

Solutions

Physics 116 - Second In-Class Practice Exam
Profs. Schnetzer and Kloet

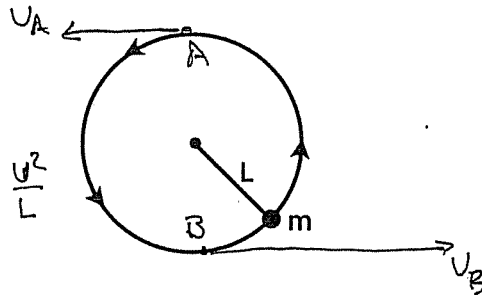
1. A ball of mass m , at one end of a string of length L moves in a vertical circle just fast enough to prevent the string from going slack at the top of the circle. The speed of the ball at the bottom of the circle is:

- a) $\sqrt{2gL}$
 b) $\sqrt{3gL}$
 c) $\sqrt{4gL}$
 — d) $\sqrt{5gL}$
 e) $\sqrt{7gL}$

TOP A

$$mg = F_{\text{NET}} = ma = m \frac{v^2}{L}$$

$$\Rightarrow v_A^2 = gL$$



ENERGY AT A AND B:

$$\frac{1}{2} m v_A^2 + m g h_A = \frac{1}{2} m v_B^2 + m g h_B$$

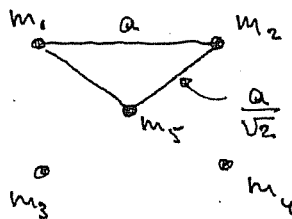
$$v_A^2 + 2g(2L) = v_B^2$$

$$\text{or } v_B^2 = gL + 4gL = 5gL$$

$$v_B = \sqrt{5gL}$$

2. Each of the four corners of a square with edge a is occupied by a point mass m . There is a fifth mass, also m , at the center of the square. The work that must be done to remove the mass from the center to a point very far away is:

- a) $4Gm^2/a$
 b) $-4Gm^2/a$
 — c) $4\sqrt{2}Gm^2/a$
 d) $-4\sqrt{2}Gm^2/a$
 e) $4Gm^2/a^2$



$$m = m_1 = m_2 = m_3 = m_4 = m_5$$

m_5 HAS DISTANCE $\frac{a}{\sqrt{2}}$ TO THE OTHER 4 MASSES

$$PE_{15} = -G \frac{m_1 m_5}{\frac{a}{\sqrt{2}}} = -\frac{G m^2 \sqrt{2}}{a}$$

$$\text{TOTAL PE} = -\frac{4G m^2 \sqrt{2}}{a}$$

To remove m_5 need POSITIVE WORK W

$$W = \frac{4G m^2 \sqrt{2}}{a}$$

3. Solid A with mass m is at its melting point T_A . It is placed in thermal contact with solid B also with mass m . Solid B is initially at temperature T_B ($T_B > T_A$). The combination is thermally isolated. A has latent heat of fusion L and when it is melted has specific heat capacity c_A . Solid B specific heat capacity c_B . If A completely melts, the final temperature of both A and B is:

- a) $(c_A T_A + c_B T_B - L)/(c_A + c_B)$
 b) $(c_A T_A - c_B T_B + L)/(c_A + c_B)$
 c) $(c_A T_A - c_B T_B - L)/(c_A + c_B)$
 d) $(c_A T_A + c_B T_B + L)/(c_A + c_B)$
 e) $(c_A T_A + c_B T_B + L)/(c_A - c_B)$

SOLID A MELTS

SOLID B STAYS SOLID

HEAT FOR MELTING OF SOLID A

$$Q_1 = mL$$

HEAT FOR ΔT OF LIQUID A

$$Q_2 = m c_A (T_f - T_A)$$

HEAT RELEASED BY SOLID B

$$Q_3 = m c_B (T_B - T_f)$$

$$Q_1 + Q_2 = Q_3$$

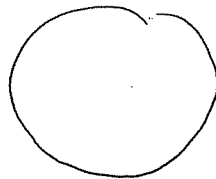
$$L + c_A (T_f - T_A) = c_B (T_B - T_f)$$

$$L - c_A T_A - c_B T_B = -(c_A + c_B) T_f$$

$$T_f = \frac{c_A T_A + c_B T_B - L}{c_A + c_B}$$

4. A 2 m^3 weather balloon is filled with helium at $P = 1 \text{ atm}$ and $T = 27^\circ \text{C}$. At an elevation of 20,000 ft., the pressure is down by a factor of 2 and the temperature is down to $T = -48^\circ \text{C}$. What is the volume of the balloon at this elevation?

