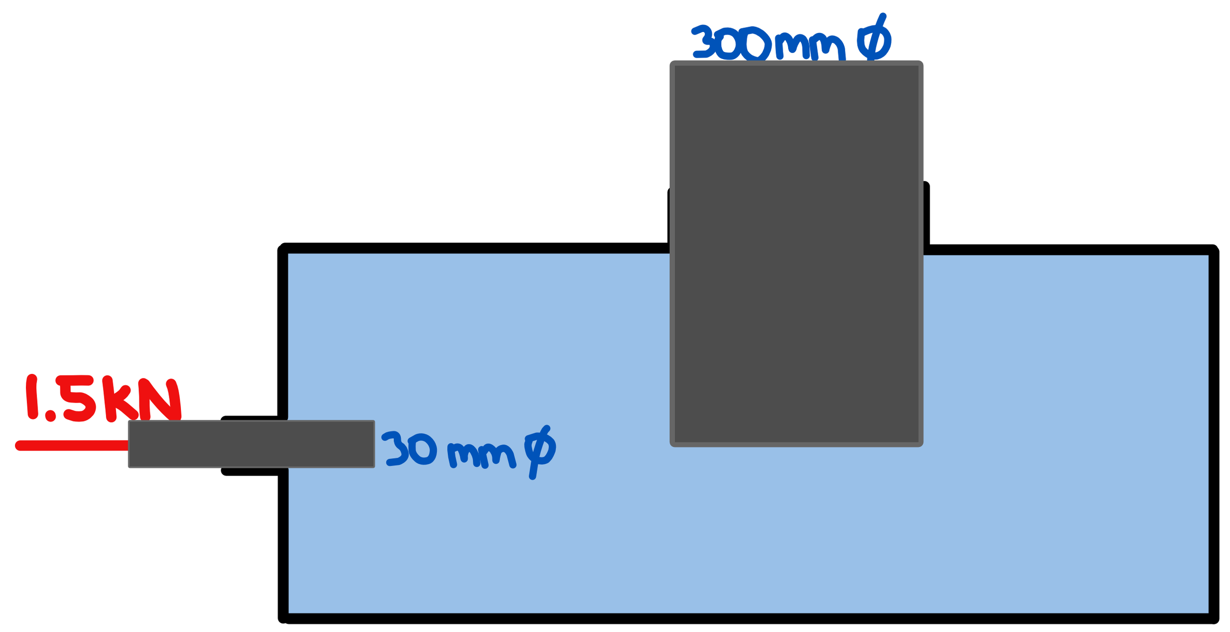
$P_A - P_B = 13.73$ kPa



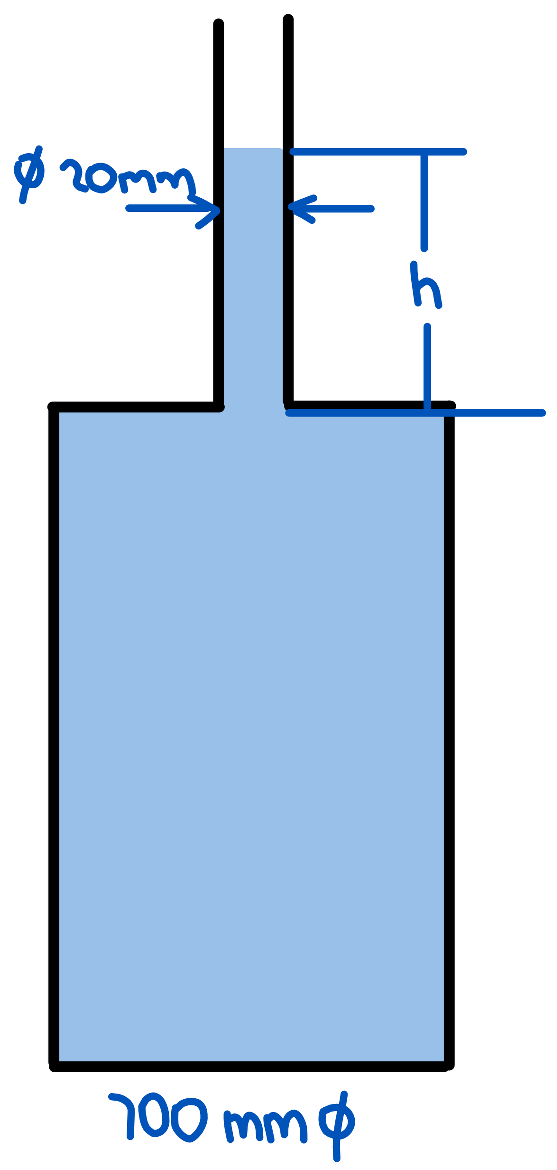
18. Determine the weight W that can be carried by the 1.5 kN force acting on the piston.

$$\frac{1.5}{\frac{\pi}{4}(30)^2} = \frac{W}{\frac{\pi}{4}(300)^2}$$

$W = 150$ kN



19. A drum 700 mm in diameter and filled with water has a vertical pipe, 20 mm in diameter, attached to the top. How many Newtons of water must be poured into the pipe to exert a force of 6500 N on the top of the drum?



Force on the top:

$\boxed{F = PA}$

$6500N = P \times \frac{\pi}{4}(700^2 - 20^2)$

$P = 0.169\ MPa$

$= 16900\ Pa$

$\boxed{P = \gamma h}$

$16900 = 9810(h)$

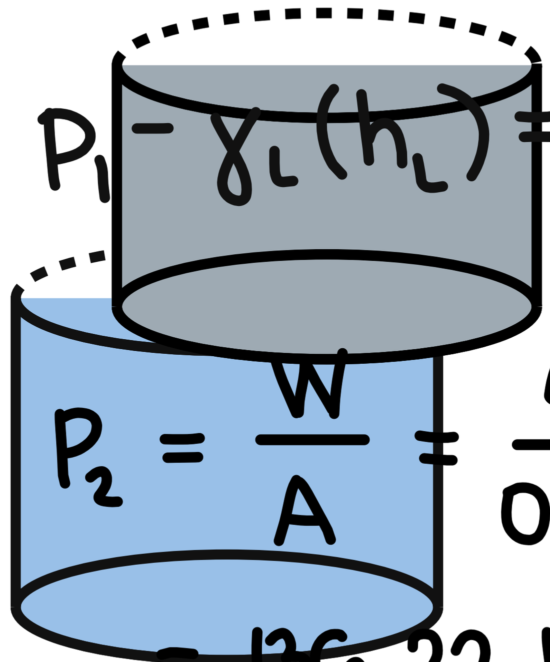
$h = 1.723\,m$

$\boxed{\gamma = \frac{W}{V}}$

$$9810 = \frac{\text{Weight}}{\frac{\pi}{4}(0.02)^2(1.723)}$$

$W = 5.31\ N$

20. What force f is required to balance the weight of the cylinder if the weight of plunger is negligible?



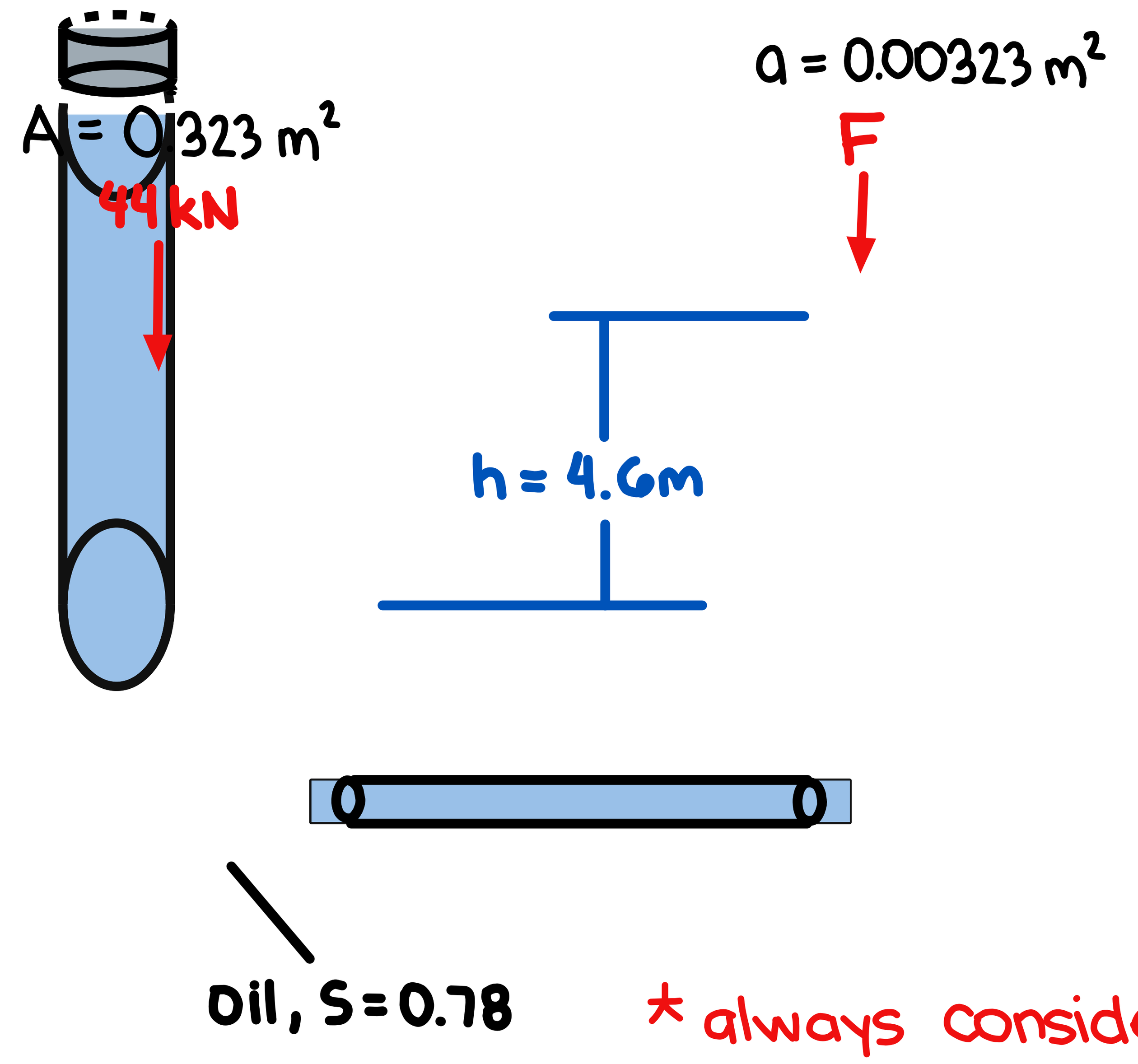
$P_1 - \gamma_L(h_L) = P_2$

$P_2 = \frac{W}{A} = \frac{44}{0.323}$

$= 136.22\ kPa$

$P_1 = \frac{F}{a} = \frac{F}{0.00323}$

$= 309.6\,F$



* always consider the difference in height

$136.22 - 309.6F = (9.81 \times 0.78)(4.6)$

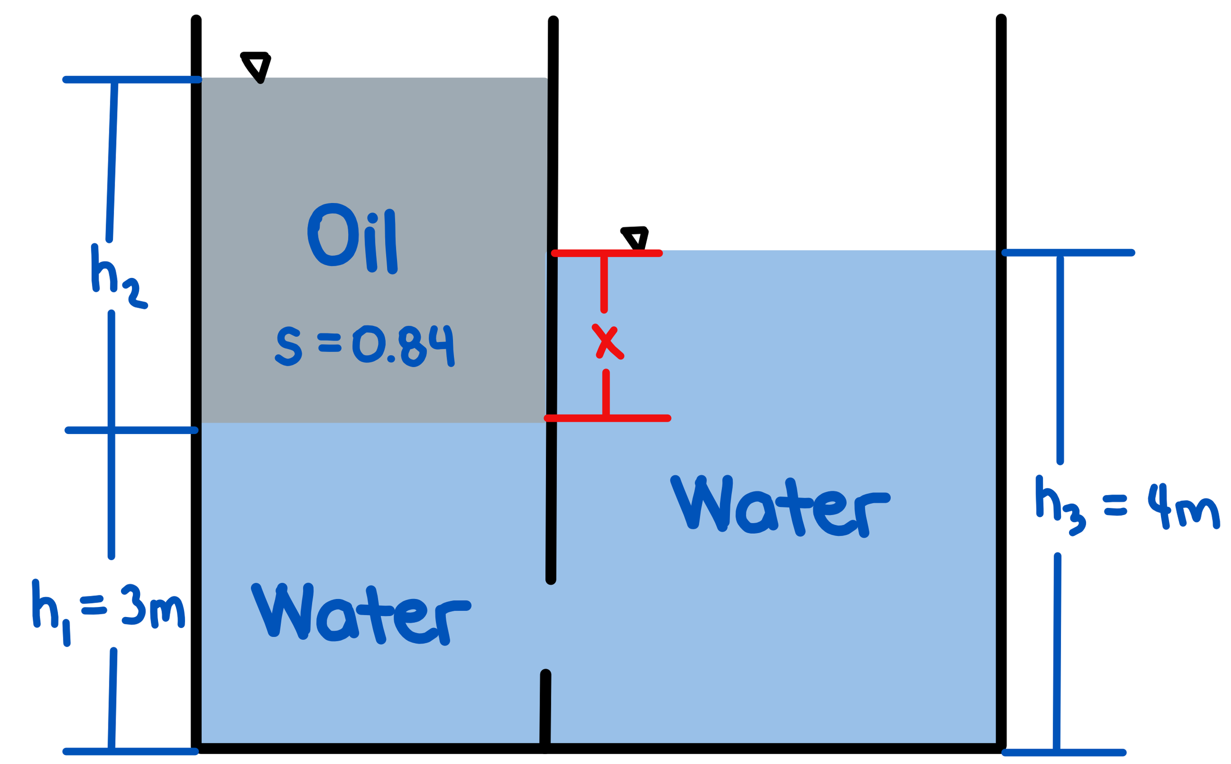
$F = 0.326\ kN$

21. Determine the value of h_2.

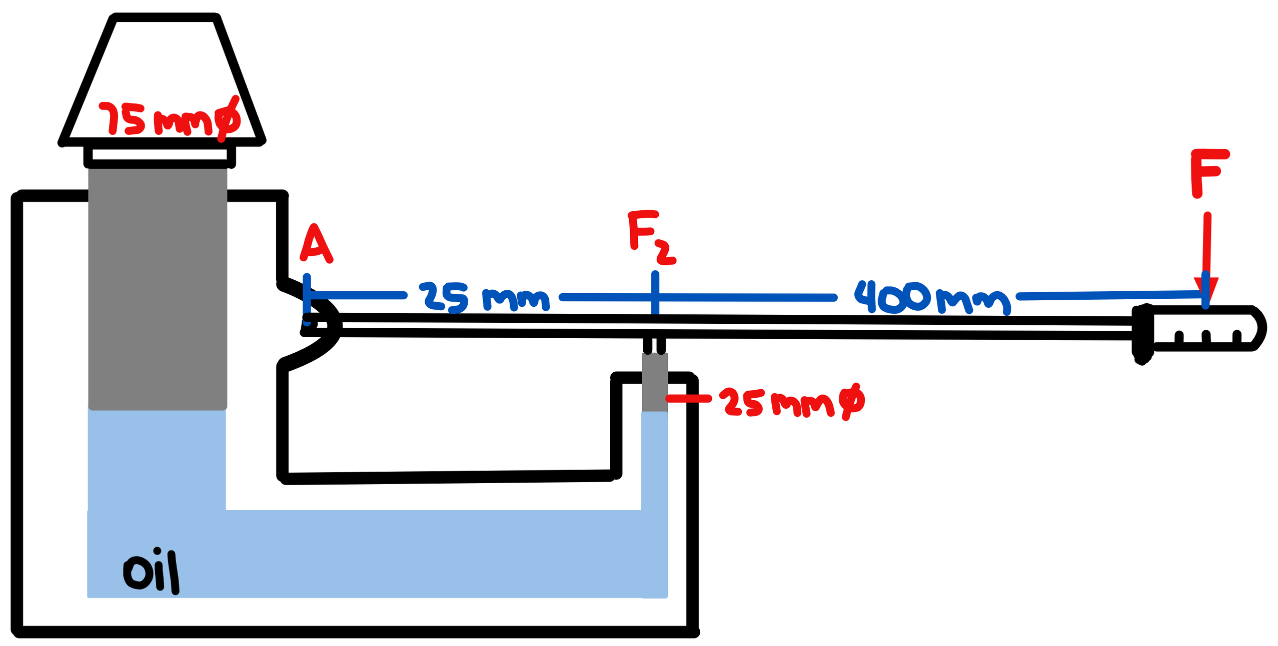
$\frac{P_1}{\gamma} + h_2(0.84) - x = \frac{P_3}{\gamma}$

$0 + 0.84h_2 - (4-3) = 0$

$h_2 = 1.19\ m$



22. The hydraulic press is filled with sp.gr. 0.82 Neglecting the weight of the two pistons, what force F on the handle is req'd to support the 10 kN weight?



