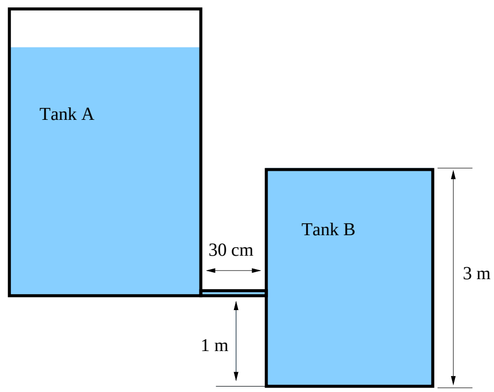
1. A water tank, 3.7 m deep and 2 m in diameter, is connected at the bottom to a second water tank by using a 2 cm diameter pipe (see the figure). The tank A is open to the air and tank B is filled to the top and sealed.



5 (a) What is the mass of the water in tank A?

5 (b) What is the gauge pressure at the bottom of tank A?

5 (c) What is the absolute pressure at the bottom of tank B?

10 (d) What is the net force on the top of tank B?

2. An airplane has a 50 m^2 wing that is designed so that air on the top travels 20% faster than the air on the bottom. The air on the bottom of the wing moves at the plane's airspeed and the unloaded airplane has a take-off speed of 90 km/h.

5 (a) What is the velocity of the air on top of the wing as the unloaded airplane becomes airborne?

10 (b) What pressure difference between the top and bottom of the wing as the unloaded airplane becomes airborne?

5 (c) What is the mass of the unloaded airplane?

15 (d) If on a particular day, the mass of the airplane is increased by 10%, what is the new take-off speed?

4. A glass cup with a mass of 0.1 kg and an initial temperature of 23 °C is filled with 0.3 kg of water at 80 °C.

10 (a) What is the final temperature of the water and cup?

10 (b) How much heat must be added to raise the temperature to 90 °C?

5 (c) † What is the change in the internal energy of the water?

5. An aluminum cup (of negligible mass) is filled with 0.5 kg of water with a temperature of 15 °C and 1.3 kg of ice (at -8 celsius) is added.

10 (a) What is the final phase or phases of the mixture?

10 (b) What is the final temperature of the mixture?

15 (c) † How much heat is required to raise the mixture to 15 °C.

Formulas

$\rho = m/V$	$\mu = m/L$
$E_{kin} = \frac{1}{2}mv^2$	$\bar{K} = \frac{3}{2}kT$
$PV = nRT$	$PV = NkT$
$k = 1.38 \times 10^{-23}$ J/K	$R = 8.32$ J/molK
$N_A = 6.02 \times 10^{23}$ mol^{-1}	$v = \lambda f$
$v = \sqrt{\frac{F_T}{\mu}}$	$v_{air} = 343$ m/s
$P_{atm} = 100$ kPa $= 1 \times 10^5$ N/m^2	g $= 9.8$ m/s^2
$\Delta U = Q - W$	$Q = mc\Delta T$
$Q = mL$	

Material	Specific Heat
Water	4186 J/kgK
Ice	2100 J/kgK
Glass	840 J/kgK

Material	Melting Point	Heat of Fusion	Boiling Point	Heat of Vap.
Water	0 °C	3.33×10^4 J/kg	100 °C	2.26×10^6 J/kg

