Physics 202
Midterm 2 Review Session
2/17/2019

These are example problems of similar *format* to those that will appear on the exam (unless otherwise indicated). They may be more or less difficult than is appropriate for an exam.

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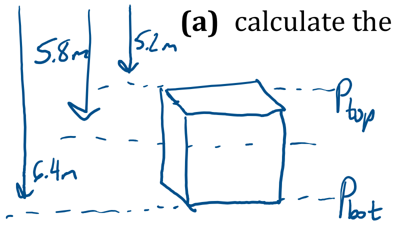
1. A cube of side length 1.2 meters is suspended so that the center of mass is 5.8 meters under the surface of a lake of water.

(a) calculate the pressure exerted by the water on the top of the cube.



$$P_{top} = P_{atm} + \rho g d$$

$$= 101{,}325 + (1000)(9.8)(5.8 - \tfrac{1.2}{2}) = 152{,}285 \text{ Pa}$$

(b) calculate the pressure exerted by the water on the bottom of the cube.

$$P_{bot} = P_{atm} + \rho g d$$

$$= 101{,}325 + (1000)(9.8)(6.4) = 164{,}045 \text{ Pa}$$

(c) What is the total force exerted on the cube by the water?

$$P = \frac{F}{A}$$

$$F = PA$$

$$F_{tot} = F_{bot} - F_{top} = AP_{bot} - AP_{top} = A\Delta P = 16{,}934 \text{ N}$$

$$A = (1.2)(1.2) = 1.44 \text{ m}^2$$

(d) Find the buoyant force on the cube by calculating the weight of the displaced fluid. How does this compare to your answer for c?

$$\text{Weight} = \rho V g = (1000)(1.728)(9.8) = 16{,}934 \text{ N}$$

$$V_{disp.} = (1.2)^3 = 1.728 \text{ m}^3$$

Same!

$F^B = A\Delta P =$ Weight of displaced fluid

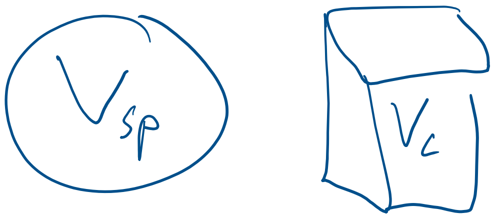
(e) What density must the cube have if the initial acceleration of the cube when released from rest is 0.12 m/s^2 downward? (ignore drag)

$F_{net} = ma$

$F^g - F^B = ma = \rho V a \Rightarrow \rho_c V_c g - \rho_f V_c g = \rho_c V_c a$

$\rho_c = \frac{\rho_f g}{(g-a)} = \frac{1000(9.8)}{9.8-0.12} = 1009\ kg/m^3$

(f) If the cube were instead a sphere, what radius of sphere would produce an equivalent buoyant force?



$V_c = V_{sph}$

$1.728\ m^3 = \frac{4}{3}\pi r^3$

$\frac{3}{4\pi}(1.728) = r^3 \Rightarrow$ $r = 74\ cm$

$\Rightarrow$ Diameter > 1.2 m ✓

For questions 2 through 4 **fill in the square** next to all correct answers, a given problem may have more or less than one correct answer. Each correctly chosen answer will receive two points. There are 8 correct answers in this section and only the first 8 filled in answers will be graded. There is no partial credit.

2. Which of the following processes will decrease the entropy of the system?

a. Boiling half of the existing water into steam in an isolated box. (system = water + steam)

b. Rubbing your hands together to warm them. (system = your right hand)

c. Freezing water in a refrigerator. (system = water/ice)

d. Freezing water in a refrigerator. (system = kitchen)

e. Moving all the red jelly beans to one side of a bowl and the blue ones to the other side. (system = bowl of jelly beans)

more ordered $\Rightarrow$ less entropy

3. Which of the following will increase the pressure in a sealed container of ideal gas by a factor of 1.5?

a. Increasing the temperature by a factor of 1.5 while holding the volume constant. $\frac{1.5}{1} = \frac{3}{2}$ ✓

b. Decreasing the temperature to 2/3rds of the initial while holding the volume constant. $\frac{2/3}{1} = \frac{2}{3}$

c. Increasing the temperature to double the initial while increasing the volume to three times the initial. $\frac{2}{3}$