$$\boxed{\frac{F_1}{A_1} = \frac{F_2}{A_2}}$$

$$\frac{10}{\frac{\pi}{4}(0.075)^2} = \frac{F_2}{\frac{\pi}{4}(0.025)^2}$$

$F_2 = 1.11$ kN

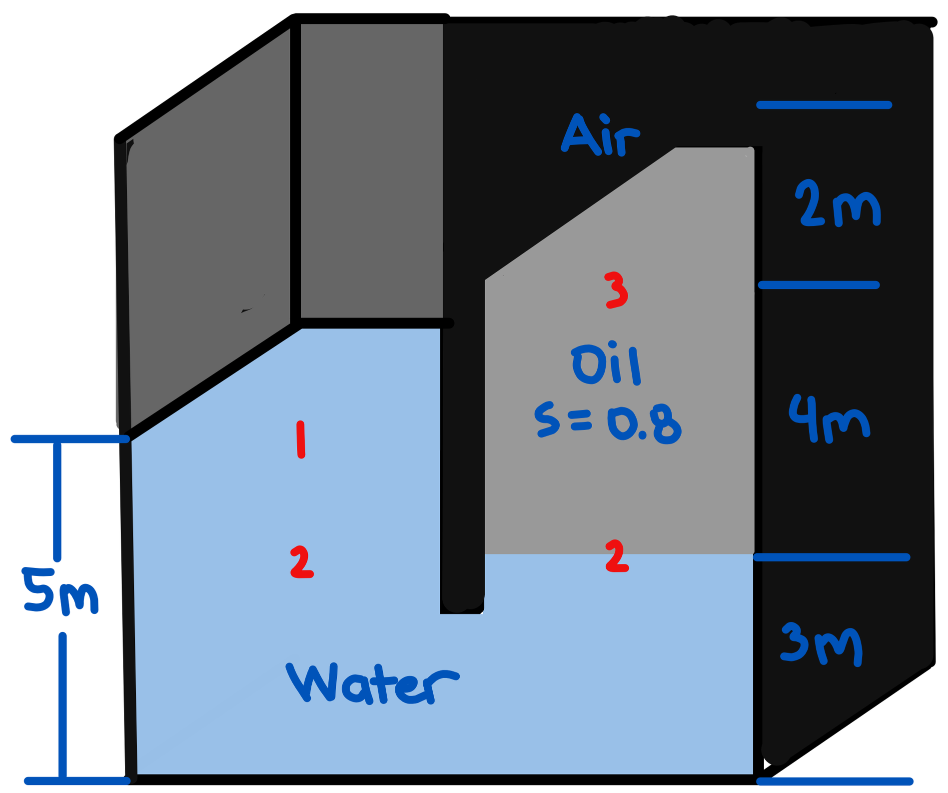
$\Sigma M_A = 0$

$F(0.425) = F_2(0.025)$

$F(0.425) = 1.11(0.025)$

$F = 0.064$ kN $= 64$ N

23. What is the static pressure in kPa in air chamber?



$P_1 = 0$

$P_2 = \gamma_w h_w$

$= 9.81 \text{ kN/m}^3 (2\text{ m})$

$= 19.62$ kPa

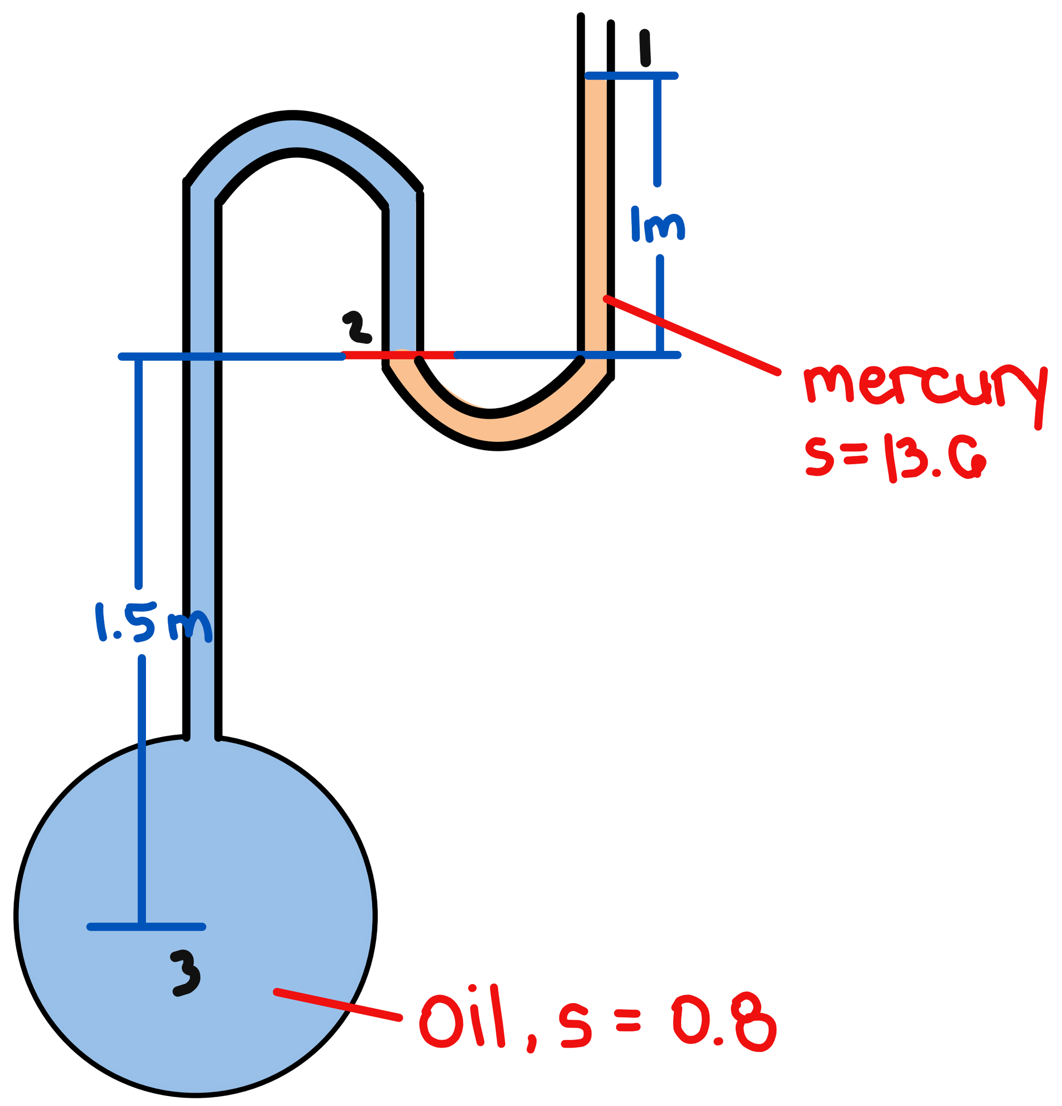
Sum up pressure head:

$$\cancel{\frac{P_1}{\gamma}}^{\,0} + 2 = 0.8(4) + \frac{P_3}{\gamma}$$

$$2 - 0.8(4) = \frac{P_3}{9.81}$$

$P = -11.77$ kPa

24. Determine the pressure at the center of the pipe.

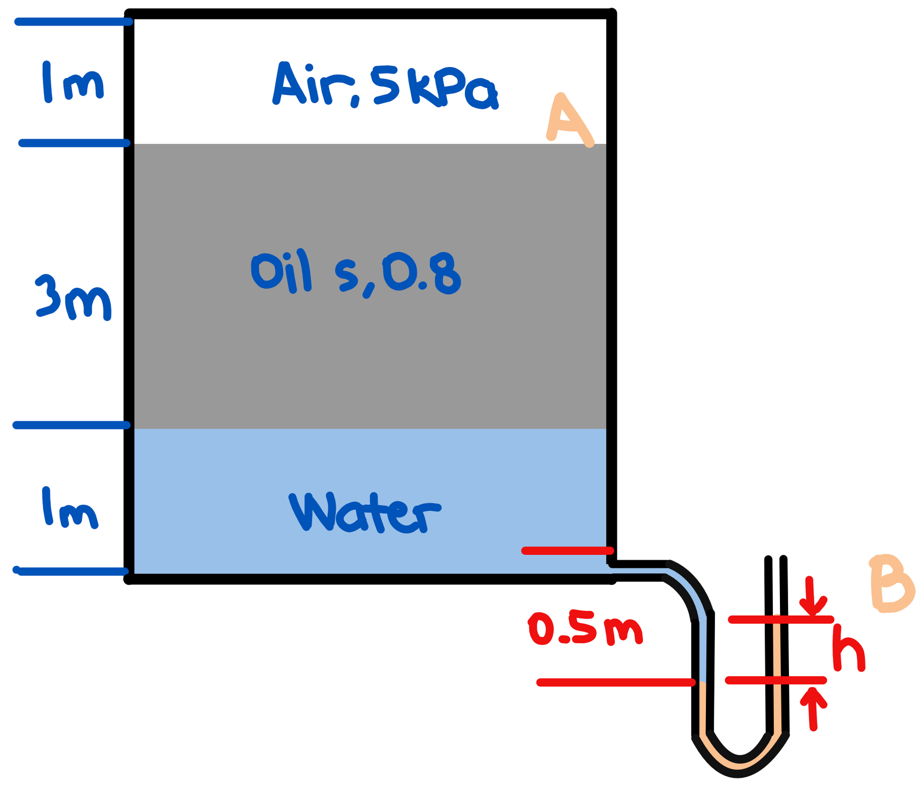


$$\cancel{\frac{P_1}{\gamma}}^{\,0} + 13.6(1) - 1.5(0.8) = \frac{P_3}{\gamma}$$

$$\frac{P_3}{\gamma} = 14.75 \text{ m of water}$$

$$P_3 = 14.75(\gamma)$$
$$= 14.75(9.81)$$
$$= \boxed{144.7 \text{ kPa}}$$

25. Determine the value of h in manometer

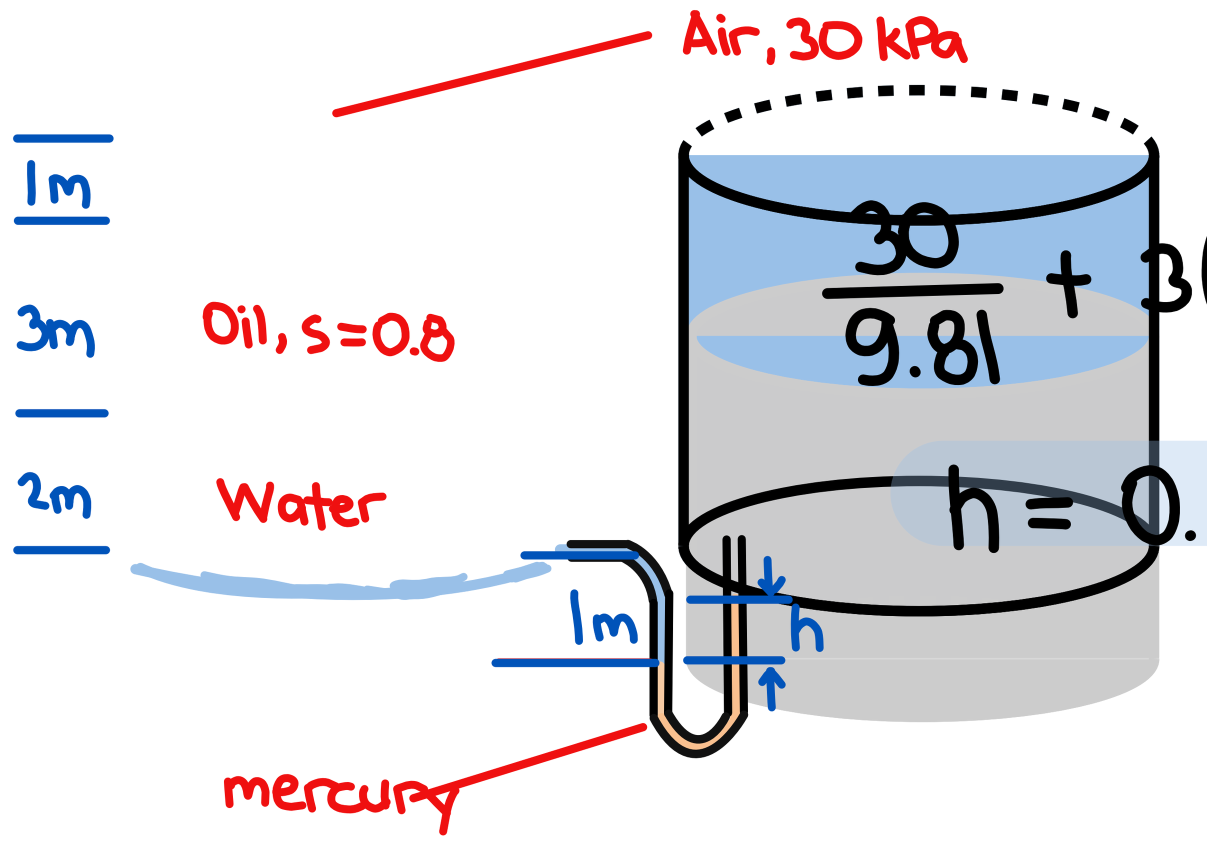


$$\frac{P_A}{\gamma} + 3(0.8) + 1.5(1) = h(13.6) + \cancel{\frac{P_B}{\gamma}}^{\,0}$$

$$\frac{5}{9.81} + 3(0.8) + 1.5(1) = h(13.6)$$

$$\boxed{h = 0.324 \text{ m}}$$

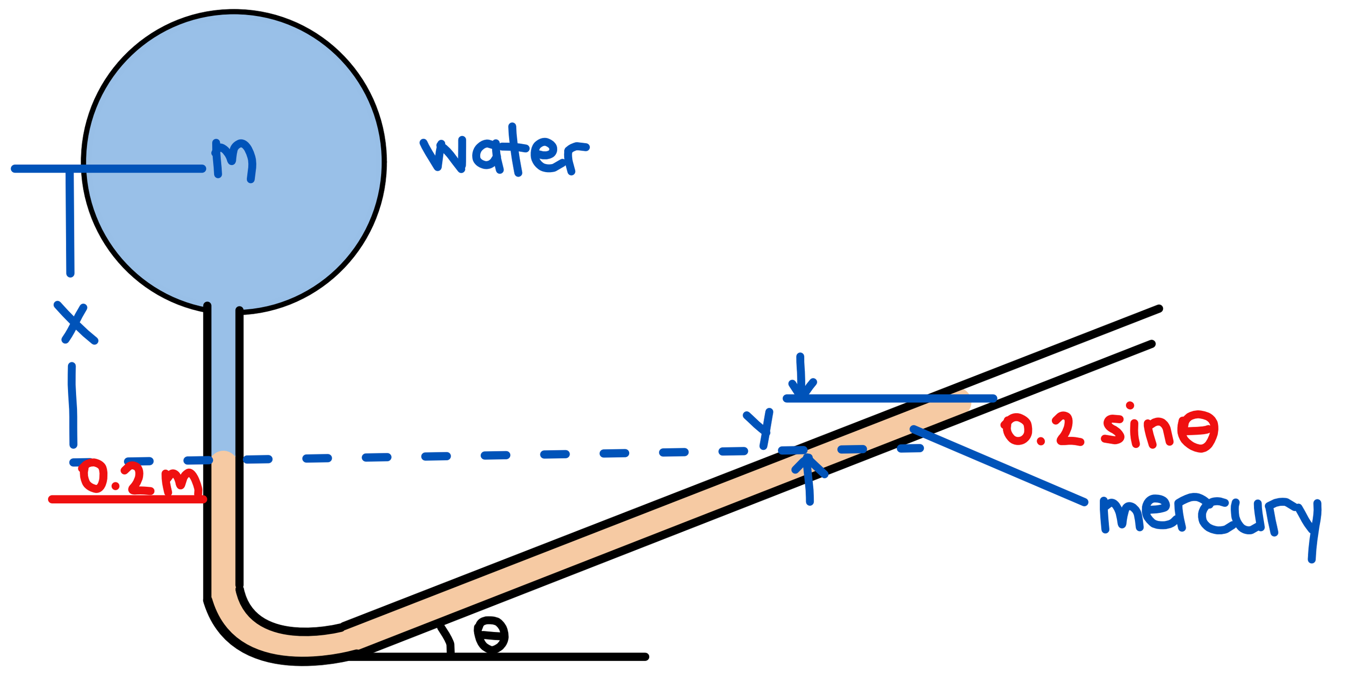
26 What is the deflection of mercury, h.



$$\frac{30}{9.81} + 3(0.8) + 2 + 1 - h(13.6) = \cancel{\frac{P_4}{\gamma}}^{\,0}$$

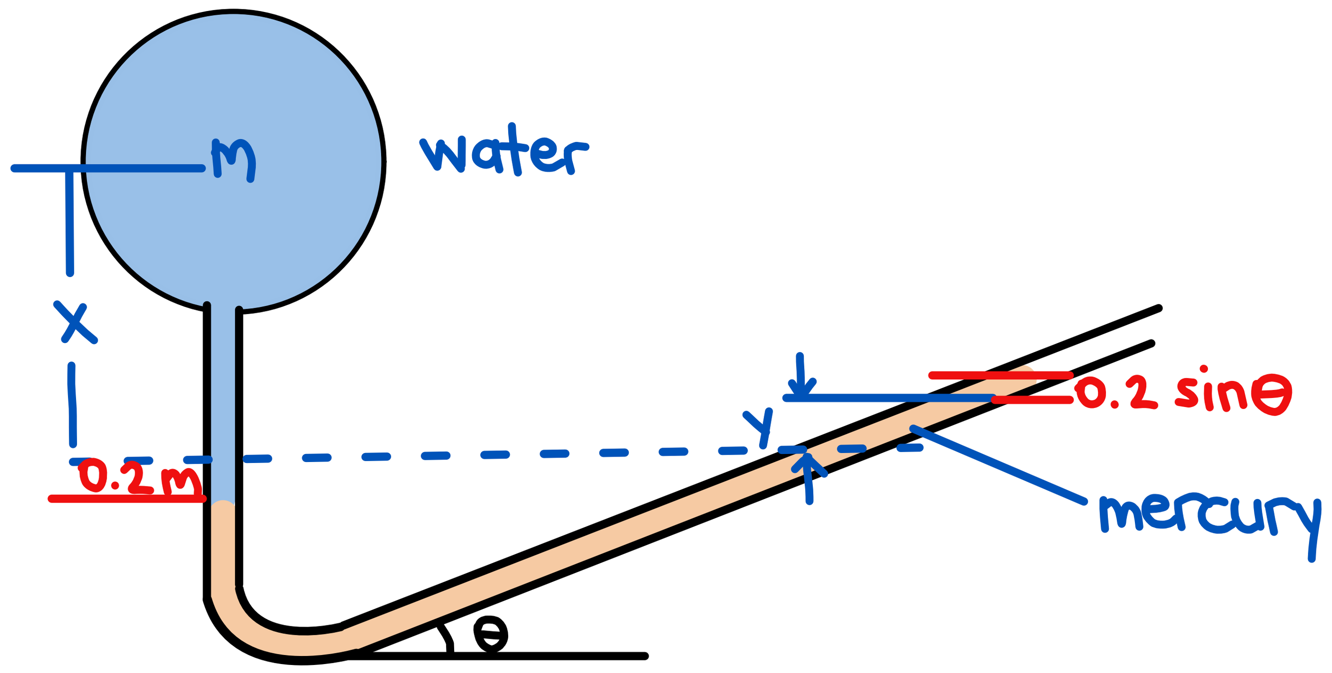
$$\boxed{h = 0.626}$$

27. The pressure at point m was increased from 70 kPa to 150 kPa. This causes the top level of mercury to move 20 mm in the sloping tube. What is the inclination, θ



$$\frac{\cancel{P_2}^{\,0}}{\cancel{\gamma}} + y(13.6) = x(1m) + \frac{P_m}{\gamma_m}$$

$$13.6y - x = \frac{70}{9.81} \quad \text{eq. 1}$$



After increasing the pressure :

$$\frac{\cancel{P_2}^{\,0}}{\cancel{\gamma}} + (0.2\sin\theta + y + 0.2)(13.6) = (x + 2)(1) + \frac{105}{9.81}$$

$$0 + 2.72\sin\theta + 13.6y + 2.72 - x - 0.2 = \frac{105}{9.81}$$

$$13.6y - x = 8.183 - 2.72\sin\theta \quad \text{eq. 2}$$

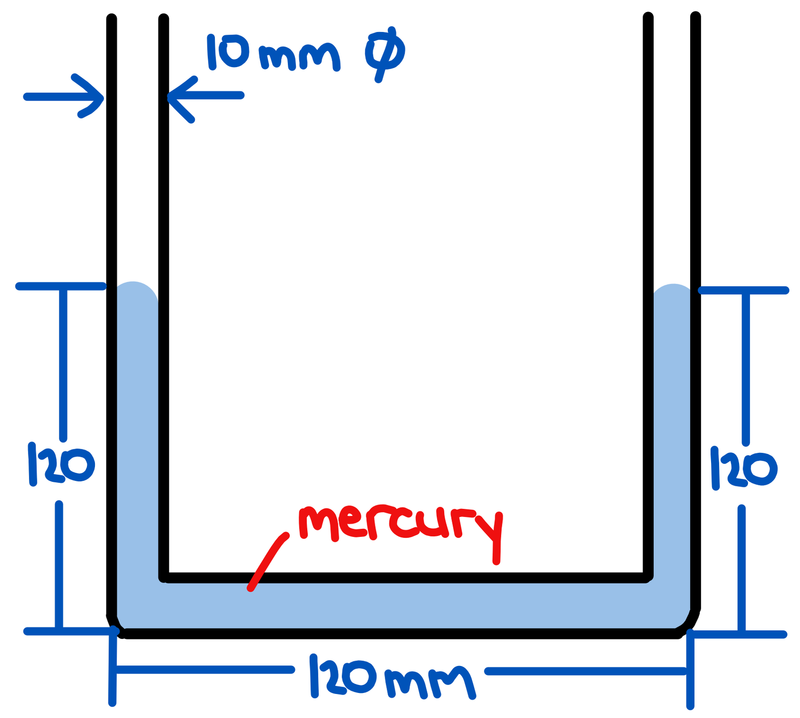
$$\cancel{13.6y} - \left(\cancel{13.6y} - \frac{70}{9.81}\right) = 8.183 - 2.72\sin\theta$$