- a) 3 m^3
 b) 4 m^3
 c) 2 m^3
 d) 2.5 m^3
 e) 5.3 m^3



$$V_1 = 2 \text{ m}^3$$

$$P_1 = 1 \text{ ATM}$$

$$T_1 = 27^\circ \text{C} = 300 \text{ K}$$

$$P_2 = 0.5 \text{ A}$$

$$T_2 = -48^\circ \text{C} = 225 \text{ K}$$

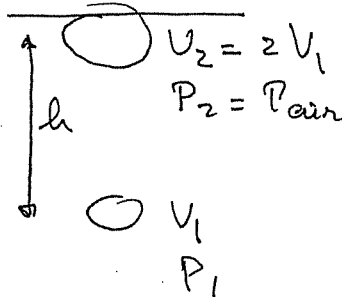
$$V_2 = ?$$

$$uR = \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$V_2 = V_1 \frac{P_1}{P_2} \frac{T_2}{T_1} = 2 \frac{1}{0.5} \frac{225}{300} = 3 \text{ m}^3$$

5. An air bubble doubles in volume as it rises from the bottom of a lake to the top. Assuming that the lake is at uniform temperature, the depth of the lake is:

- a) 21 m
 b) 0.76 m
 c) 4.9 m
 — d) 10 m
 e) 0.99 m



$$\rho_w = 1000 \frac{\text{kg}}{\text{m}^3}$$

$$P_1 = P_{\text{atm}} + \rho_w g h$$

$$P_{\text{atm}} = 1 \text{ atm}$$

$$P_1 V_1 = P_2 V_2$$

$$= P_2 \cdot 2 V_1$$

$$\Rightarrow P_1 = 2 P_2 = 2 P_{\text{atm}}$$

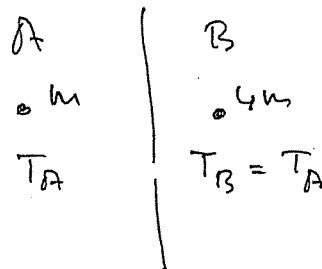
$$P_{\text{atm}} + \rho_w g h = 2 P_{\text{atm}}$$

$$\rho_w g h = P_{\text{atm}}$$

$$9800 h = 1.013 \cdot 10^5 \rightarrow h = 10 \text{ m}$$

6. Two ideal monatomic gases are in thermal equilibrium with each other. Gas A is composed of molecules with mass m while gas B is composed of molecules with mass $4m$. The ratio of the root mean square velocity of gas A to the root mean square velocity of gas B is:

- a) 1/4
 b) 1/2
 — c) 1
 d) 2
 e) 4



$$\frac{v_A}{v_B} = ?$$

FROM $\frac{1}{2} m v^2 = \frac{3}{2} kT$

$$\frac{\frac{1}{2} m_A v_A^2}{\frac{1}{2} m_B v_B^2} = \frac{\frac{3}{2} k T_A}{\frac{3}{2} k T_B}$$

$$\text{or } \frac{m \cdot v_A^2}{4m v_B^2} = 1$$

$$\left(\frac{v_A}{v_B} \right)^2 = 4$$

$$\frac{v_A}{v_B} = 2$$

7. For constant-volume processes the heat capacity of gas A is greater than the heat capacity of gas B. We conclude that when they absorb the same energy as heat at constant volume:

- a) the temperature of A increases more than the temperature of B
- b) the temperature of B increases more than the temperature of A
- c) the internal energy of A increases more than the internal energy of B
- d) the internal energy of B increases more than the internal energy of A
- e) A does more positive work than B

