p202_w24_m2

Name:______________________________ ID:______________________________

Physics 202

Midterm 2

2/21/2024

Collaboration is not allowed. Allowed on your desk are: ten 8.5 x 11 inch doubled sided sheets of notes that are bound together, non-communicating graphing scientific calculator, a page of scratch paper, writing utensils, and the exam. You will have 80 minutes to complete this exam.

For questions 1 through 7 **fill in the square** next to all correct answers. A given problem may have more than one correct answer. Each correctly bubbled answer will receive two points. There are **7** correct answers in this section and only the first **7** filled in answers will be graded. There is no partial credit.

A block of Aluminum at **20 °C** is brought into contact with a block of Copper at **-20 °C** of equal mass. The system is isolated.

Material	Density	Melting Point	c	k
Copper	8.96 g/cc	1085 °C	385 J/kg K	401 W/m K
Aluminum	2.70 g/cc	660 °C	897 J/kg K	237 W/m K

1. The most important quantity in determining the equilibrium temperature is:

☐ (a) Density
☐ (b) Melting Point
☑ (c) Specific Heat
☐ (d) Thermal Conductivity

2. The equilibrium temperature of the two metals will be:

☑ (a) Greater than zero Celsius
☐ (b) Less than zero Celsius
☐ (c) Zero Celsius
☐ (d) Unable to determine

A red and a blue dice are rolled. Each side of the dice are labeled with numbers 1 through 4. After rolling, the resulting two numbers are added, resulting in a sum between 2 and 8 (inclusive).

3. The most probable **macro**-state of the sum is:

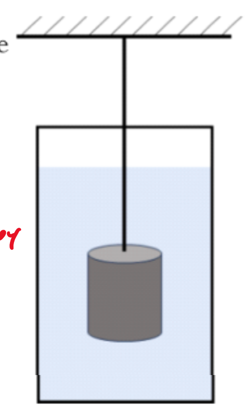
☐ (a) 3
☐ (b) 4
☑ (c) 5
☐ (d) 6
☐ (e) Each **macro**-state is equally probable

2 → 11
3 → 12 21
4 → 13 22 31
5 → 14 23 32 41
6 → 24 33 42

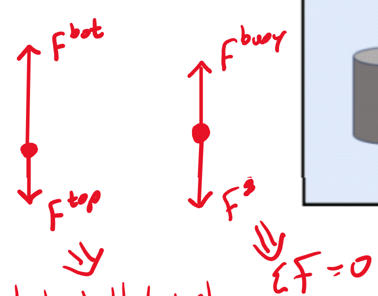
4. The most probable **micro**-state is:

☐ (a) 1:1
☐ (b) 1:2
☐ (c) 2:2
☐ (d) 2:3
☑ (e) Each **micro**-state is equally probable

5. A cylindrical metal can is fully submerged in liquid water. The density of the can is larger than that of water and the object is hung, stationary, from a string such that it is vertical and does not touch the bottom, as shown. Which one of the following forces must be the largest?



☐ (a) Net force on the object
☐ (b) Weight of the displaced fluid
☐ (c) Buoyant force on the object
☑ (d) Force from water on the bottom of the can
☐ (e) Force from water on the top of the can



$|F^{buoy}| = |F^{bot}| - |F^{top}|$

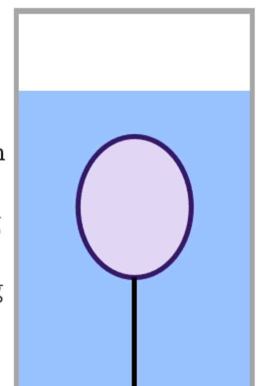
6. Two gasses have an equal number of particles and occupy the same volume of space. The mass of a particle in gas A is twice the mass of a particle in gas B. Gas A is at a temperature 5 times greater than gas B. The average (RMS) speed of particles in gas A are ________ times the average speed of particles in gas B?

$\overline{KE} = \frac{1}{2} \bar{m} v_{rms}^2 = \frac{3}{2} k_B T$

$\Rightarrow \quad v_{rms} = \sqrt{\frac{3 k_B T}{\bar{m}}} \Rightarrow \sqrt{\frac{5}{2}}$

- ☐ (a) 0.160
- ☐ (b) 0.632
- ☐ (c) 0.898
- ☑ (d) 1.58
- ☐ (e) 2.24
- ☐ (f) 6.25
- ☐ (g) 1.00

7. A balloon is filled with air and then tied via a string to the bottom of a tank of water, fully submerged as shown in the figure. If the temperature of the water increases, which of the following statements are true? Assume the air in the balloon acts like an ideal gas, the whole system is brought to equilibrium at the new temperature, and the balloon stays at the same depth in the water.