$$1.047 = 2.72\sin\theta$$

$$\sin\theta = 0.3851$$

$$\theta = 22.65°$$

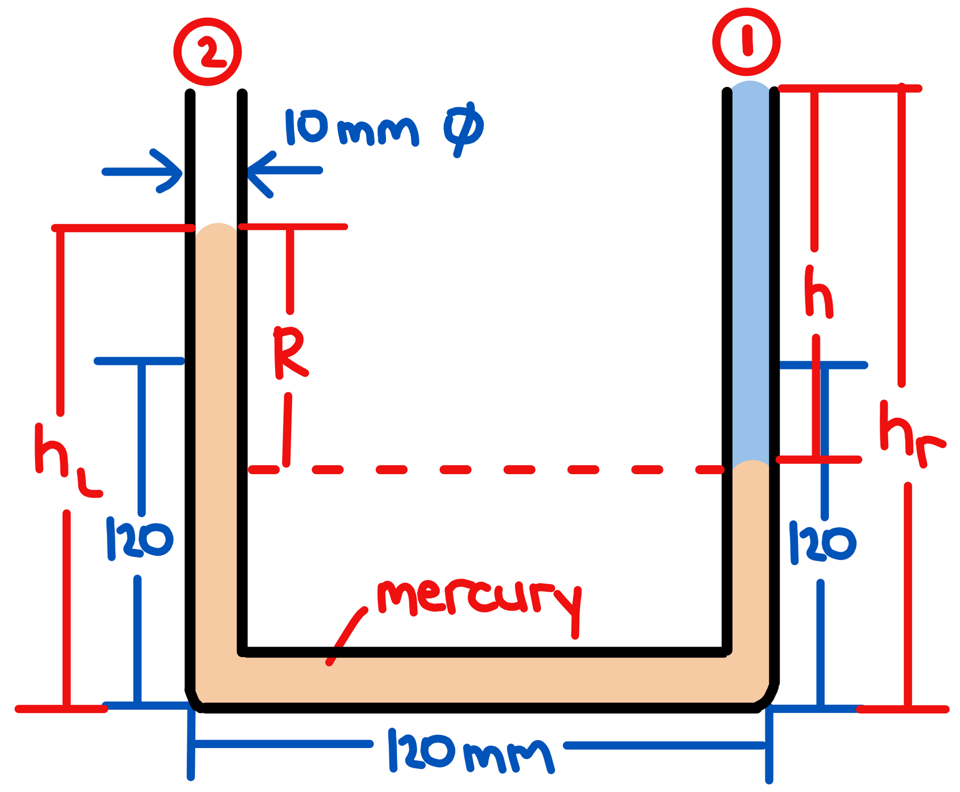
28. The U-tube shown is 10 mm ϕ and contains mercury. If 12 ml of water is poured into the right hand leg, what are the ultimate heights in the two legs



$12\text{ ml} = 12\text{ cm}^3 \qquad 10\text{ mm} = 0.1\text{ cm}$

$$\frac{\pi}{4}(0.1)^2 h = 12\text{ cm}^3$$

$$h = 15.28\text{ cm} = 152.8\text{ mm}$$



$$\cancel{\frac{P_1}{\gamma}}^{0} + 152.8(1) = R(13.6) + \cancel{\frac{P_2}{\gamma}}^{0}$$

$R = 11.24$ mm

Left leg:

$$120 - \frac{11.24}{2}$$

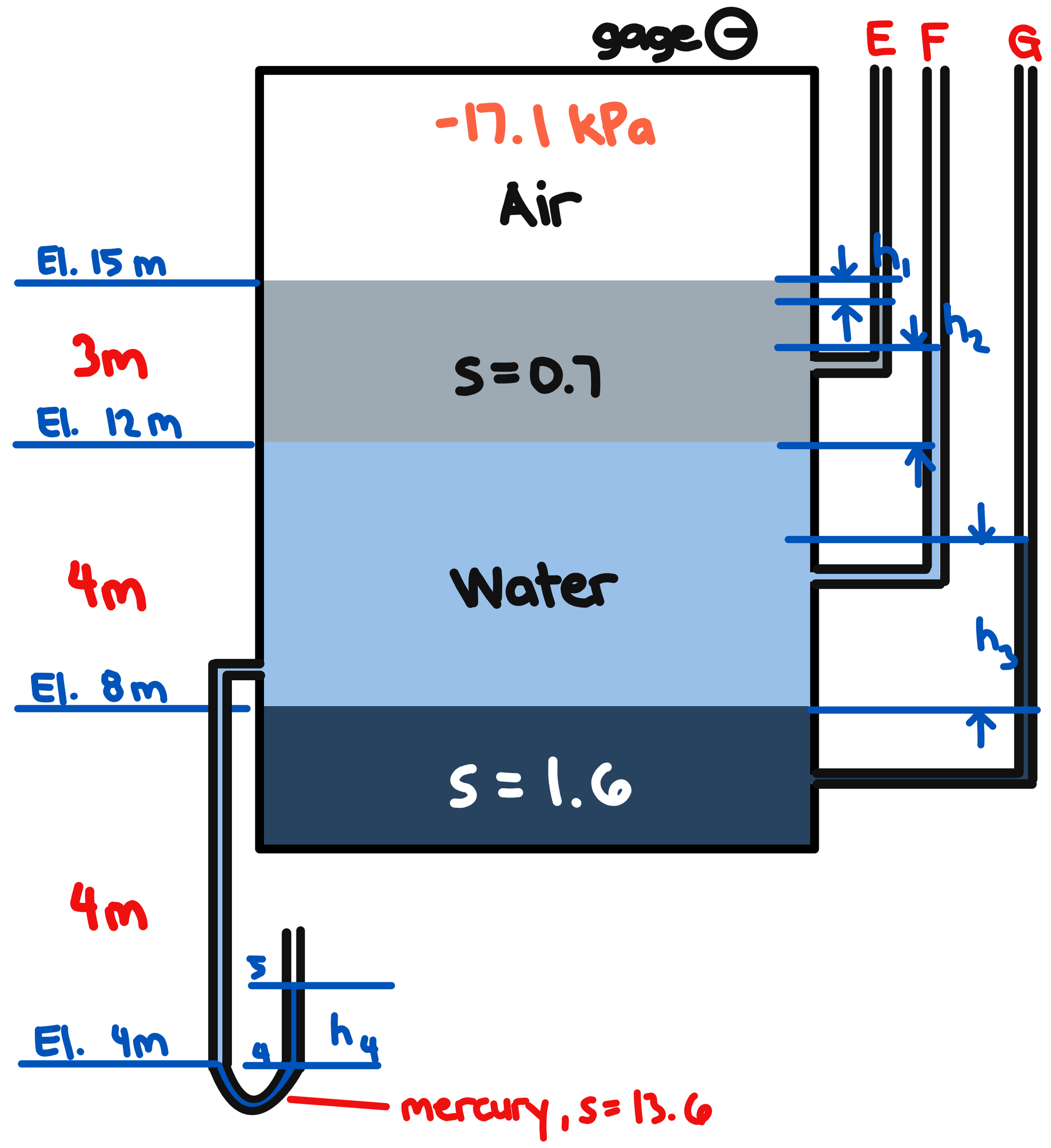
$h_L = 125.62$ mm

Right leg:

$$120 - \frac{11.24}{2} + 152.8$$

$h_R = 267.18$ mm

29. For a gage reading of -17.1 kPa, determine the elevations of the liquids in the open piezometer columns E, F and G. b) the deflection of the mercury in the U-tube manometer neglecting weight of air.



Column E:

$$\frac{P_1}{\gamma} + 0.7(h_1) = \cancel{\frac{P_E}{\gamma}}^{0}$$

$$\frac{-17.1}{9.81} = -0.7(h_1)$$

$h_1 = 2.5$ m

Surface elevation $= 15 - 2.5 = 12.5$ m

Column F:

$$\frac{P_1}{\gamma} + 3(0.7) - h_2(1) = \cancel{\frac{P_F}{\gamma}}^{0}$$

$$\frac{-17.1}{9.81} + 2.1 - h_2 = 0$$

$h_2 = 0.357$

Surface Elevation = $12 + 0.357 = 12.357\text{ m}$

Column G:

$$\frac{P_1}{\gamma} + 0.7(3) + 4(1) - h_3(1.6) = \cancel{\frac{P_G}{\gamma}}^{0}$$

$$\frac{-17.1}{9.81} + 2.1 + 4 = 1.6h_3$$

$h_3 = 2.72\text{ m}$

Surface Elevation = $8 + 2.72 = 10.72\text{ m}$

Deflection of Mercury:

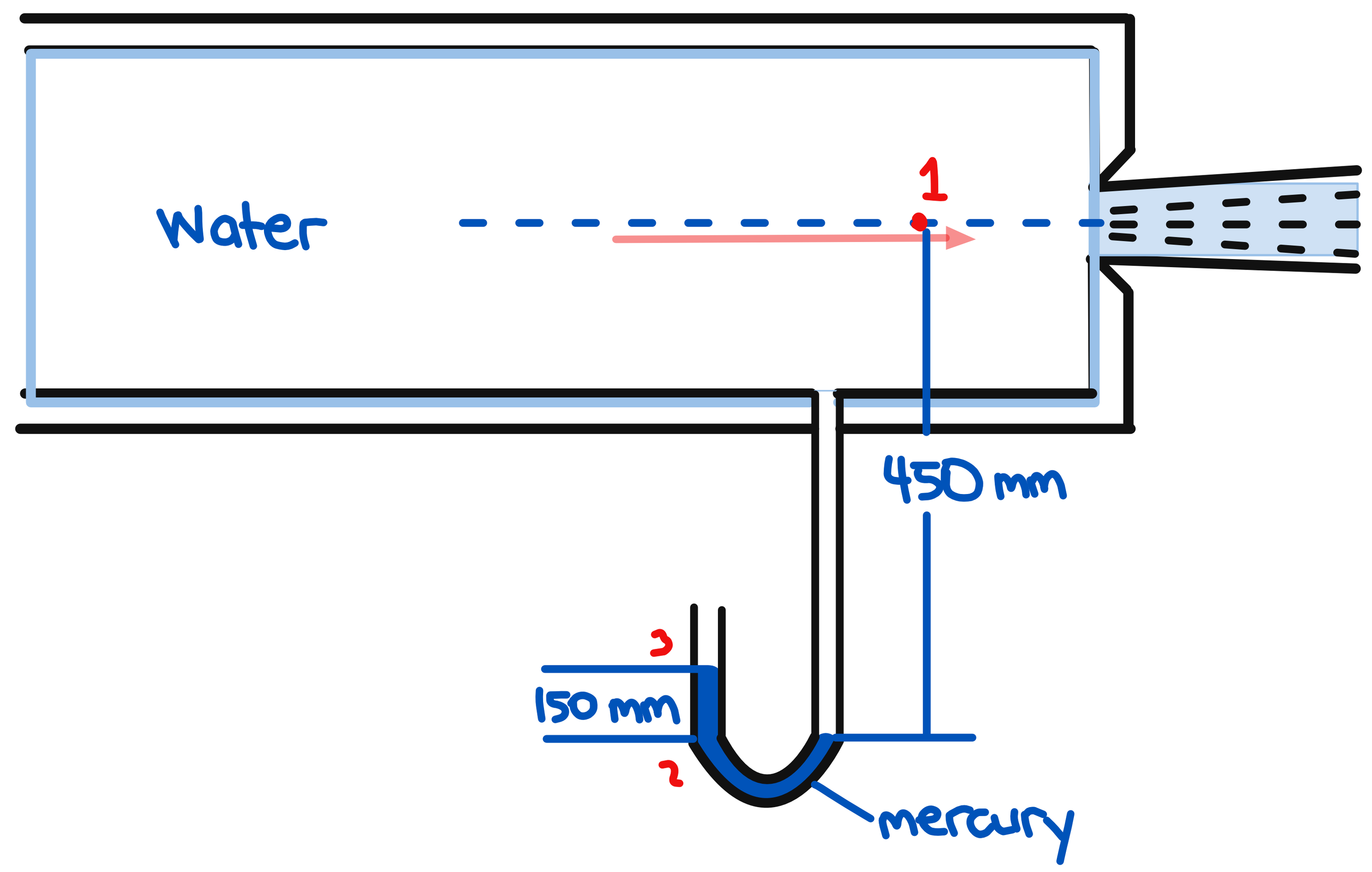
$$\frac{P_1}{\gamma} + 0.7(3) + 4 + 4 - h_4(13.6) = \cancel{\frac{P_H}{\gamma}}^{0}$$

$$\frac{-17.1}{9.81} + 2.1 + 4 + 4 = 13.6h_4$$

$h_4 = 0.614$

Surface Elevation = $4 + 0.614 = 4.614$

30. An open manometer attached to a pipe shows a deflection of 150 mmHg with the lower level of mercury 450 mm below the centerline of the pipe carrying water. Calculate the pressure at the centerline of the pipe



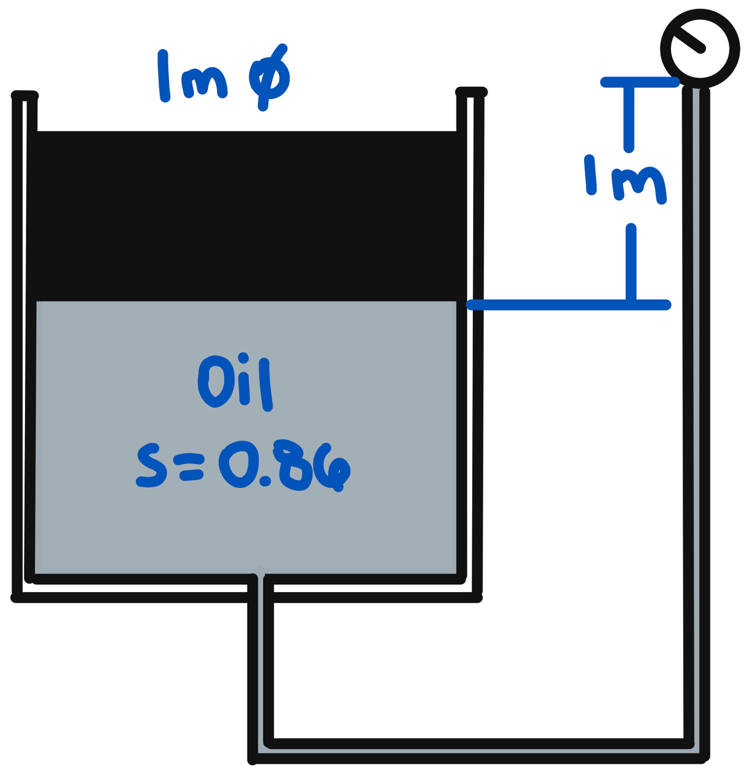
Σ Pressure Head:

$$\frac{P_1}{\gamma} + 0.45(1) - 0.15(13.6) = \cancel{\frac{P_3}{\gamma}}^{0}$$

$$\frac{P_1}{9.81} + 0.45 - 2.04 = 0$$

$P_1 = 15.6\text{ kPa}$

31. Calculate the weight of the piston if the pressure gage reading is 70 kPa.



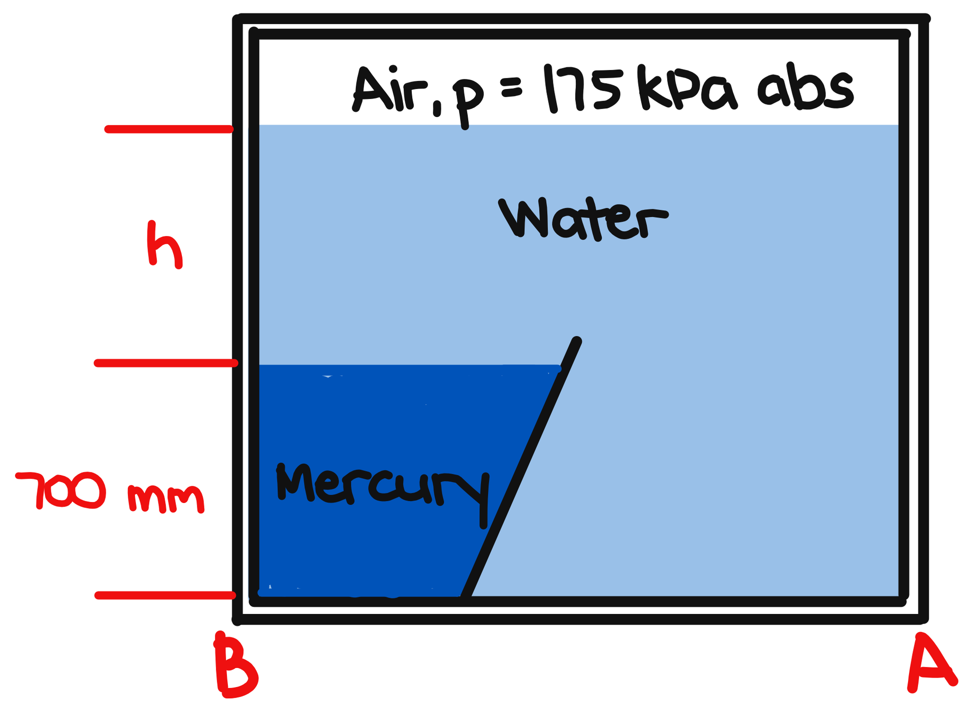
$$\frac{P_A}{\gamma} - 0.86(1) = \frac{P_B}{\gamma}$$

$$\frac{P_A}{9.81} - 0.86 = \frac{70}{9.81}$$

$$P_A = 78.44 \text{ kPa}$$

$$W = FA$$
$$= P_A A$$
$$= 78.44 \times \frac{\pi}{4}(1)^2$$
$$= 61.61 \text{ kN}$$

32. Determine the height h of water and the gage reading at a, when the absolute pressure at B is 290 kPa.



Pressure Head at B to P_2.

$$\frac{P_B}{\gamma} - 0.7(13.6) - h = \frac{P_2}{\gamma}$$

$$\frac{290}{9.81} - 9.52 - h = \frac{175}{9.81}$$

$$h = 2.2 \text{ m}$$

Pressure Head at B to A:

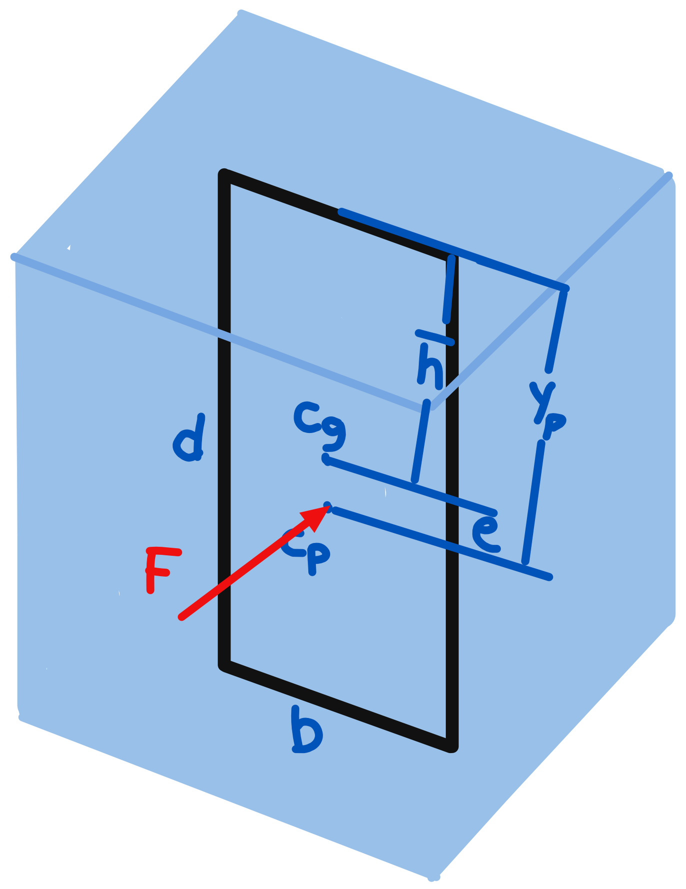
$$\frac{P_B}{\gamma} - 0.7(13.6) + 0.7(1) = \frac{P_A}{\gamma}$$