2 gases A, B with $C_A > C_B$

for same Q $\Delta T_A < \Delta T_B \rightarrow$ a wrong
 b true

$$U = \frac{3}{2} n R T$$

$$U_i + Q + W^{ON} = U_f \quad \text{SINCE } U_f = U_i \quad W = 0 \Rightarrow$$

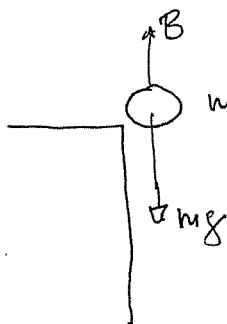
$$\text{HENCE } \Delta U = Q \Rightarrow \textcircled{c} \text{ WRONG}$$

$$\textcircled{d} \text{ WRONG}$$

e WRONG

8. A balloon is released from a tall building. The total mass of the balloon including the enclosed gas is 2 kg. Its volume is 5.0 m^3 . The density of air is 1.3 kg/m^3 . Will the balloon rise, fall or remain stationary and why?

- a) The balloon will fall because its density is greater than that of air
- b) The balloon will remain stationary because its density is less than that of air
- c) The balloon will rise because the upward buoyant force is greater than the weight
- d) The balloon will fall because the upward buoyant force is less than its weight
- e) The question cannot be answered because the density of the gas inside the balloon is not given



$$m = 2 \text{ kg}$$

$$V = 5 \text{ m}^3 \quad \rho_{\text{air}} = 1.3 \text{ kg/m}^3$$

$$\text{Buoyant force } B = 1.3 \cdot 5 \cdot 9.8 = \rho_{\text{AIR}} V_{\text{BALLOON}} g$$

$$\rho_{\text{BALLOON}} = \frac{m_{\text{BAL}}}{V_{\text{BAL}}} = \frac{2}{5} = 0.4$$

$$mg = \rho_{\text{BALLOON}} V_{\text{BAL}} g$$

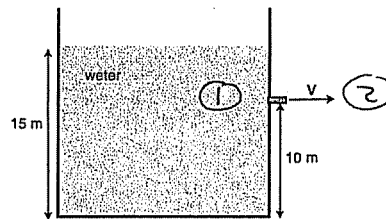
Then $mg < B$ and balloon

will rise $\Rightarrow \textcircled{c}$

density per inside NOT RELEVANT

9. A large tank is filled with water to a depth of 15 m. A spout located 10.0 m above the bottom of the tank is then opened as shown in the drawing. With what speed will water emerge from the spout?

- a) 3.1 m/s
 b) 9.9 m/s
 c) 14 m/s
 d) 17 m/s
 e) 31 m/s



$$P_1 = P_{\text{air}} + \rho_{\text{water}} g h_{\text{water}} = P_{\text{air}} + 1000 \cdot 9.8 \cdot 5$$

$$P_2 = P_{\text{air}}$$

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

$$\downarrow$$

$$P_1 - P_2 = 1000 \cdot 9.8 \cdot 5 = \frac{1}{2} \cdot 1000 \cdot v_2^2$$

$$\Rightarrow v_2^2 = 98 \Rightarrow v_2 = 9.90 \frac{\text{m}}{\text{s}}$$

10. Alyssa went to her outside faucet to fill a 0.032 m^3 bucket with water to wash her car. Water exits with a speed of 0.64 m/s . The radius of the faucet is 0.0075 m . How long does it take to fill the bucket completely? (Assume that the water is non-viscous.)

- a) 9.0 s
 b) 17.0 s
 c) 190 s
 d) 280 s
 e) 890 s

$$V = 0.032 \text{ m}^3 = \frac{\Delta V}{\Delta t} \Delta t$$

$$\frac{\Delta V}{\Delta t} = A v = \pi r^2 v$$

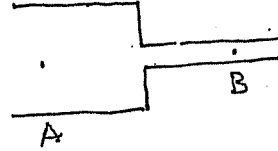
$$= \pi (0.0075)^2 \cdot 0.64$$

$$\text{So } 0.032 = \pi (0.0075)^2 \cdot 0.64 \cdot \underline{\underline{\Delta t}}$$

$$\Delta t = 283 \text{ sec}$$

11. The density of the liquid flowing through the horizontal pipe in the drawing is 1500 kg/m^3 . The speed of the fluid at point A is 5.5 m/s while at point B it is 8.0 m/s . What is the difference in pressure, $(P_B - P_A)$, between points B and A?