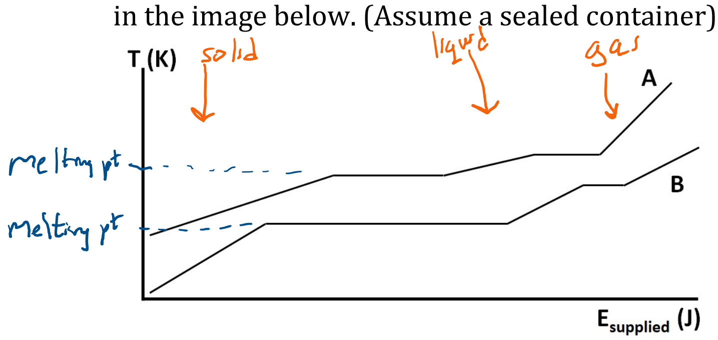
d. Decreasing the temperature to 1/2 of the initial while decreasing the volume to 1/3 of the initial. $\frac{1/2}{1/3} = \frac{3}{2}$ ✓

e. Increasing the temperature to six times the initial while increasing the volume to four times the initial. $\frac{6}{4} = \frac{3}{2}$ ✓

$PV = nRT$

$P = nR\frac{T}{V} \Rightarrow P \propto \frac{T}{V}$

4. Which of the following statements is true regarding the two substances described in the image below. (Assume a sealed container)



a. The latent heat of fusion of B is smaller than the latent heat of fusion for A. ✗

b. The melting point of A is higher than the melting point of B. ✓

c. The specific heat of A in the liquid phase is smaller than the specific heat of B in the liquid phase. ✗

d. The specific heat of A in the solid phase is greater than the specific heat of B in the solid phase. ✓

e. The latent heat of vaporization of B is smaller than the latent heat of vaporization for A. ✓

f. The boiling point of A is lower than the melting point of B. ✗

(this one may be a little more open ended than a typical exam problem.)

5. **(a)** If the substances in problem 4 were to transition into ideal monatomic gases in their respective gas phase, what would the slope of the graph be for substance **A** in its gas phase? (you should assume a sealed container of a constant volume, which means all energy added is in the form of heat) Answer symbolically in terms of state variables for gases and universal constants.

$$\Delta E = \frac{3}{2} N k_B \Delta T \qquad N k_B = nR$$

$$\frac{\text{rise}}{\text{run}}: \quad \frac{\Delta T}{\Delta E} = \boxed{\frac{2}{3 N k_B}} = \boxed{\frac{2}{3 n R}}$$

(b) What conclusions can we make about the number of particles in each gas?

Slope A > slope B $\quad \propto \frac{1}{N}$ or $\frac{1}{n}$

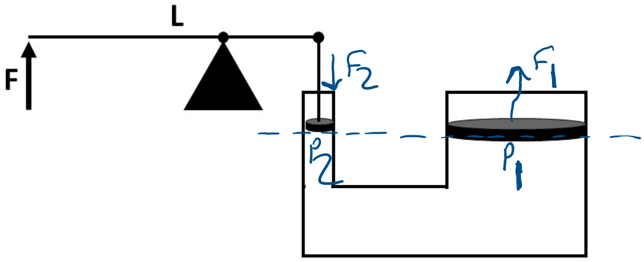
$$N_A < N_B$$

(c) Find a symbolic expression for the specific heat of the gas in terms of the number of particles in the gas, the density and the volume of the gas (and relevant universal constants).

$$\Delta E = c m \Delta T$$

$$c = \frac{1}{m} \frac{\Delta E}{\Delta T} = \frac{1}{m} \frac{3}{2} N k_B = \frac{3 N k_B}{2 \rho V}$$

6. A hydraulic system is created as shown below.



(a) What hydraulic advantage does the piston system have if the larger piston has a radius of 32.0 cm and the smaller piston has a radius of 9.50 cm? (image may not be drawn to scale!)

$P = \frac{F}{A}$

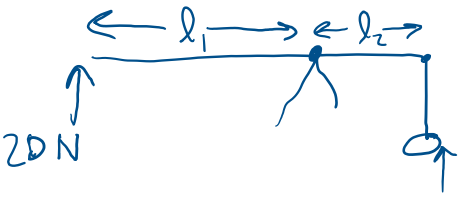
$F = PA$

$$\text{adv.} = \frac{F_1}{F_2} = \frac{P_1 A_1}{P_2 A_2} = \frac{A_1}{A_2} = \frac{\pi r_1^2}{\pi r_2^2} = \frac{r_1^2}{r_2^2}$$

$$= \frac{(0.32)^2}{(0.095)^2} = \boxed{11.3}$$

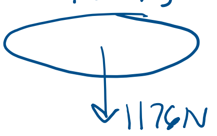
you get 11.3 × the force at the big piston that you put into the small piston

(b) If the length of the beam is L = 70.0 cm, how far from the applied force must the triangle (pivot) be placed such that with a force F = 20.0 N, we can lift a 120 kg football player who has been placed on top of the large piston?