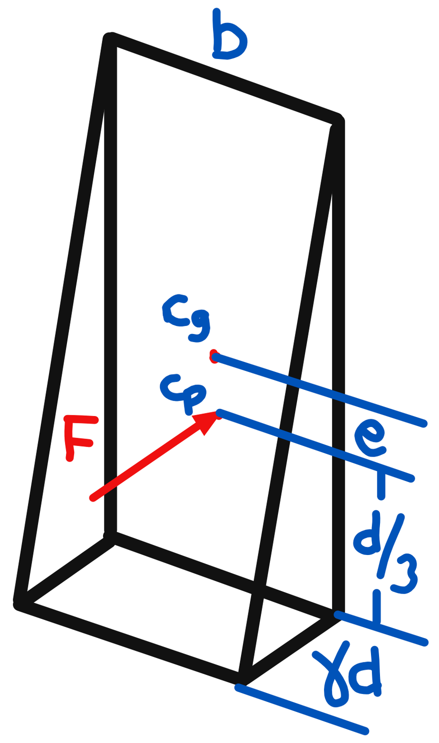
$$\frac{290}{9.81} - 9.52 + 0.7 = \frac{P_A}{9.81}$$

$$P_A = 203.5 \text{ kPa}$$

Hydrosstatic Forces on Surfaces

1. Determine the total force F acting on one side and its location from the liquid surface.





$$\boxed{F = \gamma \bar{h} A}$$

$$\bar{h} = \frac{d}{2} \qquad A = bd$$

$$F = \gamma\left(\frac{d}{2}\right)(bd)$$

$$= \frac{1}{2}\gamma b d^2$$

$$\boxed{e = \frac{I_g}{A\bar{y}}}$$

$$I_g = \frac{bd^3}{12}$$

$$e = \frac{\frac{bd^3}{12}}{(bd)(d/2)}$$

$$e = d/6$$

$$Y_p = \bar{h} + e$$

$$= \frac{d}{2} + \frac{d}{6}$$

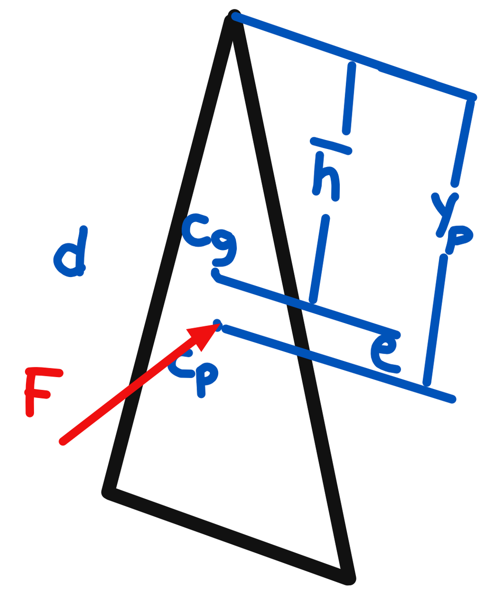
$$= 2d/3$$

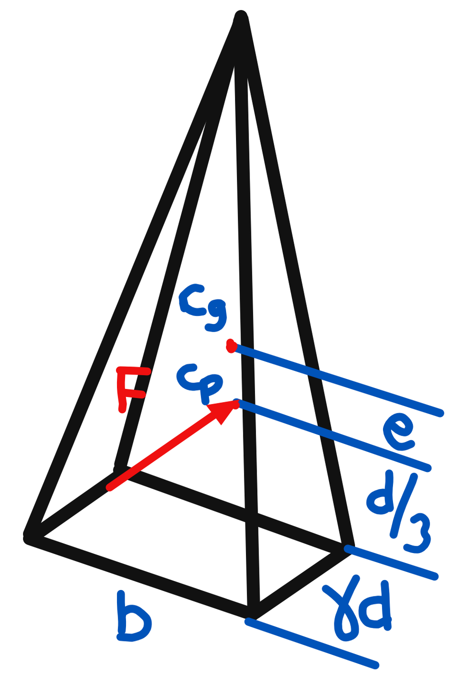
2nd Method (Pressure diagram)

$$F = \frac{1}{2}(\gamma d)(d)(b)$$

$$= \frac{1}{2}\gamma b d^2$$

2. Determine the total force F acting on one side and its location from the liquid surface.





$$\boxed{F = \gamma \bar{h} A}$$

$$\bar{h} = 2/3\, d$$

$$= \gamma(2/3\, d)\frac{1}{2} bd$$

$$= \frac{1}{3}\gamma b d^2$$

$$\boxed{e = \frac{I_g}{A\bar{y}}}$$

$$= \frac{\frac{bd^3}{36}}{\frac{bd}{2}(2d/3)}$$

$$= \frac{d}{12}$$

$$\boxed{Y_p = h + e}$$

$$= \frac{2}{3}d + \frac{d}{12}$$

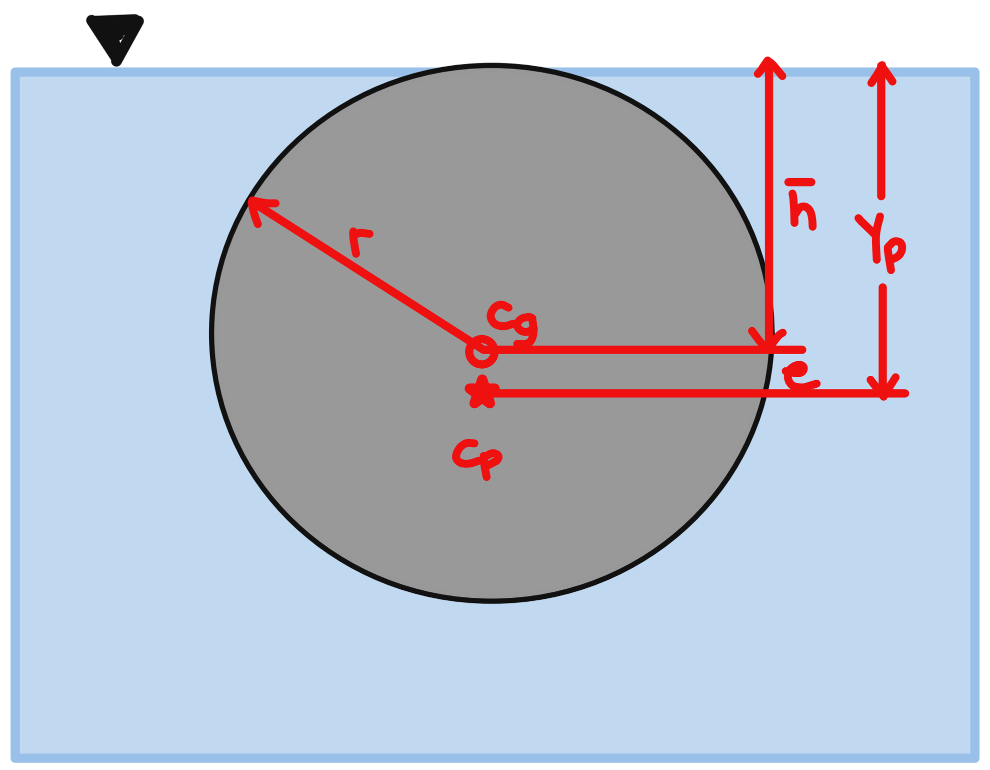
$$= \frac{3d}{4}$$

2nd Method (Pressure diagram)

$$F = \frac{1}{3}(\gamma d)(d)(b)$$

$$= \frac{1}{3}\gamma b d^2$$

3.

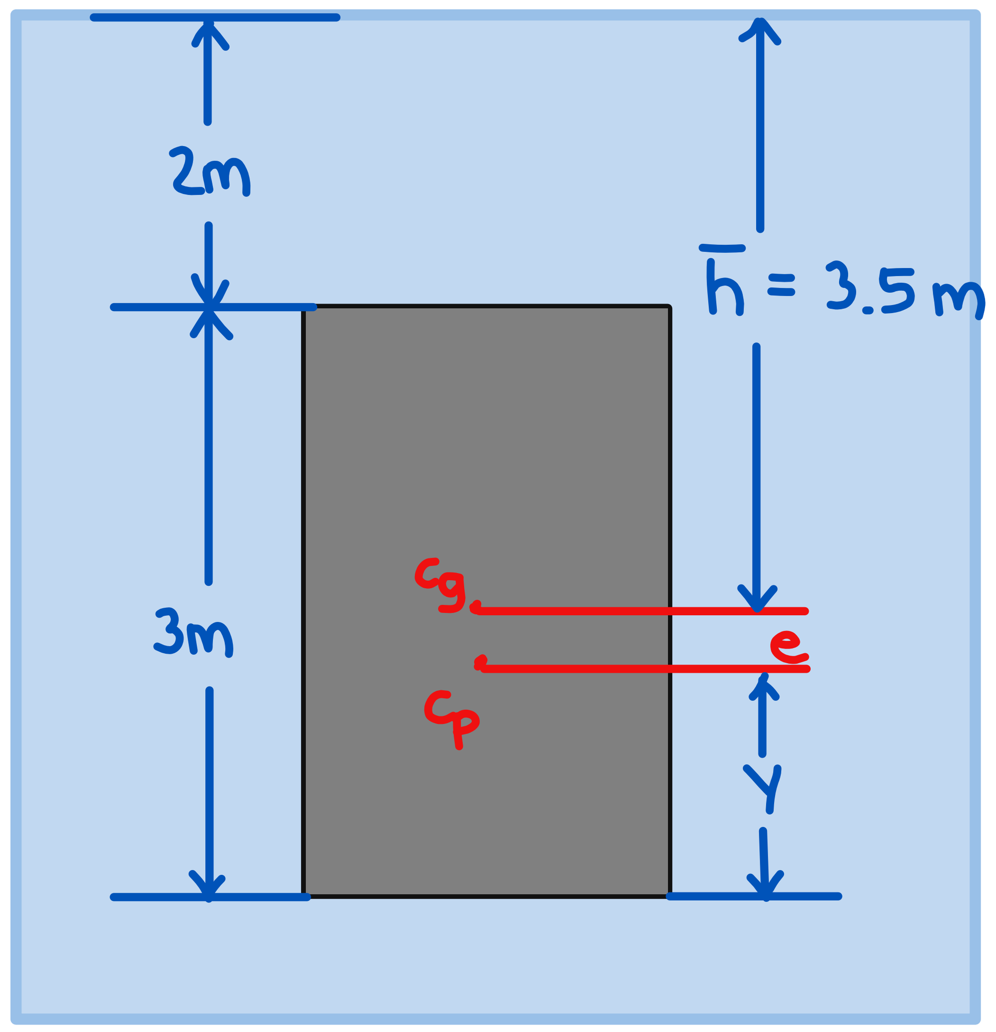


$$\boxed{F = \gamma \bar{h} a}$$
$$= \gamma (r)(\pi r^2)$$
$$= \gamma \pi r^3$$

$$\boxed{e = \frac{I_g}{A\bar{y}}}$$
$$= \frac{\frac{1}{4}\pi r^4}{\pi r^2 (r)}$$
$$= \frac{r}{4}$$

$$\boxed{y_p = r + e}$$
$$= r + r/4$$
$$= \frac{5r}{4}$$

4.

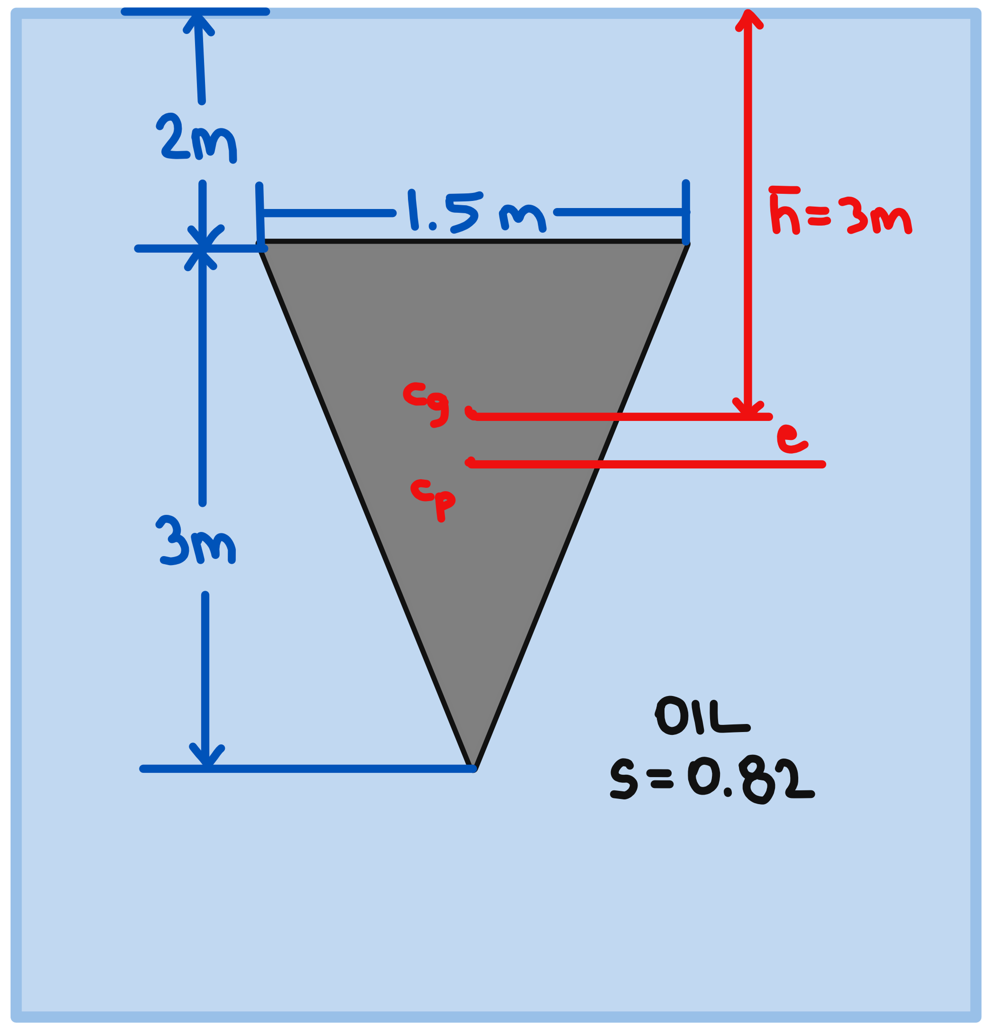


$$\boxed{F = \gamma \bar{h} A}$$
$$= 9.81(3.5)(3 \times 1.5)$$
$$= 154.5075 \text{ kN}$$

$$e = \frac{I_g}{A\bar{y}}$$
$$= \frac{\frac{(1.5)(3)^3}{12}}{(3 \times 1.5)(2 + 1.5)}$$
$$= 0.214 \text{ m}$$

$$y = 1.5 - e$$
$$= 1.5 - 0.214$$
$$= 1.286 \text{ m}$$

5.



$\boxed{F = \gamma \bar{h} A}$

$= (9.81 \times 0.82)\left[2 + \frac{1}{3}(3)\right]\left(\frac{1}{2} \times 1.5 \times 3\right)$

$= 54.3\ kN$

$\boxed{e = \frac{I_g}{A\bar{y}}}$

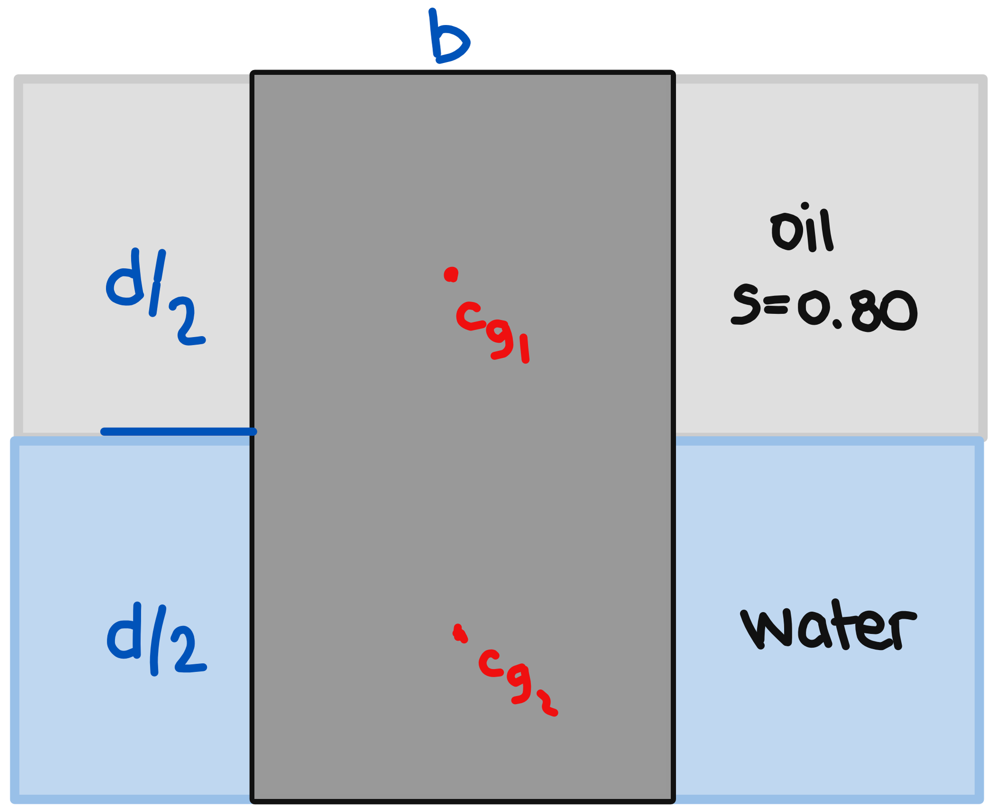
$$= \frac{\frac{1.5(3)^3}{36}}{\frac{1}{2}(1.5)(3)\left(2 + \frac{1}{3}(3)\right)}$$

$= 0.167m$

$Y_p = \bar{h} + e$

$= 3.167\ m$

6. A vertical rectangular plate is submerged half in oil (sp. gr = 0.8) and half in water such that its top edge is flushed with the oil surface. What is the ratio of the force exerted by water acting on the lower half to that by oil acting on upper half?



