EXAM III Sol Physics 121 F03 (Griffin)

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Exam III: Physics 121 F03
December 5, 2003

Exam III, Part A: Multiple Choice

This Part A of Exam III consists of 8 problems worth 10 points each and comprises 67% of the full exam. For each problem fill in the circle next to the letter of your chosen answer on the NCS answer sheet using a #2 pencil, making sure that the number of the line corresponds to the number of the problem you are answering. There is only one correct answer for each problem, and no subtractions will be made for wrong answers. Use only lines 1 through 8 on the NCS sheet.

1. One kilogram of a certain material is a cube with each edge 45.4 mm in length. What is the density of the material, most nearly?

a. 21.5 g/cm^3
b. 19.3 g/cm^3
c. 16.9 g/cm^3
d. 13.6 g/cm^3
e. 10.7 g/cm^3

$\rho = M/V = 1\,kg/(.0454)^3 m^3 = 10^3 gm/(4.54)^3 cm^3$

$\boxed{\rho = 10.68\ gm/cm^3}$

e is correct.

2. At what depth under the surface of a lake would the absolute pressure be eight times the atmospheric pressure at the surface? (1 atm = 1.01 x 10^5 Pa; 1 Pa = $1N/m^2$)

a. 1.00 m
b. 9.80 m
c. 10.3 m
d. 32.2 m
e. 72.1 m

$P_{H_2O} = \rho_{H_2O}\, g\, h$ where h is depth below surface

$P_{TOT} = P_{ATM} + P_{H_2O} = 8\, P_{ATM} \Rightarrow P_{H_2O} = 7\, P_{ATM}$

$P_{TOT} = 8\, P_{ATM}$ at depth h such that

$P_{H_2O} = 7\, P_{ATM} = \rho_{H_2O}\, g h \Rightarrow h = \dfrac{7(1.01)10^5}{10^3\,(9.8)}$

Since $\rho_{H_2O} = \dfrac{1gm}{cc} = \dfrac{10^6 gm}{m^3} = \dfrac{10^3 kg}{m^3}$: $\boxed{h = 72.14\ m}$

e is correct

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3. Two ideal gases, X and Y, are thoroughly mixed and at thermal equilibrium in a single container. The molecular mass of X is 9 times that of Y. What is the ratio of root-mean-square velocities of the two gases, $v_{X, rms}/v_{Y, rms}$?

a. 9/1
b. 3/1
c. 1/1
d. 1/3
e. 1/9

At same T AVG KE is same for 2 types

1 molecule: $\frac{1}{2} m_X v_X^2 = \frac{1}{2} m_Y v_Y^2$

So that $v_X^2 = \frac{m_Y}{m_X} v_Y^2$

$(v_X)_{RMS} = \sqrt{\frac{m_Y}{m_X}} (v_Y)_{RMS}$

ratio $\boxed{= \sqrt{1/9} = 1/3}$

d is correct

4. If the temperature of ideal gas is increased from 30 °C to 330 °C while its volume is doubled, the average kinetic energy of a molecule would increase (approximately) by a factor of:

a) 11.0 times; b) 4.0 times; c) 3.3 times; d) 2.0 times; e) 1.0 times.

Avg KE $= \langle \frac{1}{2} m v^2 \rangle_{AVG} = \frac{3}{2} k_B T_A$

Then increase from $T_i = 273 + 30 = 303K$

to $T_f = 330 + 273 = 603K$

increases $\langle KE \rangle$ by factor $\frac{603}{303} = 1.99$ times

$\boxed{\text{d is correct}}$

5. Approximately how much energy is required to change a 1.0 gm ice cube from ice at -0.5°C to steam at 100.5 °C? (Assume that the specific heats are 0.5, 1.0, and 0.5 cal/gm- ° C, for ice, water and steam respectively, and that the latent heats are 80 and 540 cal/gm for fusion and vaporization, respectively.)

a) 1 cal; b) 81 cal; c) 101 cal; d) 641 cal; e) 721 cal.