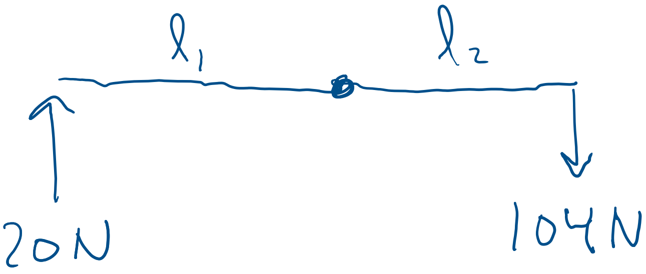


$\frac{1176}{11.3} = 104$ N

120 kg ⇒ $F = (120)(9.8) = 1{,}176$ N



⇒



$T_1 = T_2$

① $(20\text{ N})(l_1) = (104\text{ N})(l_2)$

② $l_1 + l_2 = 0.7$ m

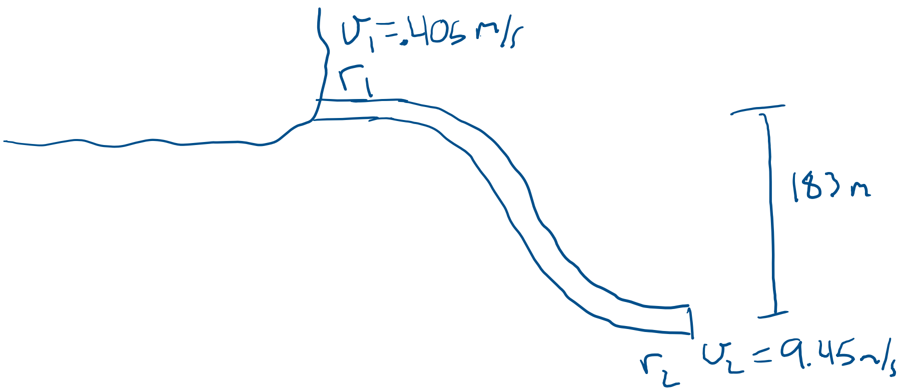
① ⇒ $l_1 = \frac{104\text{ N}}{20\text{ N}} l_2 = 5.2\, l_2$

② ⇒ $l_1 + l_2 = (5.2 l_2) + l_2 = 6.2 l_2 = 0.7$ m

⇒ $l_2 = \frac{0.7\text{ m}}{6.2} = 11.3$ cm ⇒ ② ⇒ $l_1 = 58.7$ cm

7. A water intake at a reservoir has a radius of 0.486 m. The water flows in at a speed of 0.405 m/s. At the generator building, 183 m below the intake point, the water flows out at a speed of 9.45 m/s.

(a) What is the radius of the outlet?



$$A_1 v_1 = A_2 v_2$$

$$\pi r_1^2 v_1 = \pi r_2^2 v_2$$

$$r_2 = \sqrt{\frac{r_1^2 v_1}{v_2}}$$

$$= (0.486)(0.207)$$

$$r_2 = 10 \text{ cm}$$

(b) What is the difference in pressure between the intake and outlet?

ΔP

$$P_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g y_2 + \frac{1}{2}\rho v_2^2$$

$$P_2 - P_1 = \Delta P = \rho g y_1 + \frac{1}{2}\rho v_1^2 - \rho g y_2 - \frac{1}{2}\rho v_2^2$$

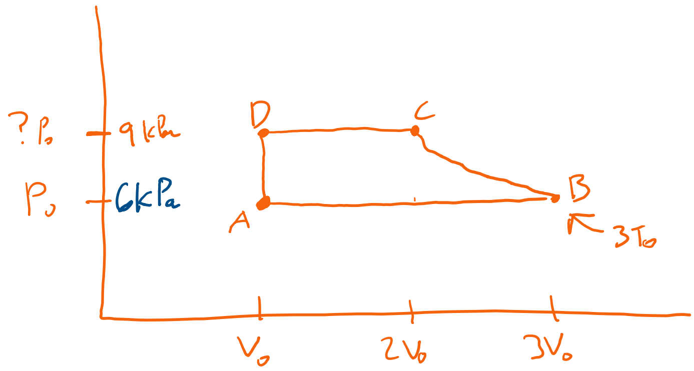
$$= \rho g (y_1 - y_2) + \frac{1}{2}\rho (v_1^2 - v_2^2)$$