- ☐ (a) The buoyancy force on the balloon will decrease, while the tension in the string will increase.
- ☐ (b) The buoyancy force on the balloon will increase, while the tension in the string will decrease.
- ☑ (c) Both the buoyancy force on the balloon and the tension in the string will increase.
- ☐ (d) Both the buoyancy force on the balloon and the tension in the string will decrease.

$PV = nRT$ for gas in balloon

same ↑ ↑

$F^{Buoy} = \rho_f V_b g$

↑ ↑

8. (5 points) The International Space Station lives in an environment too cold for humans, yet it is able to maintain a livable temperature. This requires regulating energy in and energy out. To increase temperature, the station can convert electrical energy (stored or from solar cells) or chemical energy (fuels) into thermal energy.

(a) What other **heat transfer mechanisms** can contribute to increasing the station temperature? Explain.

(b) What **heat transfer mechanisms** can contribute to decreasing the station temperature? Explain.

(a) There is no air in space so there is no medium to transfer conduction or convection. The only option to get energy via heat into the station is through absorbing radiation from the sun.

(b) Similar to part (a), the only heat transfer mechanism to expel energy out is via radiation because there is no medium outside the station for conduction or convection.

Extra tidbit:
The ISS has radiation absorbing and emitting panels that can change their orientation relative to the sun's radiation. If it the station needs to warm up, they rotate the panels perpendicular to the sun's rays and get a net radiation into the station. If the station needs to cool down, they can rotate the panels parallel to the sun's radiation to collect less of it. This means more radiation leaves the station into the cold vacuum of space than comes in from the sun. You can feel this effect when you face the sun on a cold day. The rays warm you up. If you turned 90 degrees, you only get rays hitting your side and it may not be enough to warm you up from the cold.

Rubric:

(a) 2.5 points total
1 pt - answer
1.5 pts - reasoning

(b) 2.5 points total
1 pt - answer
1.5 pts - reasoning

9. (7 points) Deep sea oil rigs often have gigantic chambers that go vertically down all the way to the seafloor. The chambers are sealed well enough to evacuate the water and pump in air so that people can work at the bottom of the ocean without special equipment. In one case there are two vertical chambers, left (L) and right (R), that are connected by a horizontal chamber on the seafloor. The horizontal chamber has a circular door, with a radius of **1.1 meters**, which can isolate both sides from each other. During an accident, a hole is punctured on the right chamber and water flows in. Due to high salinity, seawater has a density of **1024 kg/m³**. The door at the bottom is closed after water on the left chamber reaches a height of $\mathbf{d_L}$, but water still flows into the right chamber and is at a height of $\mathbf{d_R}$. The latch on the door will break once the force on the door reaches **3.815 x 10⁶ N**. How much higher is the water column on the right side than the left side when the door latch breaks? Assume the drawing is not to scale.

$$\Delta P = P_R - P_L = \frac{F^{\Delta P}}{\pi r^2} \quad (i)$$

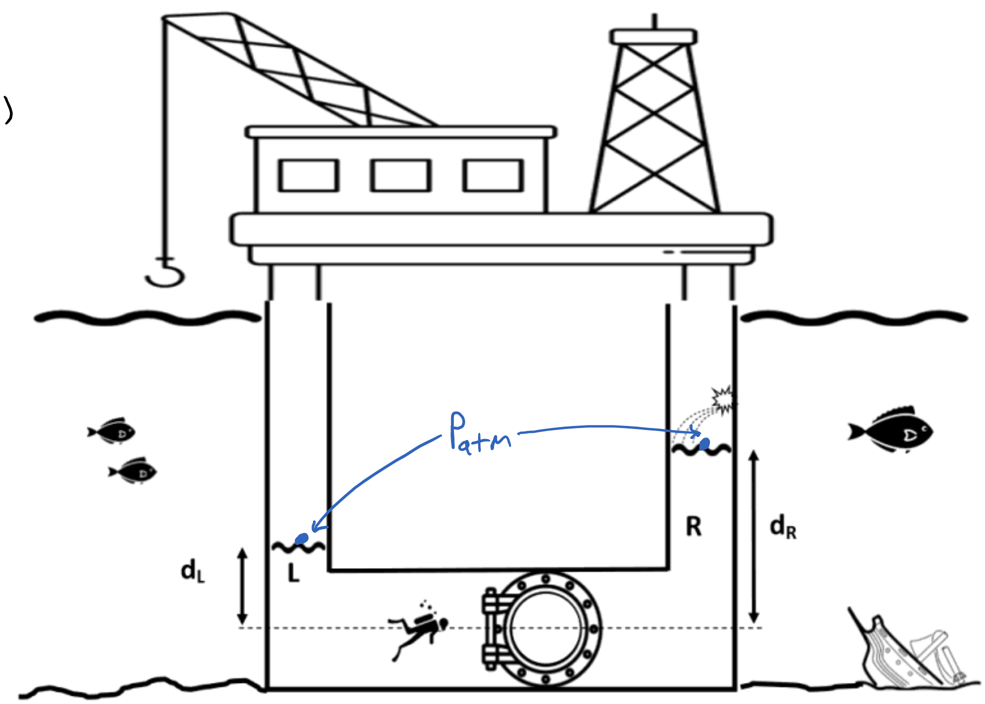
$$P_L = P_{atm} + \rho g d_L \quad (ii)$$