(i) $(0.5)\cdot(0.5^\circ) = 0.25$ cal — to raise temp of ice to 0°C
(ii) 80 cal $= L_f = 80.$ — to convert ice to H_2O Liquid
(iii) $(100^\circ)\cdot 1 = 100.$ — to raise H_2O temp to 100°C
(iv) 540 cal $= L_V$ 540 — " convert Liq H_2O to Steam Vapor
(v) $(0.5)(0.5^\circ) = .25$ cal — to raise Steam Temp to 100.5°C

Total Heat Energy $= 720.5$ cal

e is correct

6. Measurements on two stars indicate that Star X has a surface temperature of 1400K and Star Y has a surface temperature of 3330K. If both stars have the same radius, what is the ratio of the luminosity (total radiated power output) of Star Y to the luminosity of Star X? (Both stars can be considered to be ideally black body radiators with an emissivity of 1.0.) The ratio is, most nearly

a) 2; b) 4; c) 8; d) 16; e) 32.

$P = \sigma e A T^4$ (Stefan Boltzmann Law for Radiant Power)

$$\frac{P_y}{P_x} = \frac{\cancel{\sigma} \cancel{e_y} \cancel{A_y} T_y^4}{\cancel{\sigma} \cancel{e_x} \cancel{A_x} T_x^4} = \frac{T_y^4}{T_x^4} = \left(\frac{3330}{1400}\right)^4 = 32.01$$

e is correct.

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7. A hypothetical heat engine receives 8 000 J of heat from its combustion process and loses 1 500 J through the exhaust and 500 J though friction. What is its efficiency, approximately?

a. 93.8%
b. 81.2%
c. 74.9%
d. 25.0%
e. 18.7%

$$e = \frac{8000 - (1500+500)}{8000} = .75 = 75\%$$

(C) is correct

8. One kilogram of boiling water at 1.00 atm. (boiling point = 100 °C) is heated reversibly until all the water vaporizes. What is its change in entropy most nearly? (For water, the latent heat of vaporization is $L_v = 2.26 \times 10^6$ J/kg.)

a. 22 600 J/K
b. 8 280 J/K
c. 6 060 J/K
d. 3 030 J/K
e. 1 515 J/K

$$\Delta S = Q/T = \frac{2.26 \times 10^6 \frac{J}{kg} \cdot (1\,kg)}{373\,K} = 6100\ J/K$$

since $Q = 1\,kg \times L_v$

$T = 373\,K = 100° + 273°$

$$\boxed{\Delta S = 6100\ J/K}$$

(C) is correct

Ex III, Part B Physics 121 F03 (Griffin)

Printed Family Name:________________________ and Student I. D. No:________________

Every student must complete the above identifications on pages 7 and 9!

Exam III: Physics 121 F03
October 31, 2003

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The following 4 problems (9, 10, 11, 12) worth 10 points each will be fully graded and partial credit will be given for incomplete solutions. For full credit, you must show that you understand the physics; the answer alone is not enough.

9. One way to heat a gas is to compress it. A gas at 1.00 atm. at 27.0° C is compressed to one eighth of its original volume, and it reaches 40.0 atm. pressure. Obtain and evaluate an expression for its new temperature.

Apply $PV = nRT$ to initial & final states and take ratios

to get $\frac{T_f}{T_i} = \frac{nRT_f}{nRT_i} = \frac{P_f V_f}{P_i V_i} = \frac{(40)}{(1)} \cdot \frac{1}{8} = 5$

$$\boxed{T_f = 5T_i = 5(273+27) = 1500\,K}$$

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10. Twenty grams of a solid at 70 °C is placed in 50 grams of a water at 29 °C in a thermally isolated container. Thermal equilibrium is reached at 30 °C Obtain an expression for the specific heat of the solid, and evaluate its numerical value in cal/gm-°C.

Cons of Energy ⇒ Heat out of Solid = Heat into H_2O.

Let C_S = Sp heat of solid: $C_S(20)(70-30) = 50\cdot(1)(30-29)$

(& Recall $c_{H_2O} = 1$ cal/gm °C)

$$C_S = \frac{50(1)(1)}{(20)(40)} = \boxed{0.0625 \frac{\text{cal}}{\text{gm °C}}}$$

Printed Family Name:______________________________ and Student I.D. No:______________

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(Part B, continued) The following are fully graded problems. Show enough work on this sheet to show that you understand the process. For these fuly graded problems, the answer is not enough. Ask for extra paper if needed.