$\boxed{F_o = \gamma \bar{h} A}$

$= (\gamma_w \times 0.8)\left(\frac{d}{4}\right)\left(b \times \frac{d}{2}\right)$

$= 0.1\,\gamma_w b d^2$

$\boxed{F_w = P_{cg2} \times A}$

$P_{cg2} = \gamma_o h_o + \gamma_w h_w$

$(\gamma_w \times 0.8)\frac{d}{2} + \gamma_w \frac{d}{4}$

$= 0.65\,\gamma_w d \times \left(b \times \frac{d}{2}\right)$

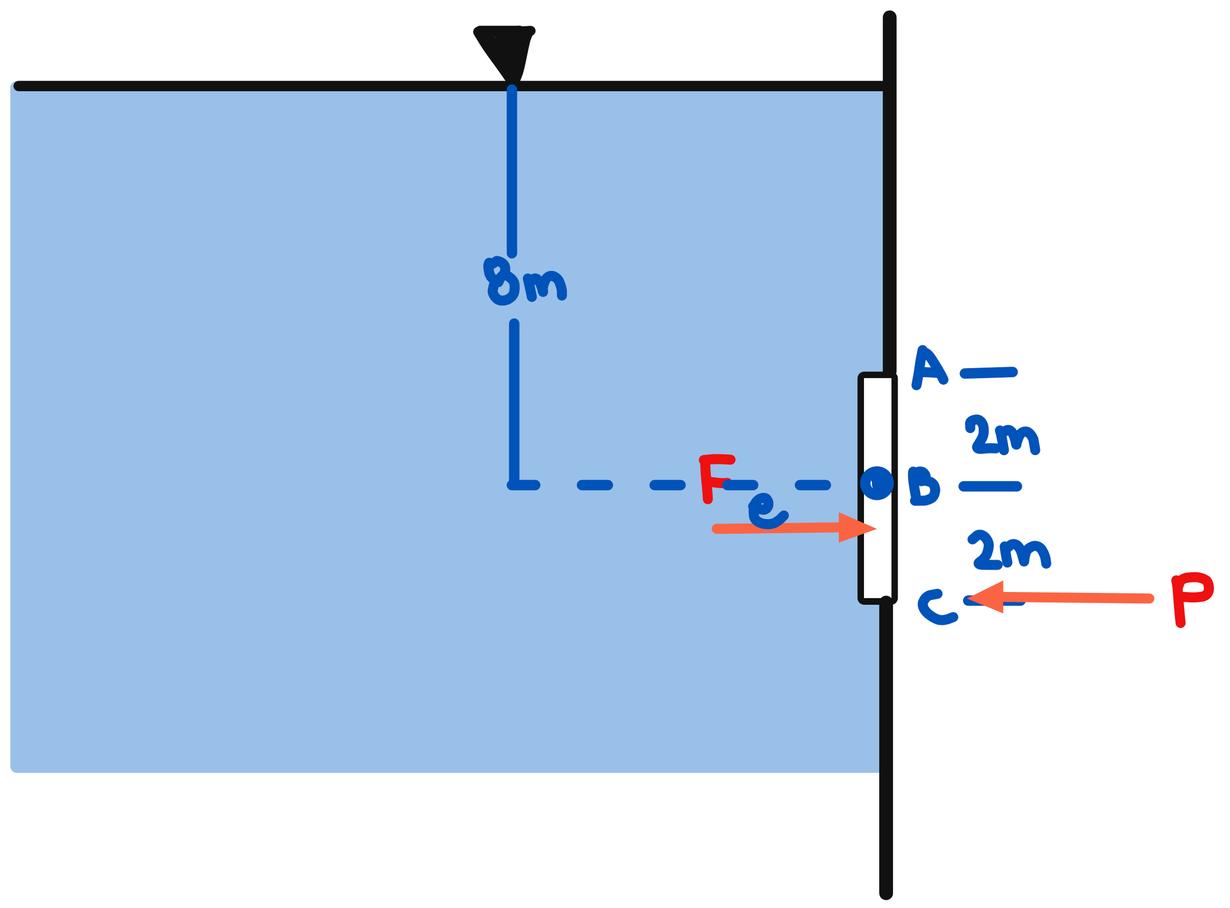
$= 0.325\,\gamma_w b d^2$

Ratio

$\frac{F_w}{F_o} = \frac{0.325}{0.1}$

$= 3.25$

7. A circular gate ABC is 4 m in diameter is hinged at B. Compute the force P just sufficient to keep the from opening when h is 8m.



$$\boxed{F = \gamma \bar{h} A}$$

$$= 9.81(8)(\tfrac{\pi}{4} 4^2)$$

$$= 986.2 \text{ kN}$$

$$e = \frac{\frac{\pi(4)^4}{64}}{(\frac{\pi}{4} \times 4^2)(8)}$$

$$= 0.125$$

$$y_p = 8 + 0.125$$

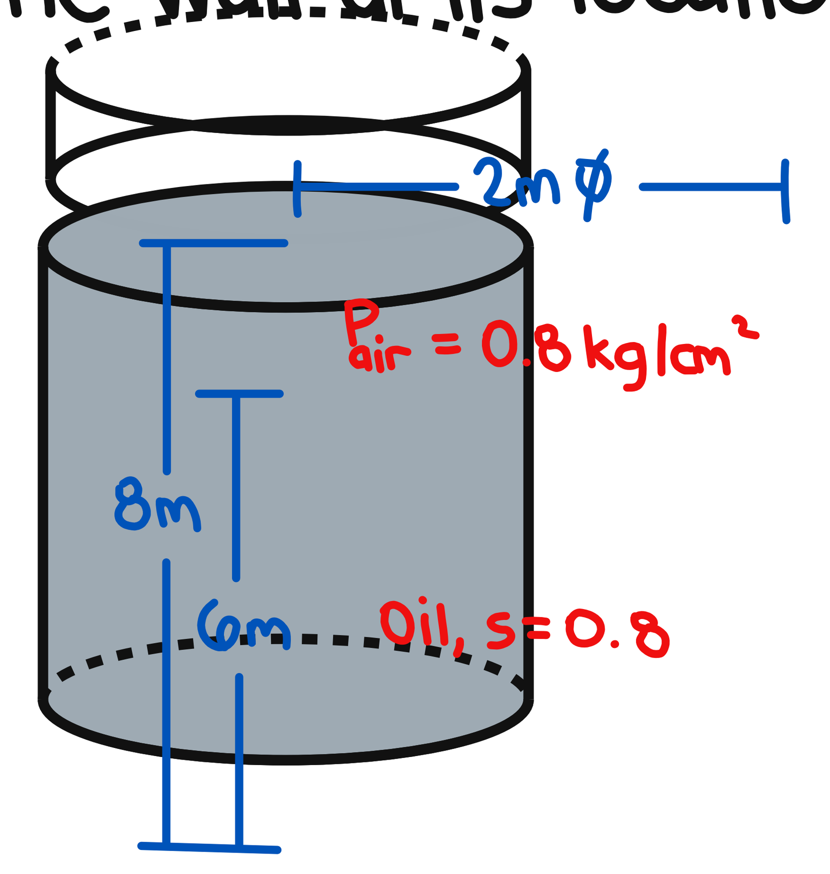
$$= 8.125 \text{m}$$

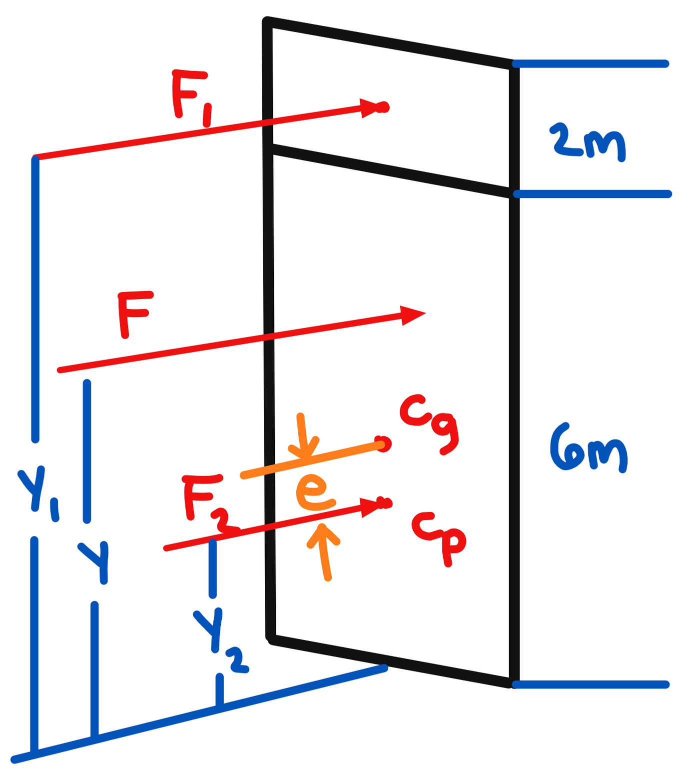
$$\Sigma M_B = 0$$

$$P(2) - 986.2(0.125)$$

$$P = 61.63 \text{ kN}$$

9. Determine the total normal force in kg acting on the wall at its location from the bottom of the tank.





$$\frac{0.8\text{ kg}}{\cancel{cm}^2} \times \frac{10000\ \cancel{cm}^2}{m^2} = 8000\text{ kg/m}^2$$

$\boxed{F_1 = P_{air} A}$

$= 8000\,(2\pi \times 2m)$

$= 32000\pi$ kg

$y_1 = 6 + 1 = 7$ m

$\boxed{F_2 = P_{cg} A}$

$= [(1000 \times 0.8)(3) + 8000](2\pi \times 6)$

$= 124800\pi$ kg

$F_2 = \gamma_o \bar{h} A$

$124800\pi = (1000 \times 0.8)\bar{h}\,(2\pi \times 6)$

$\bar{h} = \bar{y} = 13$ m

$\boxed{e = \frac{I_g}{A\bar{y}}}$

$$= \frac{\frac{\pi r h^3}{12}}{A\bar{y}}$$

$$= \frac{\frac{\pi(2)(6)^3}{12}}{\pi(2)(6)(13)}$$

$= 0.23$ m

$y_2 = 3 - e$

$= 2.77$ m

$F = F_1 + F_2$

$= 156{,}800\pi$ kg total normal force

10. Stop B will break if the force on it reaches 40 kN. Find the critical water depth. The length of the gate perpendicular to the sketch is 1.5m.

$$\boxed{F = \gamma \bar{h} A}$$

$$= 9.81\,\bar{h}(1 \times 1.5)$$

$$= 14.715\,\bar{h}$$

$$e = \frac{I_g}{A\bar{y}}$$

$$= \frac{\frac{(1.5)(1)^3}{12}}{(1.5 \times 1)\bar{h}}$$

$$= \frac{1}{12}\bar{h}$$

$$z = e + 0.5$$

$$\frac{1}{12\bar{h}} + 0.5$$

$$\Sigma M_{hinge} = 0$$

$$40\text{kN}(1) = F(z)$$

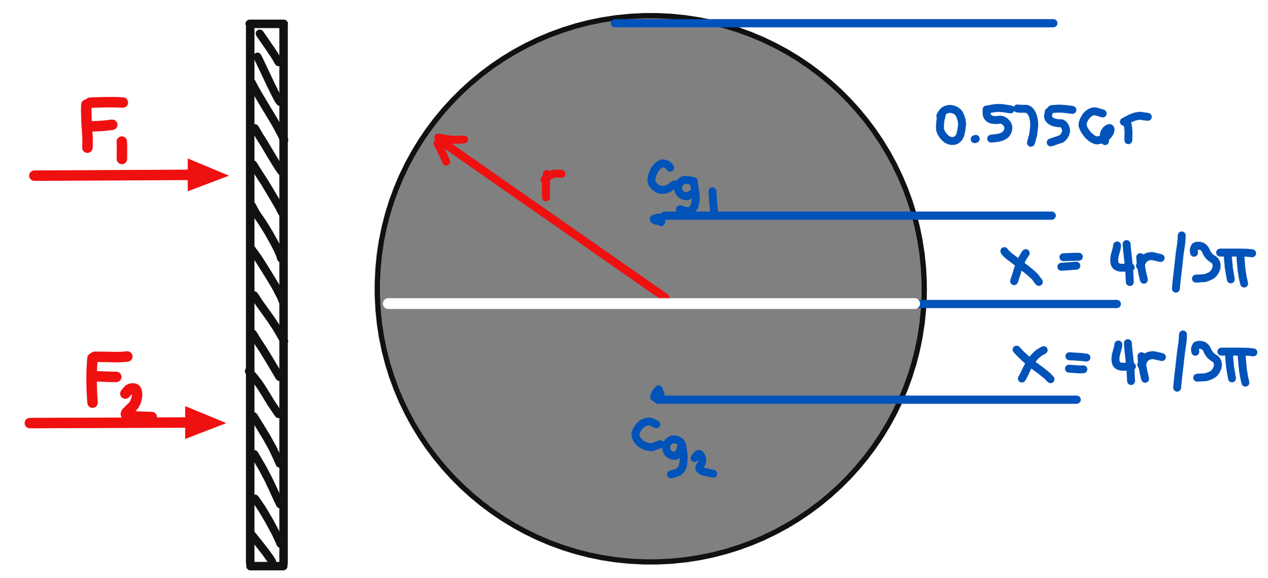
$$40 = 14.175\bar{h}\left(0.5 + \frac{1}{12\bar{h}}\right)$$

$$\bar{h} = 5.27\text{m}$$

$y = \bar{h} + 0.5$ = 5.77m critical water depth

11. A vertical circular gate is submerged in a liquid so that its top edge is flushed with the liquid surface, find the ratio of the total force acting on the lower half to that acting on the upper half.

$1 - \frac{4}{3\pi} = 0.5756$



$$\text{Ratio} = \frac{F_2}{F_1}$$

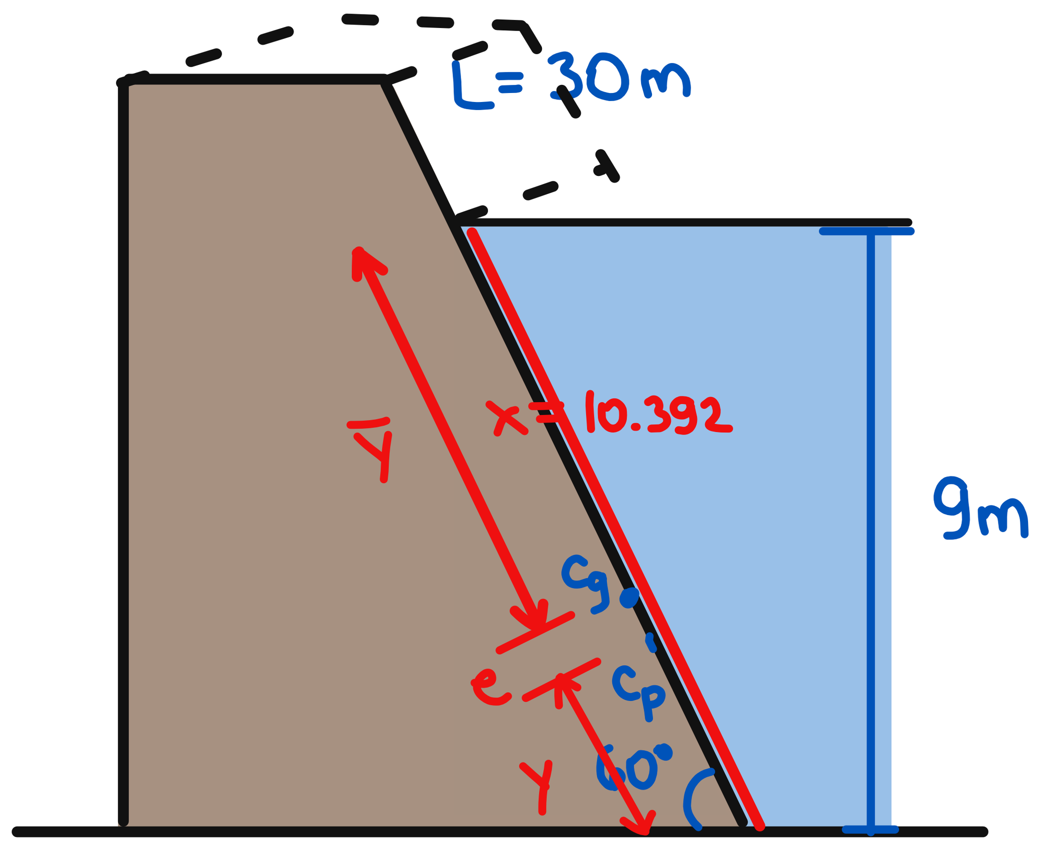
$$= \frac{\cancel{\gamma}\bar{h}_2 \cancel{A_2}}{\cancel{\gamma}\bar{h}_1 \cancel{A_1}}$$

$$= \frac{\bar{h}_2}{\bar{h}_1}$$

$$= \frac{1.424r}{0.5756r}$$

$$= 2.474$$

12. A 30 m long dam retains 9 m of water. Find the total resultant force acting on the dam and the location of the center of pressure from the bottom.



$\sin 60 = \dfrac{9}{x}$

$x = 10.392$

$\boxed{F = \gamma \bar{h} A}$

$= 9.81(4.5)(30 \times 10.392)$

$= 13{,}763$ kN

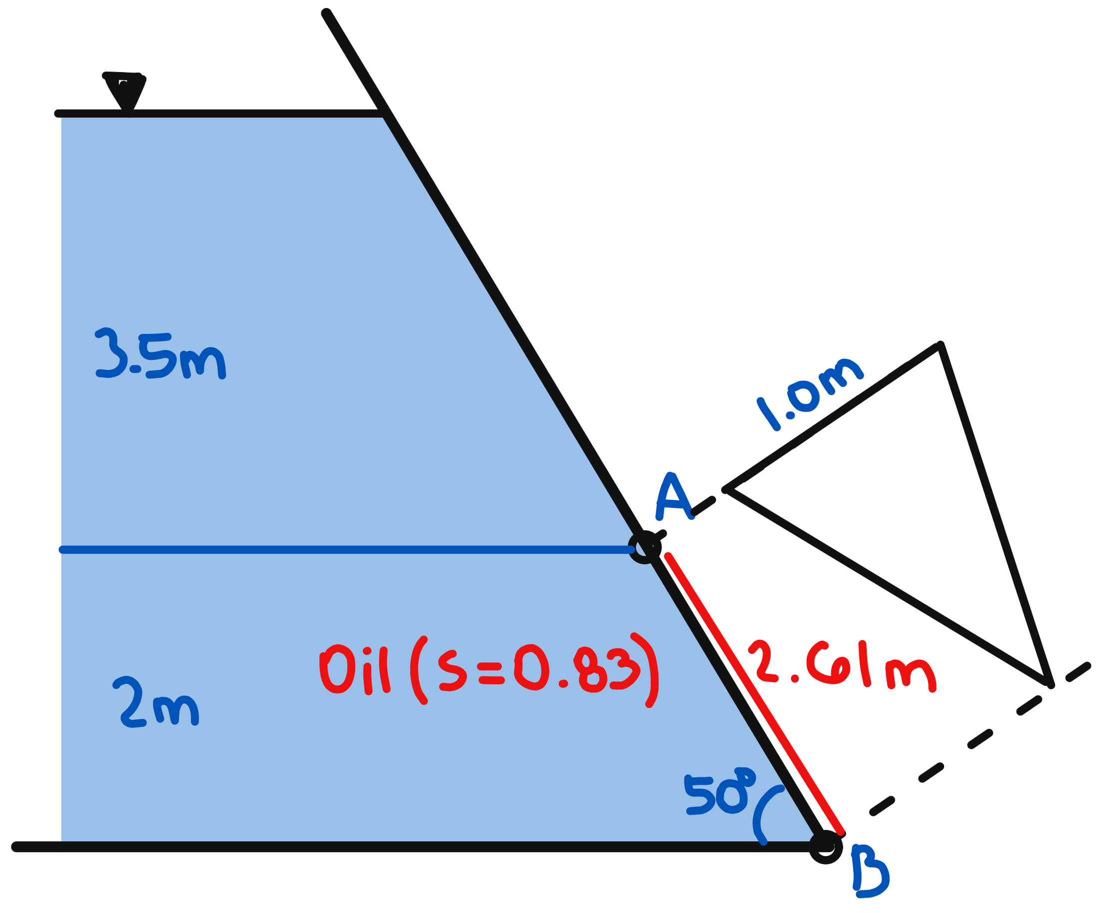
$\boxed{e = \dfrac{I_g}{A\bar{y}}}$

$$= \frac{\dfrac{30(10.392)^3}{12}}{(30 \times 10.392)(4.5 \sin 60)}$$

$= 1.732$ m

$y = \frac{1}{2}(10.392) - 1.732 = 3.464$ m

13. The isosceles triangle gate is hinged at A and weighs 1500 N. What is the total hydrostatic force acting on one side of the gate in kN?