- a) $+3.8 \times 10^3 \text{ Pa}$
 b) $-1.9 \times 10^3 \text{ Pa}$
 c) $+5.0 \times 10^4 \text{ Pa}$
 — d) $-2.5 \times 10^4 \text{ Pa}$
 e) $-7.6 \times 10^5 \text{ Pa}$



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

$$v_A = 5.5 \text{ m/s}$$

$$v_B = 8.0 \text{ m/s}$$

$$P_A + \frac{1}{2} \rho v_A^2 = P_B + \frac{1}{2} \rho v_B^2$$

$$P_B - P_A = \frac{1}{2} \rho (v_A^2 - v_B^2) = \frac{1500}{2} (5.5^2 - 8.0^2) \\ = -2.5 \times 10^4 \text{ Pa}$$

12. The pressure of an ideal gas is doubled during a process in which the energy lost as heat by the gas equals the work done on the gas. As a result, the volume is:

- a) doubled
 — b) halved
 c) unchanged
 d) more information is needed to answer
 e) the process is impossible

$$P_1$$

$$P_2 = 2P_1$$

$$Q_{\text{LOST}} = W_{\text{ON GAS}}$$

$$U_i + Q^{\text{ADD}} + W^{\text{ON}} = U_f$$

$$U_i - Q^{\text{LOST}} + W^{\text{ON}} = U_f \Rightarrow U_i = U_f$$

$$\alpha \quad \frac{3}{2} nRT_i = \frac{3}{2} nRT_f$$

$$(\text{Since } pV = nRT)$$

$$\alpha \quad P_i V_i = P_f V_f \\ P_i V_i = 2P_i V_f$$

$$\boxed{V_f = \frac{1}{2} V_i}$$

13. A monatomic ideal gas has molar specific heat C_p at constant pressure. When the temperature of n moles of the gas is increased by ΔT the increase in the internal energy of the gas is:

- a) $nC_p\Delta T$
 b) $n(C_p + R)\Delta T$
 — c) $n(C_p - R)\Delta T$
 d) $n(2C_p + R)\Delta T$
 e) $n(2C_p - R)\Delta T$

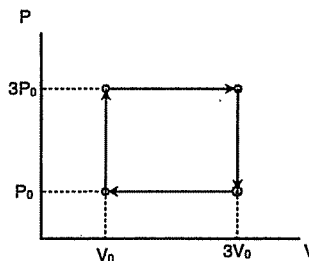
$$C_p = \frac{5}{2}R \rightarrow C_p - R = \frac{3}{2}R$$

$$U = \frac{3}{2}nRT$$

$$\Delta U = \frac{3}{2}nR\Delta T = n(C_p - R)\Delta T$$

14. An ideal gas is taken through the cycle shown in the figure. What is the net amount of heat that flows into the gas in each cycle?

- a) $8P_0V_0$
 b) $-8P_0V_0$
 — c) $4P_0V_0$
 d) $-4P_0V_0$
 e) zero



$$W^{\text{BY GAS}} = \text{AREA} = 2P_0 \cdot 2V_0 = 4P_0V_0$$

$$\text{cycle} \rightarrow \Delta U = 0$$

$$U_i + Q^{\text{ADD}} + W^{\text{ON}} = U_f$$

becomes

$$Q^{\text{ADD}} + W^{\text{ON}} = 0$$

$$\text{or } \boxed{Q^{\text{ABS}} = W^{\text{BY}} = 4P_0V_0}$$

15. An inventor claims to have a heat engine that has an efficiency of 40% when it operates between a high temperature reservoir of 150° C and a low temperature reservoir of 30° C. This engine:

- a) violates more than one of the laws of thermodynamics
- b) violates only the first law of thermodynamics
- c) violates only the second law of thermodynamics
- d) violates only the third law of thermodynamics
- e) does not violate any of the laws of thermodynamics

$$\begin{aligned} \text{CARNOT ENGINE : } \quad \eta &= 1 - \frac{T_c}{T_h} \\ &= 1 - \frac{303}{423} \\ &= 0.28 \end{aligned}$$

So violates 2nd law

No claim contradicts 1st law