Formulas

$$\rho = m/V$$
$$P = \rho g h$$
$$P_2 - P_1 = -\rho g(y_2 - y_1)$$
$$\frac{F_{out}}{F_{in}} = \frac{A_{out}}{A_{in}}$$
$$P_1 + \frac{1}{2}\rho_1 v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho_2 v_2^2 + \rho g y_2$$
$$E_{kin} = \frac{1}{2}mv^2$$
$$Q = \frac{\pi R^4 \Delta P}{8\eta L}$$
$$f = 1/T$$
$$\omega = \sqrt{\frac{k}{m}}$$
$$\omega = 2\pi f = \frac{2\pi}{T}$$
$$U = \frac{1}{2}kx^2$$
$$v = \pm\sqrt{\frac{k}{m}\left(A^2 - x^2\right)}$$
$$\cos\theta \approx 1 - \theta^2$$
$$d\sin\theta = \cos\theta$$
$$\omega = \sqrt{\frac{K}{I}}$$
$$m\frac{d^2x}{dt^2} + b\frac{dx}{dt} + kx = 0$$
$$\alpha = \frac{b}{2m}$$
$$f = \frac{\omega'}{2\pi}$$
$$v = \sqrt{\frac{F_T}{\mu}}$$
$$v = \sqrt{\frac{B}{\rho}}$$
$$I = \bar{P}/A$$
$$D(x,t) = D_m \sin\left(\frac{2\pi}{\lambda}x - \frac{2\pi}{T}t\right)$$
$$\frac{\partial D}{\partial x} - \frac{1}{v^2}\frac{\partial D}{\partial t} = 0$$
$$P_{atm} = 100 \text{ kPa} = 1 \times 10^5 \text{ N/m}^2$$

$$P = F/A$$
$$\frac{dP}{dy} = -\rho g$$
$$P = P_0 + \rho g h$$
$$\rho_1 A_1 v_1 = \rho_2 A_2 v_2$$
$$W = F\Delta x$$
$$F = \eta A \frac{v}{l}$$
$$F = -kx$$
$$\frac{d^2x}{dt^2} + \frac{k}{m}x = 0$$
$$x = A\cos\left(\omega t + \phi\right)$$
$$E_{tot} = \frac{1}{2}kA^2$$
$$v_{max} = \omega A$$
$$\sin\theta \approx \theta$$
$$d\cos\theta = -\sin\theta$$
$$\omega = \sqrt{\frac{g}{L}}$$
$$F_{damp} = -bv$$
$$x = Ae^{-\alpha t}\cos\left(\omega' t + \phi\right)$$
$$\omega' = \sqrt{\frac{k}{m} - \frac{b^2}{4m^2}}$$
$$v = \lambda f$$
$$v = \sqrt{\frac{E}{\rho}}$$
$$\bar{P} = 2\pi^2 \rho A v f^2 D_m^2$$
$$D(x,t) = D_m \sin\left[\frac{2\pi}{\lambda}\left(x - vt\right)\right]$$
$$D(x,t) = D_m \sin\left(kx - \omega t\right)$$
$$Re = \frac{2\bar{v}r\rho}{\eta}$$
$$\text{g} = 9.8 \text{ m/s}^2$$

Material	Young's Modulus	Density	Viscosity
Iron, cast	100×10^9 N/m^2	7.8×10^3 kg/m^3	
Steel	200×10^9 N/m^2	7.8×10^3 kg/m^3	
Brass	100×10^9 N/m^2	8.9×10^3 kg/m^3	
Aluminum	70×10^9 N/m^2	2.7×10^3 kg/m^3	
Granite	45×10^9 N/m^2	2.7×10^3 kg/m^3	
Air		1.3 kg/m^3	1.8×10^{-5} Pa-s
Water		1×10^3 kg/m^3	1.8×10^{-5} Pa-s

TO PREPARE FOR THE MIDTERM EXAM, YOU SHOULD REVIEW ALL THE HOMEWORK PROBLEMS ASSIGNED SO FAR (from ch. 9,10,14,17,18)

ADDITIONAL PRACTICE PROBLEMS (time 50 minutes):

- **Problem 1**

An advertisment claims that a centrifuge takes up only 0.127m of bench space but can produce a radial acceleration of 3000g at 50000 rev/m. Calculate the required radius of the centrifuge. Is the claim realistic?

- **Problem 2**

Small blocks, each with mass m, are clamped at the ends and at the center of a rod of length L. Compute the moment of inertia of the system about an axis perpendicular to the rod and passing throughh a point 1/4 of the length from one end. You can ignore the moment of inertia of the rod.

- **Problem 3**

At a certain point in a horizontal pipeline, the speed of water is 2.5 m/s, and the gauge pressure is 1.8 x 10^5Pa. What is the pipe radius at a constriction if the pressure there is reduced to 1.2 x 10^5Pa ?