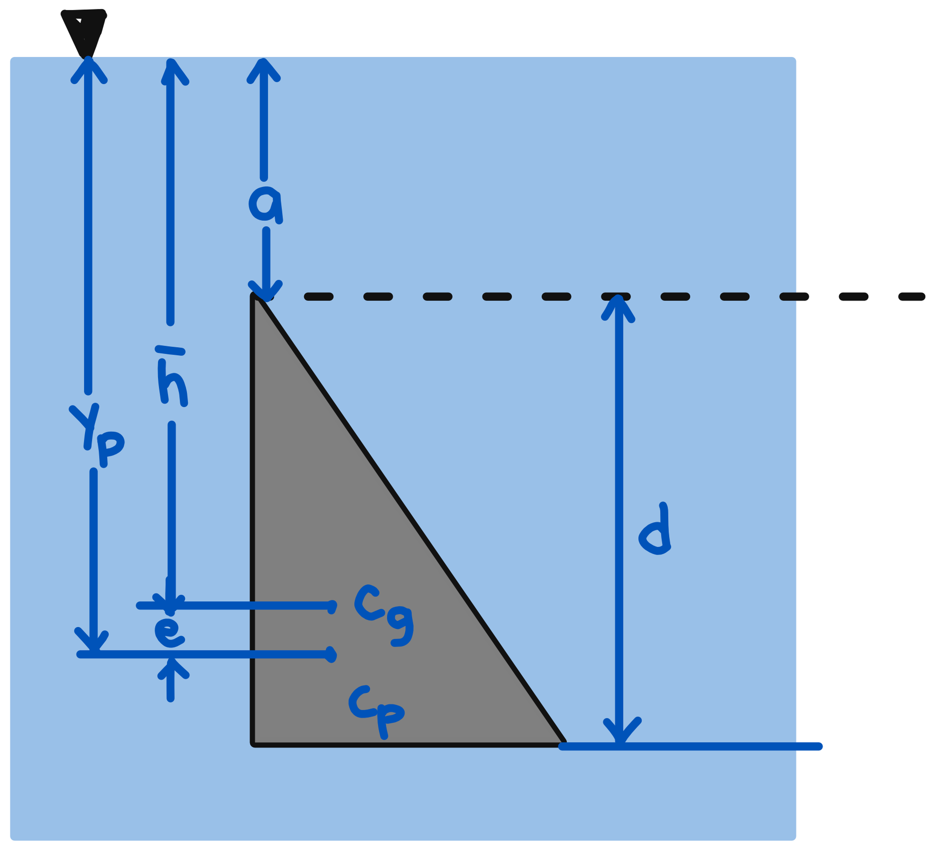
$\sin 50° = \dfrac{2}{x}$; $x = 2.61$

$\boxed{F = \gamma \bar{h} A}$

$= (9.81 \times 0.83)(3.5 + 2(\frac{1}{3}))[\frac{1}{2} \times 1 \times 2.61]$

$= 44.1$ kN

14. If a triangle of height d and base b is vertical and submerged in liquid with its vertex a distance a below the liquid surface, derive an expression for the depth to its center of pressure



$$\boxed{Y_p = \bar{h} + e}$$

$$e = \frac{I_{cg}}{A\bar{y}}$$

$$\frac{\frac{\cancel{b}d^3}{36}}{\frac{1}{2}\cancel{bd}\left(a+\frac{2}{3}d\right)} = \frac{d^2}{18\left(a+\frac{2}{3}d\right)}$$

$$Y_p = \left(a+\frac{2}{3}d\right) + \frac{d^2}{18\left(a+\frac{2}{3}d\right)}$$

$$= \frac{18\left(a+\frac{2}{3}d\right)^2 + d^2}{18\left(a+\frac{2}{3}d\right)}$$

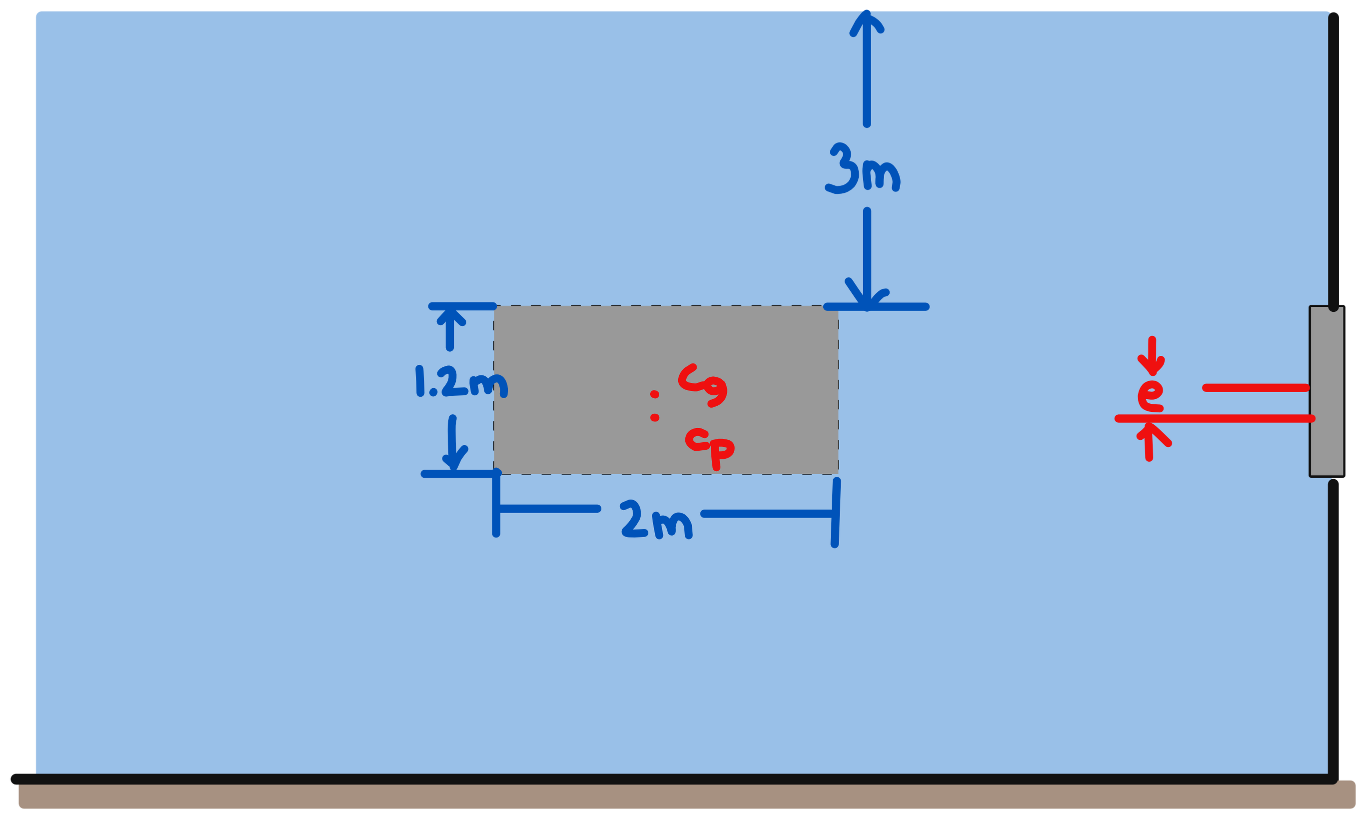
$$= \frac{18\left(a^2 + \frac{4}{3}ad + \frac{4}{9}d^2\right) + d^2}{18\left(a+\frac{2}{3}d\right)}$$

$$= \frac{18a^2 + \frac{72}{3}ad + \frac{72}{9}d^2 + \frac{9}{9}d^2}{18\left(a+\frac{2}{3}d\right)}$$

$$= \frac{18a^2 + 24ad + 9d^2}{18\left(a+\frac{2}{3}d\right)}$$

$$\boxed{= \frac{6a^2 + 8ad + 3d^2}{6\left(a+\frac{2}{3}d\right)}}$$

15. Determine the total resultant force acting on the gate and the location of the center of pressure.



$$\boxed{F = \gamma \bar{h} A}$$

$$= 9.81\left(3 + \frac{1}{2}(1.2)\right)(1.2 \times 2)$$

$$= 84.758 \text{ kN}$$

$$\boxed{e = \frac{I_g}{A\bar{y}}} = \frac{\frac{1}{12}(2)(1.2)^3}{(2 \times 1.2)(3 + 1.2/2)}$$

$$= 0.033 \text{ m}$$

$$Y_p = \bar{h} + e$$

$$= 3.6 + 0.033$$

$$= 3.633 \text{ m}$$

16. Solve using integration method:

$$\boxed{F = \int \gamma h \, dA}$$

$$= \int_0^{1.2} (9.81)(3+y)(2)\,dy$$

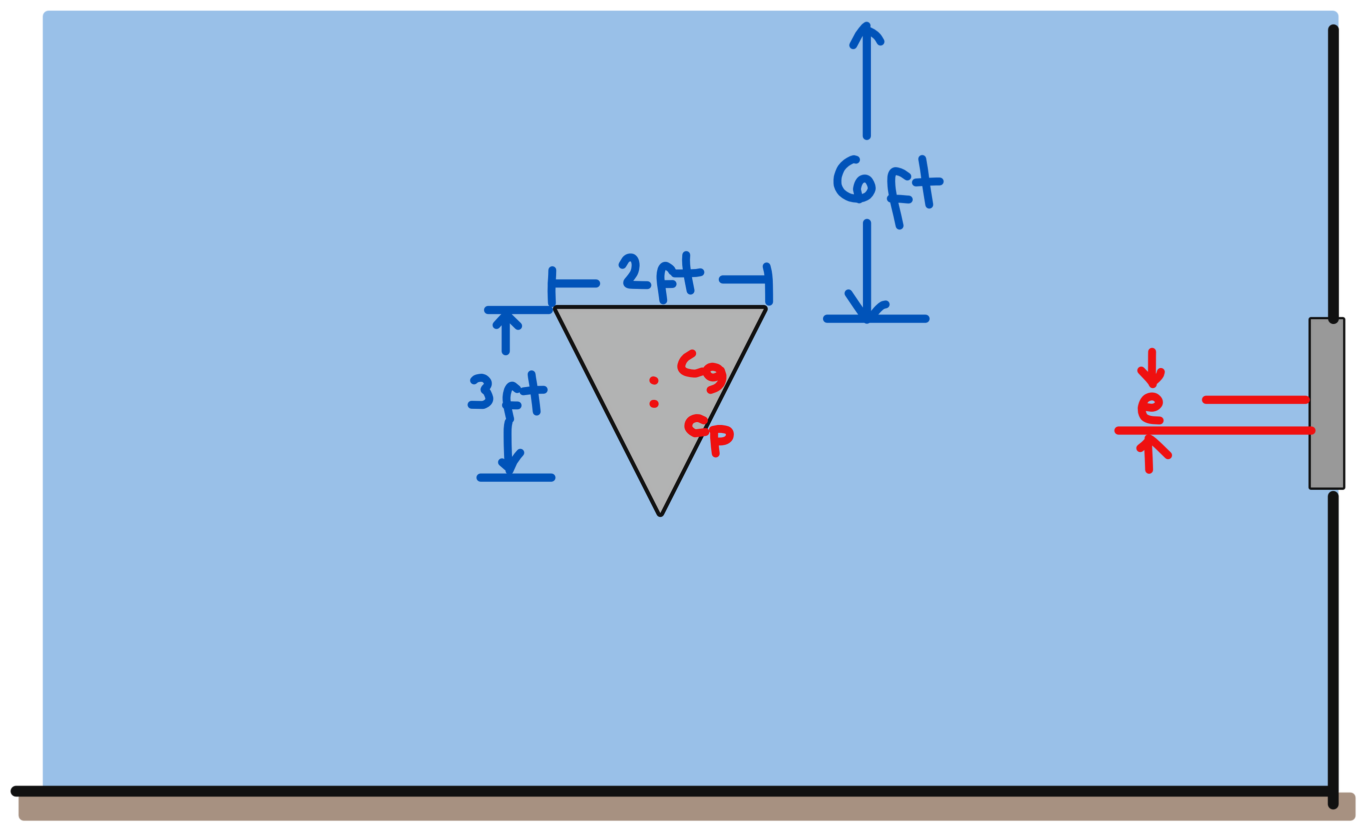
$$= 84.758 \text{ kN}$$

$$\boxed{Y_p = \frac{\int \gamma h^2 \, dA}{F}}$$

$$= \frac{\int_0^{1.2} (9.81)(3+y)^2(2)\,dy}{84.758}$$

$$= 3.633 \text{ m}$$

17. Determine the total resultant force acting on the gate and the location of the center of pressure.



$$\boxed{F = \gamma \bar{h} A}$$

$$= (62.4)\left(6+\frac{1}{3}(3)\right)\left(\frac{1}{2}\times 3\times 2\right)$$

$$= 1310.4 \text{ lb}$$

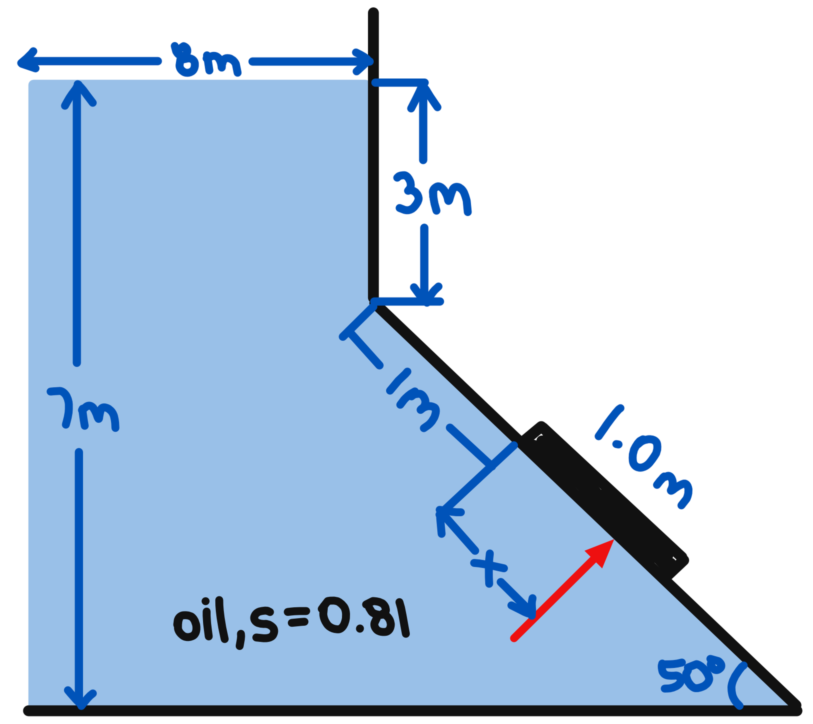
$$\boxed{e = \frac{I_g}{A\bar{y}}}$$

$$= \frac{\frac{1}{36}(2)(3)^3}{\frac{1}{2}(2)(3)\left(6+\frac{1}{3}(3)\right)}$$

$$= 0.071 \text{m}$$

$$\boxed{y_p = \bar{h} + e} = 7 + 0.071 = 7.071 \text{ ft}$$

18. Gate AB is 1.0 m long and 0.9 m wide. Calculate force F on the gate and the position X of its center of pressure.



$$\boxed{F = \gamma \bar{h} A}$$

$$= (9.81\times 0.81)\left[(3 + 1.5\sin 50^\circ)\right](1\times 0.9)$$

$$= 29.67 \text{ kN}$$

$$\boxed{e = \frac{I_g}{A\bar{y}}}$$

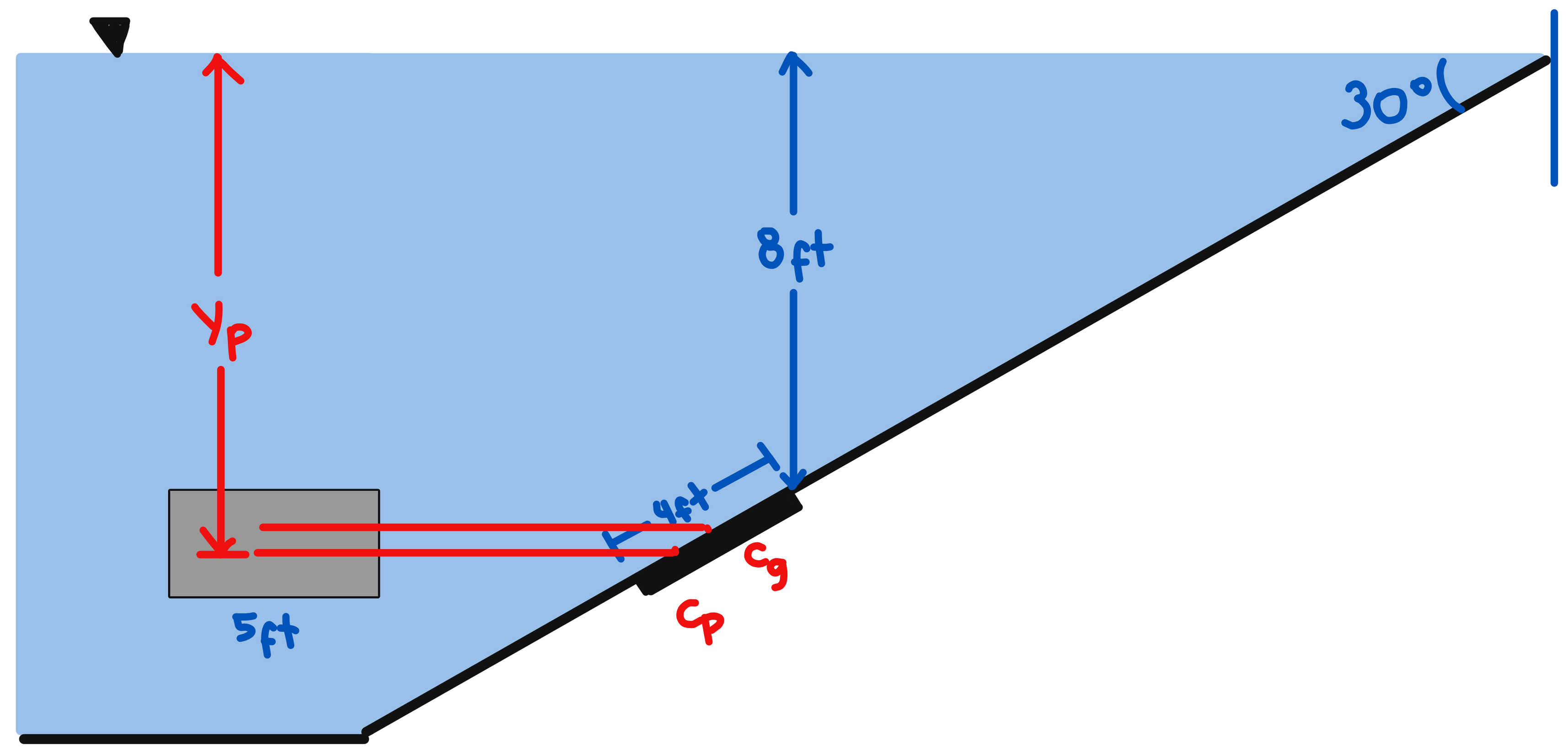
$$= \frac{\left[\frac{0.9(1.0)^3}{12}\right]\sin 50^\circ}{(0.9\times 1.0)(3 + 1.5\sin 50^\circ)}$$

$$= 0.015 \text{ m}$$

$$x = 1.0/2 + 0.015$$

$$= 0.515 \text{ m}$$

19. An inclined, rectangular gate with water on one side. Determine the total resultant force acting on the gate and the location of the center of pressure.