$$P_R = P_{atm} + \rho g d_R \quad (iii)$$

combine (i), (ii), & (iii)

$$\rho g \Delta d_{Max} = \frac{F^{\Delta P}_{max}}{\pi r^2}$$

$$\boxed{\Delta d_{max} = 100 m}$$



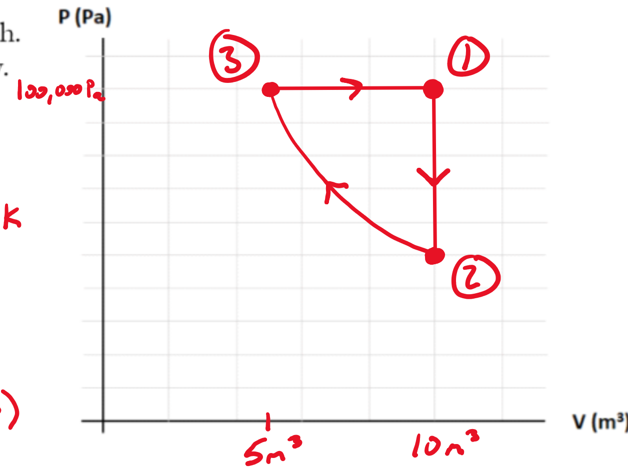
Rubric

1 pt - pressure difference creates force
1 pt - pressure is force per area
0.5 pt - area = pi*r^2
1 pt - pressure at a depth equation
3 pt - Application: taking the difference between pressure at a depth to L and R and getting delta P = rho*g*delta_d , combining delta_P to connect ideas
0.5 - correct answer and units

10. (13 points) Three moles of ideal gas are put through the following processes, resulting in a cycle. The gas starts at equilibrium state 1, with pressure of **100,000 Pa** and a volume of **10 m³**.

1 ⟶ 2: isochoric decrease in pressure to half of equilibrium state 1
2 ⟶ 3: isothermal compression to initial pressure of equilibrium state 1
3 ⟶ 1: isobaric expansion to equilibrium state 1

(a) Neatly draw this cycle on the provided PV graph. Make sure to proportion the processes correctly.



(b) What is the temperature of equilibrium state 3?

$PV = nRT \Rightarrow$

$P_2 = 50{,}000$ Pa

$V_2 = 10\ m^3$

$n = 3$

$T_2 = \frac{PV}{nR} = 20{,}000$ K

$T_3 = T_2 = 20{,}000$ K

(c) What is the work done during the third process (3 ⟶ 1)?

$W = \pm P\Delta V = (100{,}000\ Pa)(5m^3)$

$W = -500{,}000$ J

expansion ⇒ negative work

(d) Is the heat transfer between environment and gas during the third process (3 ⟶ 1) positive, negative, or zero? Explain.

Sign Sensemaking

$\Delta E^{th} = W + Q$

ΔE^{th}: + W: − Q: must be +

Since the thermal energy is increasing (P=const, $V\uparrow \Rightarrow T\uparrow$) and the work done on the gas is negative (expansion), the heat must be adding energy to the gas

⇒ Q is +

(e) Is this a heat engine or a heat pump? Explain using the concept of net work done on or by the gas (explain beyond clockwise or counterclockwise ideas).

Work in process 1→2 = 0

Work in process 2→3 = (+)

Work in process 3→1 = (−)

the work under process 3→1 is larger in magnitude than work under process 2→3. ⇒ net work is negative

⇒ Q_H → W_{out}, Q_C ⇒ heat engine (we get work out!)