- **Problem 4**

An ice cube with mass 0.075 kg is taken from a freezer, where the cube's temperature was -10 degC, and dropped into a glass of water at 0 degC. If no heat is gained or lost from outside, how many grams of water will freeze onto the cube?

- **Problem 5**

Alarge cylindrical tank contains 0.75 $m^3$of nitrogen gas at 27 deg C and 1.5 x 10^5Pa. The tank has a tigh-fitting piston that allows the wolume to be changed. What will be the pressure if the volume is decreased to 0.48 m^3 and the temperature is increased to 157 degC?

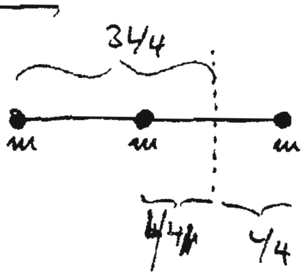
SOLUTIONS

PROBLEM 1

$$r = \frac{a_{rad}}{\omega^2} = \frac{3000 \times 9.81\ m/s^2}{\left[3000\ \frac{rev}{min} \cdot \frac{\pi}{30}\ \frac{rad/s}{rev/min}\right]^2} = 10.7\ cm$$

$d = 2r > 0.127\ m$ Not realistic

PROBLEM 2



$$I = m\left(\frac{L}{4}\right)^2 + m\left(\frac{L}{4}\right)^2 + m\left(\frac{3L}{4}\right)^2 = \frac{11}{16} m L^2$$

PROBLEM 3

→ see next page

[illegible]

[illegible]

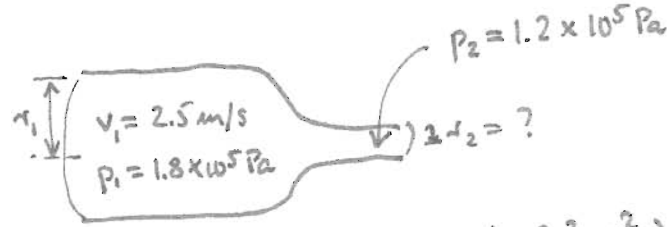
PROBLEM 4

$$m_{water} = \frac{m_{ice} \cdot c_{ice} \cdot \Delta T_{ice}}{L_f} = \frac{0.075\ kg \times 2100\ J/kgK \cdot 10\ K}{334 \times 10^3\ J/kg} = 4.72 \times 10^{-3}\ kg = 4.72\ g$$

PROBLEM 5

$$p_2 = p_1 \left(\frac{T_2}{T_1}\right)\left(\frac{V_1}{V_2}\right) = 1.5 \times 10^5\ Pa \left(\frac{430.15\ K}{300.15\ K}\right)\left(\frac{0.750\ m^3}{0.48\ m^3}\right) = 3.36 \times 10^5\ Pa$$

PROBLEM 3



$$p_2 = p_1 + \tfrac{1}{2}\rho(v_1^2 - v_2^2)$$

$$v_2 A_2 = v_1 A_1$$

$$v_2 = v_1 \frac{A_1}{A_2} = v_1 \frac{\pi r_1^2}{\pi r_2^2}$$

$$= p_1 + \tfrac{1}{2}\rho v_1^2 \left(1 - \left(\frac{r_1}{r_2}\right)^4\right)$$

$$\Rightarrow \frac{(p_2 - p_1)}{\frac{1}{2}\rho v_1^2} = 1 - \frac{r_1^4}{r_2^4}$$

$$\Rightarrow \left(\frac{r_1}{r_2}\right)^4 = 1 - \frac{(p_2 - p_1)}{\frac{1}{2}\rho v_1^2} \Rightarrow \frac{r_1}{r_2} = \left[1 - \frac{p_2 - p_1}{\frac{1}{2}\rho v_1^2}\right]^{1/4}$$

$$\Rightarrow r_2 = r_1 \underbrace{\left[1 - \frac{p_2 - p_1}{\frac{1}{2}\rho v_1^2}\right]^{-1/4}}_{0.47}$$

Note that r_1 was not specified in problem!