$$\boxed{F = \gamma \bar{h} A}$$

$$= (62.4)\left[8 + \tfrac{1}{2}(4\sin 30)\right](4\times 5)$$

$$= 11{,}232 \text{ lb}$$

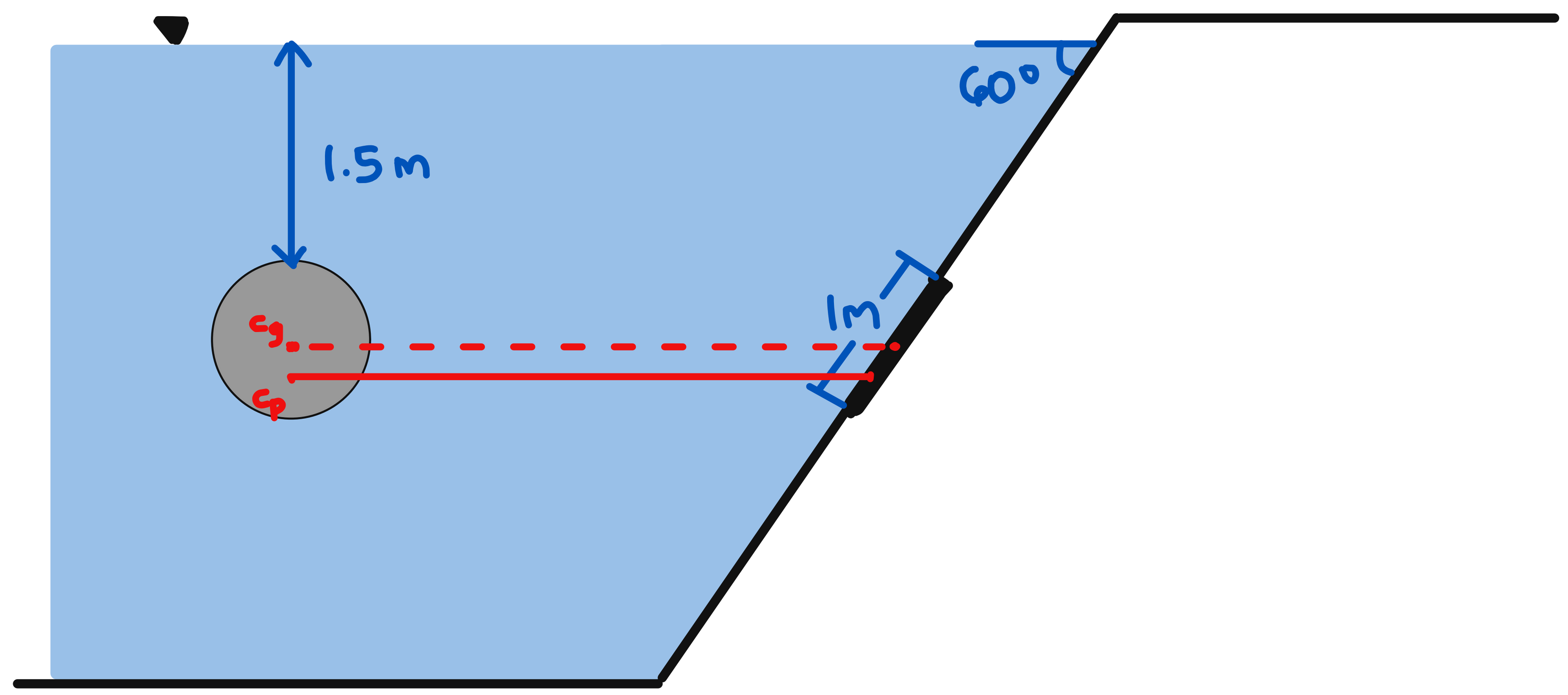
$$e = \frac{\frac{5(4)^3}{12}}{(5\times 4)(8 + \frac{1}{2}(4\sin 30))}$$

$$= 0.148 \text{ m}$$

$$Y_p = 9 + 0.148$$

$$= 9.148 \text{ m}$$

20. An inclined, circular gate with water on one side. Determine the total resultant force acting on the gate and the location of the center of pressure.



$$\boxed{F = \gamma \bar{h} A}$$

$$= (9.81)\left[1.5 + \tfrac{1}{2}(1\sin 60)\right]\left(\frac{\pi(1.0)^2}{4}\right)$$

$$= 14.89 \text{ kN}$$

$$\boxed{e = \frac{I_g}{A\bar{Y}}} = \frac{\pi(1.0)^4/64}{\frac{\pi}{4}(1.0)^2\underbrace{\left[1.5 + \frac{1}{2}(1\sin 60)\right]}_{1.933}}$$

$$= 0.032 \text{ m}$$

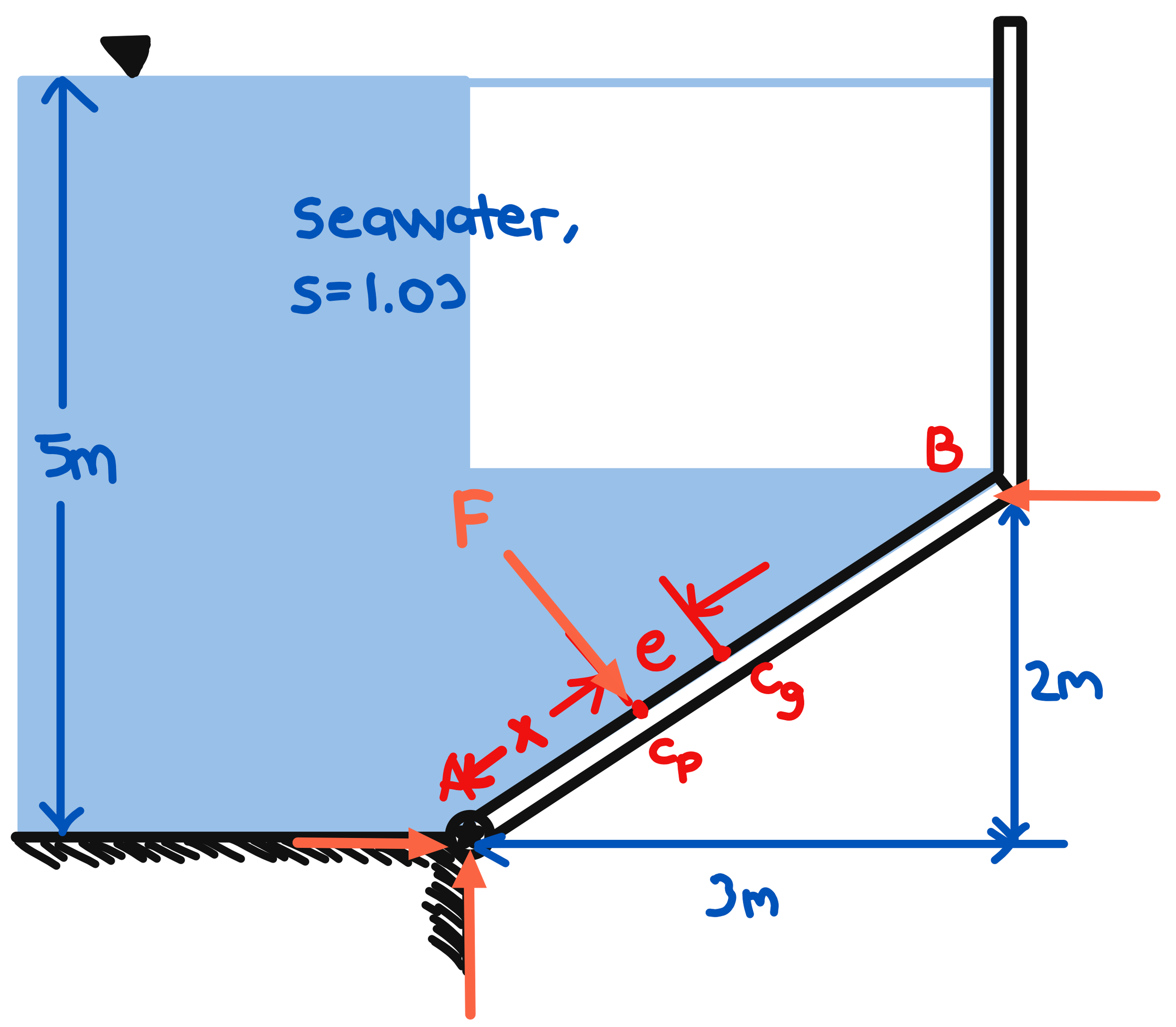
$$Y_p = \bar{h} + e$$

$$= 1.933 + 0.032$$

$$= 1.965 \text{ m}$$

21. The gate is 1.5 m wide, hinged at point A, and rest against a smooth wall at B. Compute the total force on the gate due to seawater.

b. reaction at hinge and B.



Length of the gate

$d = 3^2 + 2^2$

$= 3.6$ m

$\theta = \tan^{-1}(2/3)$

$= 33.69°$

$$\boxed{F = \gamma \bar{h} A}$$

$$(9.81 \times 1.03)(3 + \frac{3.6}{2}\sin 33.69°)(3.6 \times 1.5)$$

$= 218.168$ kN

$$e = \frac{\frac{1}{12}(1.5)(3.6)^3}{(1.5 \times 3.6)(\frac{3.6}{2}\sin 33.69°)}(\sin 33.69)$$

$= 0.1498$ m

$x = 1.8 - 0.1498$

$= 1.65$ m

$\Sigma M = 0$

$218.168(1.65) - R_B(2) = 0$

$R_B = 180$ kN

$\Sigma F_H = 0$

$R_{Ah} + F\sin\theta - R_B = 0$

$R_{Ah} + 218.168\sin 33.69 - 180 = 0$

$R_{Ah} = 58.94$ kN

$\Sigma F_V = 0$

$R_{AV} - F\cos\theta = 0$

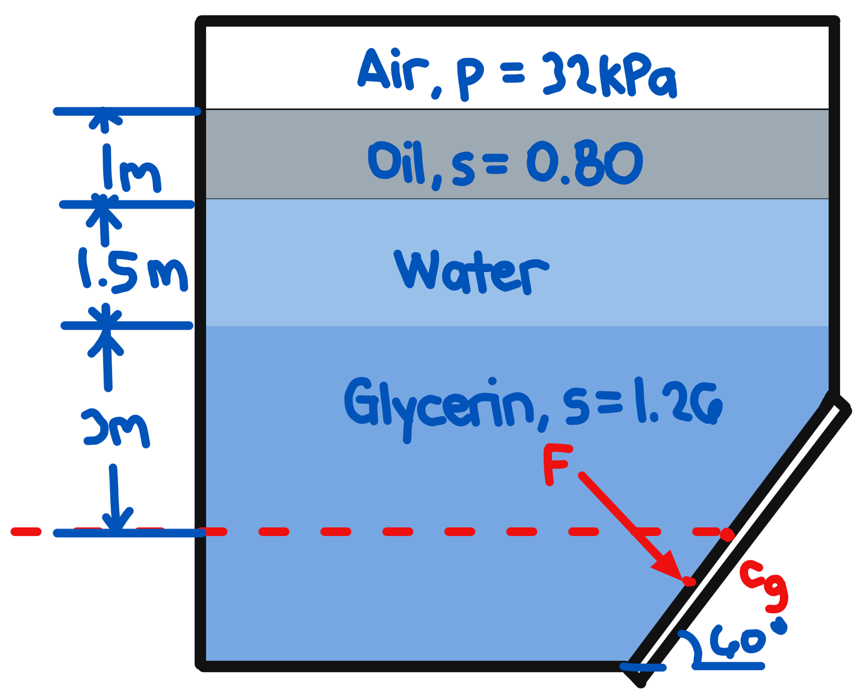
$R_{AV} - 218.168\cos 33.69 = 0$

$R_{AV} = 181.6$ kN

$R = \sqrt{(58.94)^2 + (181.6)^2}$

$= 191$ kN

22. Determine the total hydrostatic forces acting on the 2m x 4m gate.



$\boxed{F = P_{cg} A}$

$$P_{cg} = 32 + (9.81 \times 0.8)(1) + (9.81)(1.5) + (9.81 \times 1.26)(3)$$
$$= 91.645 \text{ kPa}$$

$$= 91.645(2 \times 4)$$
$$= 733.16 \text{ kN}$$

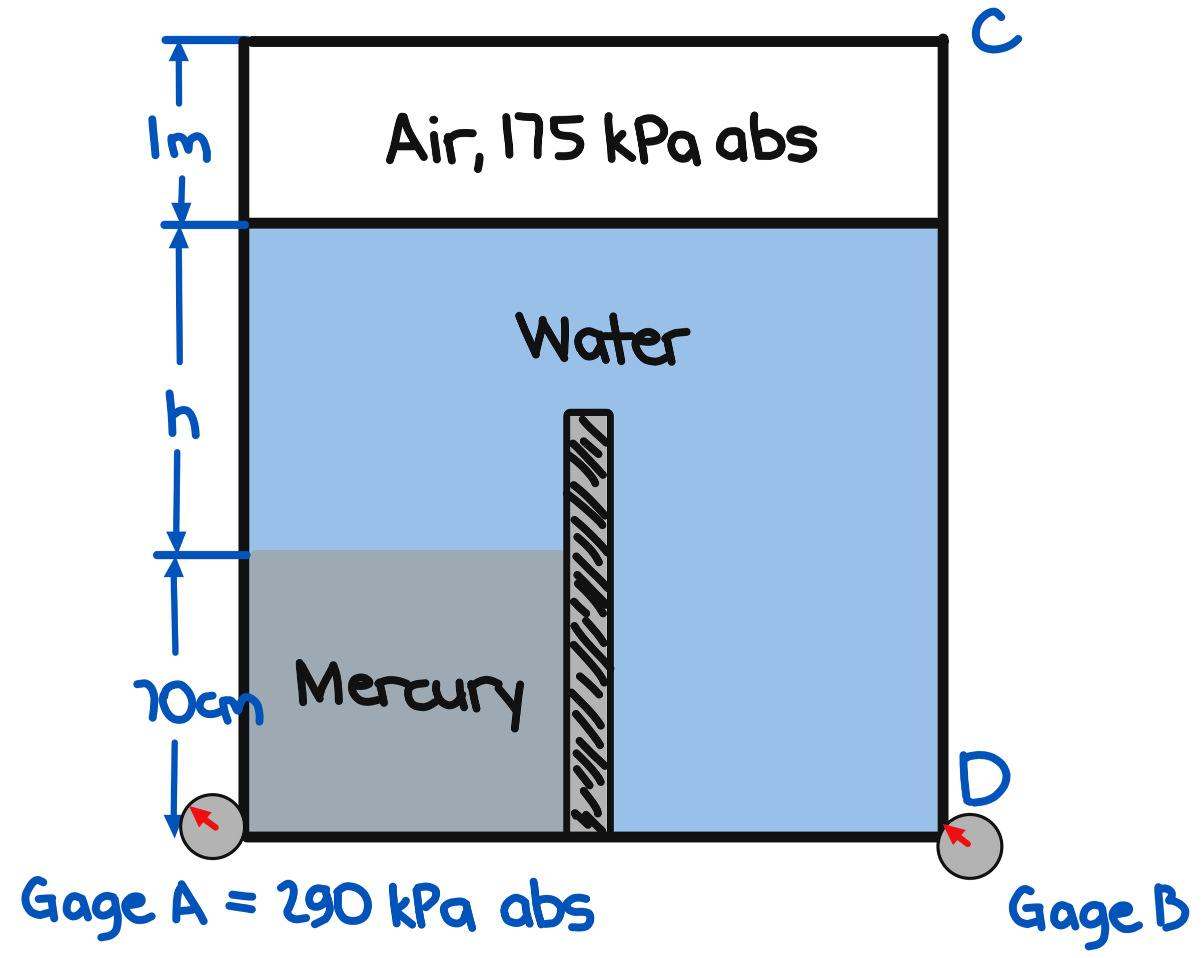
$\boxed{F = \gamma \bar{h} A}$

$$733.16 = (9.81 \times 1.26)\bar{h}(2 \times 4)$$
$$\bar{h} = 7.414$$

$$e = \frac{\frac{1}{12}(2)(4)^3}{(2 \times 4)(7.414)} \sin 60^\circ$$
$$= 0.156 \text{ m}$$

$$z = 2 - 0.156 = 1.844 \text{ m}$$

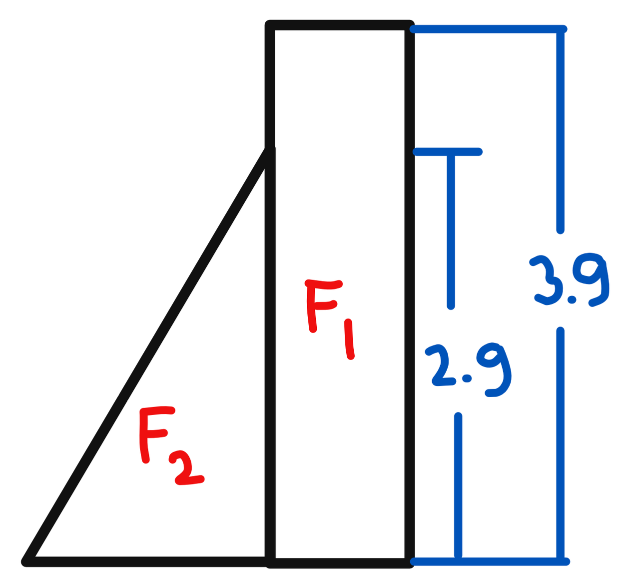
23. The tank is 2m wide perpendicular to the figure. Assume atmospheric pressure to be 1 bar. Determine the total pressure acting on side CD.