11. Three moles of an ideal monatomic gas are initially in state A at pressure, volume, and temperature, (P_0, V_0, T_0), respectively. An isovolumetric heating raises the temperature from T_o to $T_B = 5T_o$ along path AB of Fig 11. Then an isothermal expansionalong path ~~BA~~ BC carries the system to the state C: (P_C=P_o, V_C, T_C=T_B=5T_o). Finally an isobaric compression returns the system to its initial state, A, along the path CA in Fig 11.

a. (5 points.) Obtain an expression for P_B (in terms of P_o).

$$\frac{P_B \cancel{V_0}}{P_0 \cancel{V_0}} = \frac{\cancel{n}\cancel{R} T_B}{\cancel{n}\cancel{R} T_0} = 5$$

$$\boxed{P_B = 5P_0}$$

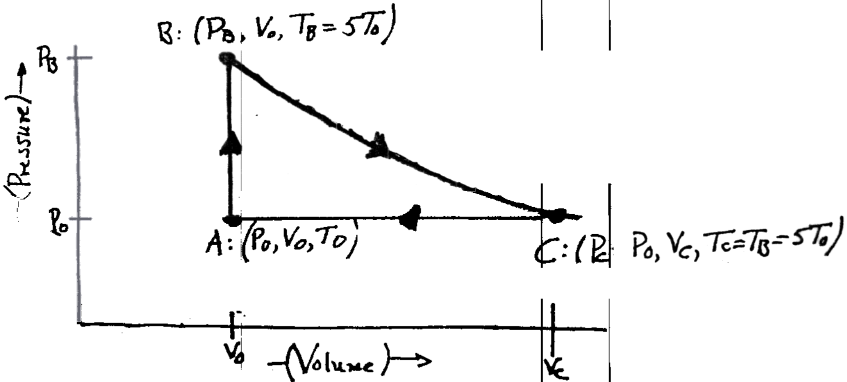

Fig. 11.

b. (5 points.) Obtain an expression for V_C (in terms of P_o and V_o).

$$P_0 V_C = nRT_C = nRT_B = nR(5T_0)$$

$$P_0 V_0 = nRT_0$$

Then Ratio yields $\frac{\cancel{P_0} V_C}{\cancel{P_0} V_0} = \frac{\cancel{n}\cancel{R} \cdot 5\cancel{T_0}}{\cancel{n}\cancel{R}\cancel{T_0}} = 5 \Rightarrow \boxed{V_C = 5V_0}$

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12. Recall that the internal energy of an ideal monatomic gas is U = 3nRT/2. Then for the processes of problem 11 above,

a) (5 points.) Obtain an expression (in terms of P_o and V_o) for the heat energy entering the system in the process which carries it from A to B.

For A→B: $\Delta U = Q^{IN} + W^{IN} = Q^{IN} + 0$ since $\Delta V_{AB} \equiv 0$.

$\Delta U = \frac{3}{2} nRT_B - \frac{3}{2} nRT_A = \frac{3}{2} nRT_0(5-1) = 6nRT_0$

and use Ideal Gas Law $P_0V_0 = nRT_0$ to find

$$\boxed{\Delta U = 6P_0V_0}$$

b) (5 points.) Given that $V_C = 5V_o$, obtain an expression (in terms of P_o and V_o) for the heat energy leaving the system during the process which carries it from C to A.

For C → A.

$\Delta U = Q^{IN} + W^{IN} = \frac{3}{2} nR(T_A - T_C) = \frac{3}{2} nRT_0(1-5) = -6nRT_0$

$6P_0V_0 = nRT_0 \Rightarrow$ $\Delta U = -6P_0V_0$.

Also $W^{IN} = -P_0 \Delta V_{CA} = -P_0(V_0 - 5V_0) = +4P_0V_0$

Then $Q^{IN} = \Delta U - W^{IN} = -6P_0V_0 - 4P_0V_0$

$Q^{IN} = -10(P_0V_0)$

Then Heat leaving system in C→A is

$$\boxed{Q^{OUT} = -Q^{IN} = +10P_0V_0}$$

****** End of Exam III******