$$= (1000)(9.8)(183) + \frac{1}{2}(1000)(-89.1)$$

$$P_2 - P_1 = \Delta P = 1.75 \times 10^6 \text{ Pa}$$

8. 3.0 moles of an ideal gas is subjected to the following processes. First the volume is tripled in an isobaric process, then it undergoes an isothermal process to a pressure of 9.0 kPa. The volume is then halved in another isobaric process. Finally, it returns to the original pressure and volume in an isochoric process.

(a) If the isothermal process occurs at a temperature of 900 K, what are the Pressure, Temperature, and Volumes for each of the inflection points.



A) $P_0 V_0 = nRT_0$

B) $P_0 3V_0 = nR(3T_0)$

C) $(3T_0)nR = (2V_0)(\frac{3}{2}P_0)$

$9\,kPa = \frac{3}{2}P_0$

$\Rightarrow P_0 = 6\,kPa$

D) $V\downarrow_2 \Rightarrow T\downarrow_2$

$\Rightarrow (\frac{3}{2}T_0)nR = V_0(\frac{3}{2})P_0$

$P_0 = \frac{2}{3}(9\,kPa) = 6\,kPa$

$= P_A,\ P_B$

$P_C = 9\,kPa$

$T_A = \frac{1}{3}T_B = 300\,K$

$T_B = T_C = 900\,K$

$T_D = \frac{T_C}{2} = 450\,K$

$P_B V_B = nRT_B$

$(6000)V_B = (3.0)(8.31)(900)$

$V_B = 3.74\,m^3 = 3V_0$

$V_A = V_0 = 1.25\,m^3$

$V_C = 2V_0 = 2.49\,m^3$

$V_D = V_0 = 1.25\,m^3$

(b) Is the process a heat pump or a heat engine. Explain.

Work = area under curve

More area under curve for $B \to C$ + $C \to D$

$\Rightarrow$ Compressing $\Rightarrow$ net work is positive on gas $\Rightarrow$ heat pump

(c) Find the work done on the gas, the heat in and out of the gas, and the change in thermal energy for each of the processes.

$A \to B \Rightarrow \Delta E = \frac{3}{2} N k_B \Delta T = \frac{3}{2} n R \Delta T = \frac{3}{2}(3.0)(8.314)(600)$

$\Delta E_{AB} = +22{,}400\ J$

$\Delta E_{BC} = 0\ J$

$\Delta E_{CD} = -\frac{3}{2}(3.0)(8.314)(450)$

$= -16{,}800\ J$

$\Delta E_{DA} = -\frac{3}{2}(3.0)(8.314)(150)$

$= -5{,}600\ J$

$W_{AB} = -P\Delta V$

$= -(6000)(3.74 - 1.25)$

$W_{AB} = -14{,}900\ J$

$\Delta E_{AB} = W_{AB} + Q_{AB}$

$22{,}400 = -14900 + Q_{AB}$

$Q_{AB} = 37{,}300\ J$

$W_{BC} = -nRT \ln\left(\frac{V_C}{V_B}\right)$

$= -(3.0)(8.314)(900) \ln\left(\frac{2 V_0}{3 V_0}\right)$

$W_{BC} = +9{,}100\ J$

$\Delta E_{BC} = W_{BC} + Q_{BC}$

$0 = 9100 + Q_{BC}$

$Q_{BC} = -9100$

$W_{DA} = 0$

$\Delta E_{CD} = W_{CD} + Q_{CD}$

$-16800 = 11300 + Q_{CD}$

$Q_{CD} = -28{,}100\ J$

$W_{CD} = -P\Delta V$

$= -(9000)(1.25 - 2.49) = +11{,}300\ J = W_{CD}$

$\Delta E_{DA} = W_{DA} + Q_{DA}$

$-5610\ J = Q_{DA}$

(d) What is the efficiency of the engine or coefficient of performance (for both a refrigerator and a radiator) for the cycle?

$COP_{rad} = \frac{Q_H}{W_{in}} = \frac{42{,}800\ J}{5{,}500\ J} = 7.78$

$COP_{fridge} = \frac{Q_C}{W_{in}} = \frac{37{,}300\ J}{5{,}500\ J} = 6.78$