$\boxed{P_A = \Sigma \gamma h + P_{top}}$

$$290 = 175 + 9.81(h) + (9.81 \times 13.6 \times 0.7)$$
$$h = 2.2 \text{ m}$$

@ side CD, 1 bar = 100 kPa



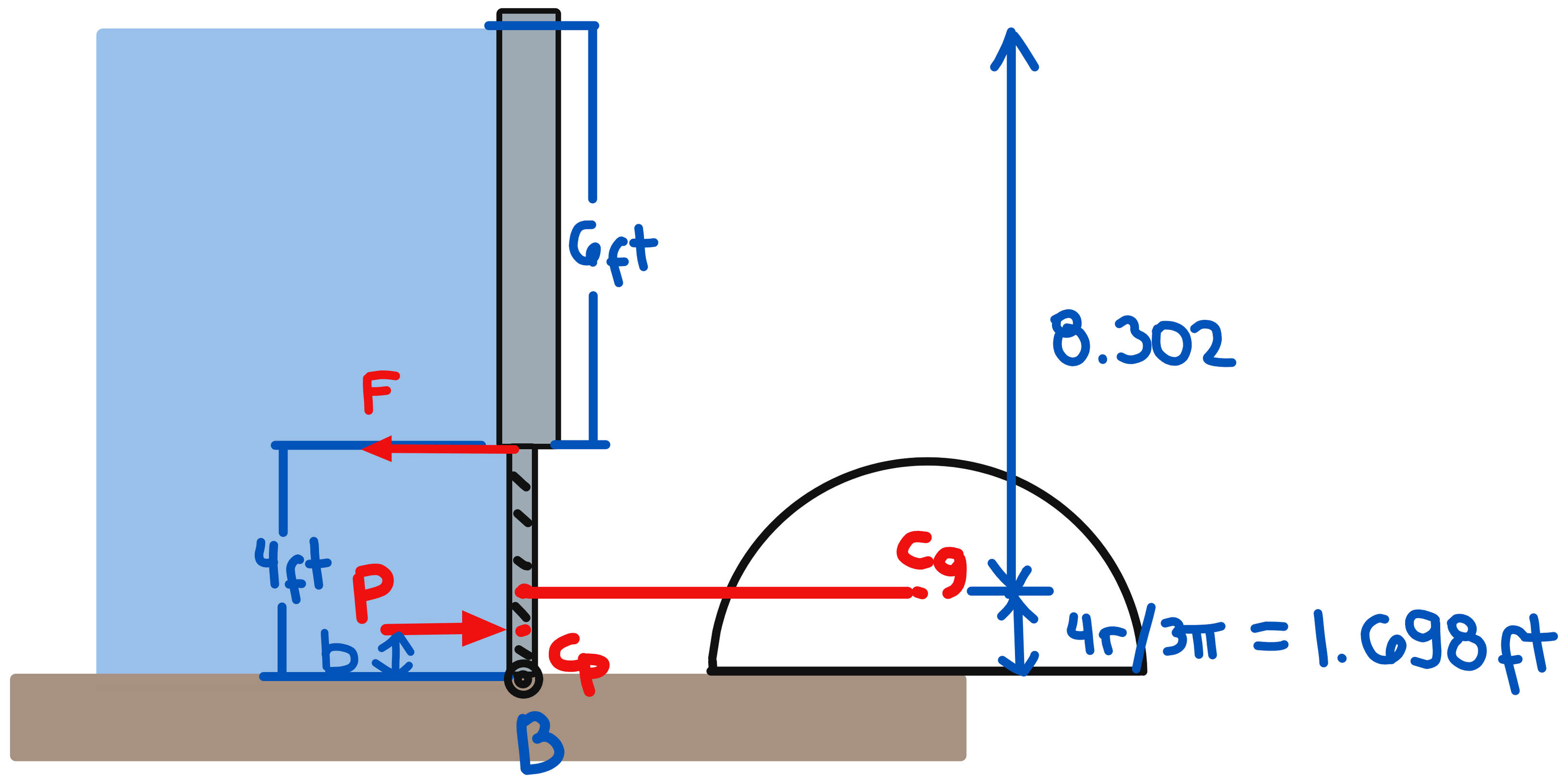
$$P_1 = 175 - 100$$
$$= 75 \text{ kPa}$$
$$P_2 = 9.81(2.9)$$
$$= 28.449 \text{ kPa}$$

$$F_1 = (75)(3.9)(2)$$
$$= 585 \text{ kN}$$

$$F_2 = \frac{1}{2}(28.449)(2.9)(2)$$
$$= 82.5 \text{ kN}$$

$$F = 585 + 82.5 = 667.5 \text{ kN}$$

24. The semi-circular gate is hinged at B. Determine the force F required to hold the gate in position.



$$\boxed{P = \gamma \bar{h} A}$$

$$\bar{h} = \bar{y} = 8.302 \text{ ft}$$

$$= 62.4(8.304)\left[\frac{\pi(4)^2}{2}\right]$$

$$= 13{,}023 \text{ lbs}$$

$$\boxed{e = \frac{I_g}{A\bar{y}}}$$

$$= \frac{0.11(4)^4}{\frac{\pi(4)^2}{2}(8.304)}$$

$$= 0.1349 \text{ ft}$$

$$b = 1.698 - 0.1349$$

$$= 1.5631 \text{ ft}$$

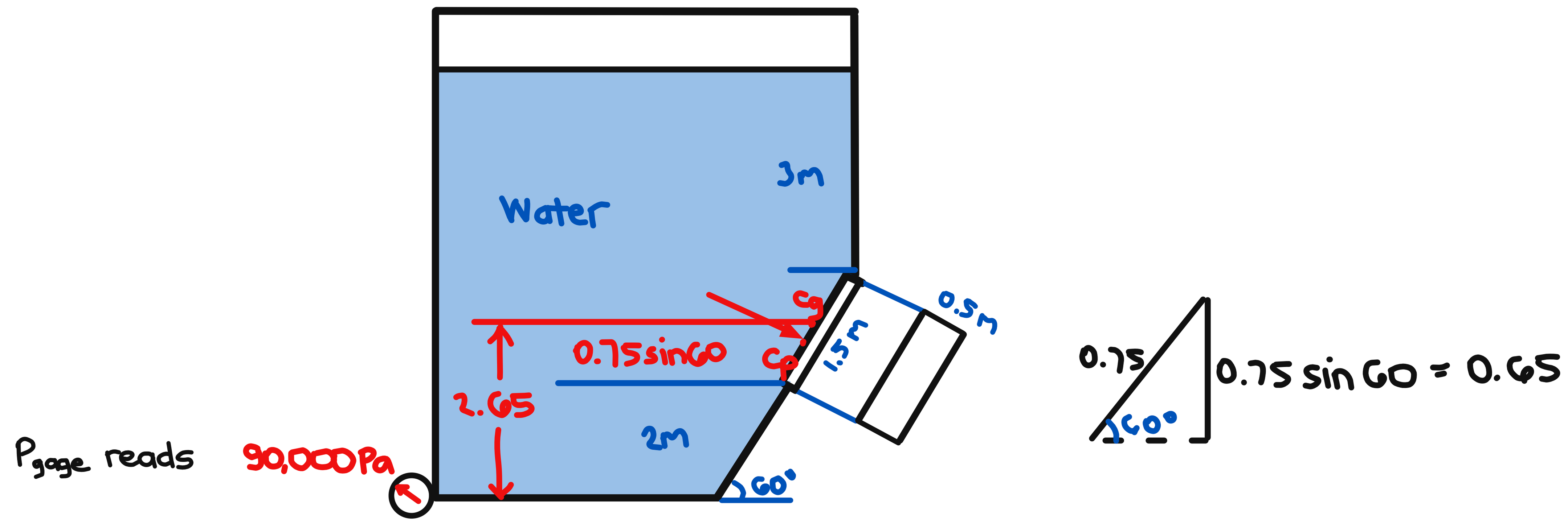
$$\Sigma M_B = 0$$

$$P(b) - F(4) = 0$$

$$13{,}023(1.5631) = F(4)$$

$$F = 5089 \text{ lbs}$$

25 Determine the magnitude of the force on the inclined gate.



$$\boxed{F = P_{cg} A}$$

$$P_2 - P_{cg} = \gamma \bar{h}$$

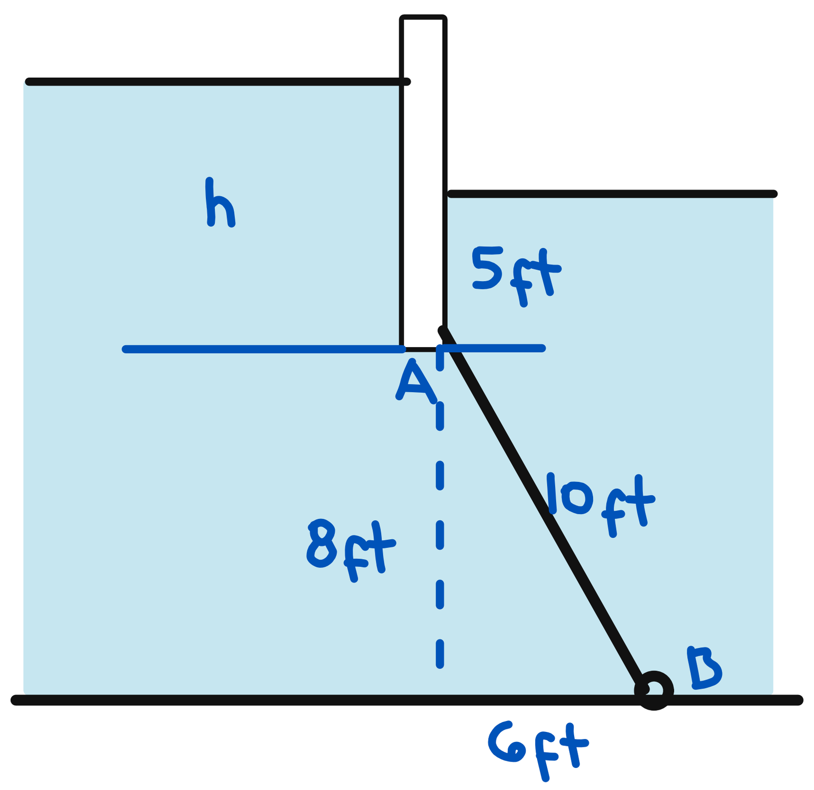
$$90{,}000 - P_{cg} = 9800(2.65)$$

$$P_{cg} = 64{,}030 \text{ Pa}$$

$$F = 64{,}030(0.5 \times 1.5)$$

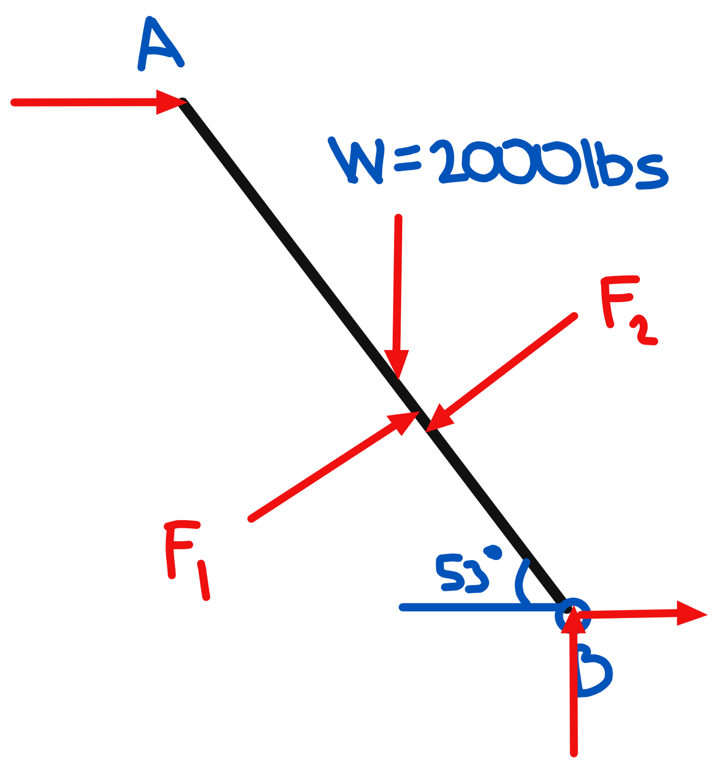
$$= 48{,}023 \text{ N}$$

Gate AB is 6 ft. wide and weighs 2000 lb when submerged. It is hinged at B and rest against a smooth wall at A. Determine the water level h which will just cause the gate to open.



$$\sin\theta = \frac{8}{10}$$

$$\theta = 53.13°$$



$$F_1 = 62.4\left(h + \frac{10}{2}\sin 53.13\right)(10 \times 6)$$

$$= 3744h + 14{,}976$$

$$e_1 = \frac{\frac{6(10)^3}{12}}{(h + 5\sin 53.13)(10\times 6)}\sin 53.13$$

$$= \frac{6.67}{(h+4)}$$

$$F_2 = 62.4\left(5 + \frac{10}{2}\sin 53.13\right)(10 \times 6)$$

$$= 33696 \text{ lbs}$$

$$e_2 = \frac{\frac{6(10)^3}{12}}{(5 + 5\sin 53.13)(10\times 6)}\sin 53.13$$

$$= 0.74 \text{ ft}$$

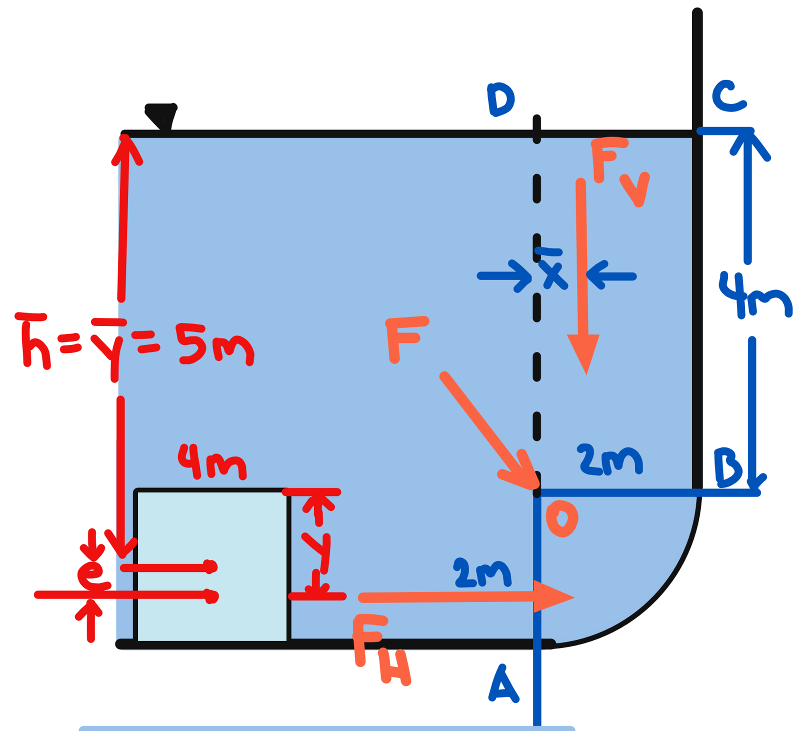
$$\Sigma M_B = 0$$

$$(3744h + 14{,}976)\left(5 - \frac{6.67}{h+4}\right) - 33696(5 - 0.741)$$

$$- \underbrace{2000}_{\text{Weight of the gate}}\left(\frac{6}{2}\right) = 0$$

$$h = 5.32 \text{ ft}$$

26.



$$\boxed{F_H = \gamma \bar{h} A}$$
$$= 9.81(5)(4\times2)$$
$$= 392.4 \text{ kN}$$

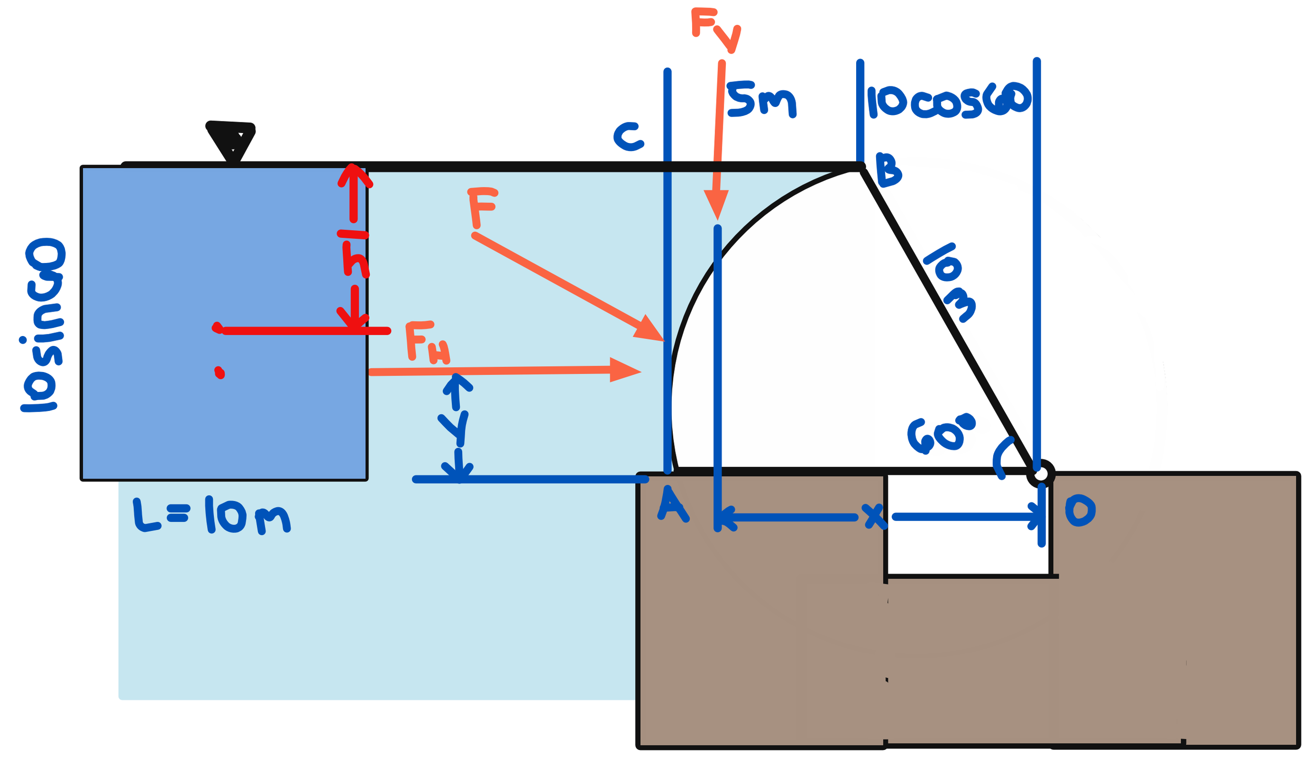
$$e = \frac{\frac{4(2)^3}{12}}{(4\times2)(5)}$$
$$= 0.067$$

$$y = 1 + e$$
$$= 1.067 \text{ m}$$

$$\boxed{F_V = W_{above}}$$
$$= \gamma V_{ABCD}$$
$$= 9.81\left[(4\times2)+\left(\frac{\pi}{4}2^2\right)\right](4)$$
$$= 437.196 \text{ kN}$$

$$\Sigma M_o = 0$$
$$F_V\bar{x} - F_H y = 0$$
$$437.196(\bar{x}) = 392.4(1.067)$$
$$\bar{x} = 0.9577 \text{ m}$$

27.



$$\boxed{F_H = \gamma \bar{h} A}$$
$$= (9.81)(10\sin60/2)(10\times 10\sin60^\circ)$$
$$= 3679 \text{ kN}$$

$$y = \frac{1}{3}(8.66) = 2.886 \text{ m}$$

$$\boxed{F_v = \gamma V_{above}}$$
$$V_{ABC} = V_{AOBC} - V_{AOB}$$
$$= \frac{5+10}{2}(8.66)\times10 - \frac{1}{2}(10)^2\left[60^\circ \times \frac{\pi}{180^\circ}\right]\times 10$$
$$= 125.9 \text{ m}^3$$
$$F_v = 9.81(125.9)$$
$$= 1235 \text{ kN}$$

$$\Sigma M_o = 0$$
$$1235(x) - 3679(2.877) = 0$$
$$x = 8.57 \text{ m}$$