Fall 2007 RED Barcode Here

Physics 105, sections 1 and 2

Exam 4 Please write your CID_____

Colton 2-3669

3 hour time limit. One 3″ × 5″ <u>handwritten</u> note card permitted (both sides). Calculators permitted. No books.

<u>Constants/some formulas:</u>

$g = 9.80$ m/s^2
$G = 6.67 \times 10^{-11}$ N·m^2/kg^2
Mass of Sun = 1.991×10^{30} kg
Mass of Earth = 5.98×10^{24} kg
Radius of Earth = 6.38×10^{6} m
Radius of Earth's orbit = 1.496×10^{11} m

$I_{pt\ mass} = mR^2$
$I_{sphere} = (2/5)\ mR^2$
$I_{hoop} = mR^2$
$I_{disk} = (1/2)\ mR^2$
I_{rod} (center) = $(1/12)\ mL^2$
I_{rod} (end) = $(1/3)\ mL^2$

Quadratic formula: $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Keep four significant digits throughout your calculations; do not round up to less than four. When data is given, assume it has at least four significant digits. For example "15 meters" means 15.00 meters.

You are strongly encouraged to **write your work on the exam pages and circle the correct answer.** Of course also **record your final answers on the bubble sheet**.

→Write your CID above upper right corner. Did you do this ________? You won't get your exam back without writing your CID.

Problem 1. A NASA training pool filled with water is 50 m long and 50 m wide, and 4 m deep. The *absolute* pressure at the bottom of the pool is __________ Pa.

a. less than 109 kPa
b. 109 – 119
c. 119 – 129
d. 129 – 139
e. More than 139 kPa

$P = P_0 + \rho g h$ **= 1.01e5 + 1000*9.8*4 = 140200 Pa**

Problem 2. The pool is now half drained, and the top half is filled with a light oil (density 400 kg/m^3). The *absolute* pressure at the bottom of the pool is now:

a. less than 110 kPa
b. 110 – 118
c. 118 – 126
d. 126 – 134
e. More than 134 kPa

Oil and water:

$$P_1 = P_0 + \rho_1 g h_1$$
$$P_2 = P_1 + \rho_2 g h_2$$
$$P_2 = P_0 + \rho g h_1 + \rho g h_2$$

= 1.01e5 + 400*9.8*2 + 1000*9.8*2 = 128440 Pa

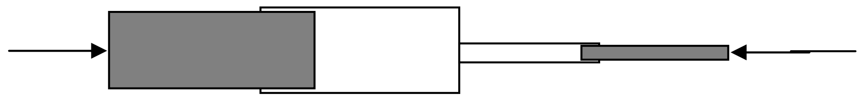
Problem 3. When divers come up from the bottom of the pool, they experience a buoyancy force in the oil that is _________ the buoyancy force they felt in the water.

a. greater than
b. less than
c. the same as

The density of the fluid they displace is less, so buoyant force is less.

Problem 4. Two pistons push on hydraulic fluid at rest. The diameter of the left piston is 5 cm. The diameter of the right piston is 1.3 cm. If the force on the left is 1000 N, the force on the right will be _________ N.

a. Less than 66 N
b. 66 – 67
c. 67 – 68
d. 68 – 69
e. More than 69 N



$$P = \frac{F_1}{A_1} = \frac{F_2}{A_2}$$

Pressure is constant

$$F_2 = F_1 \frac{A_2}{A_1} = 1000 \frac{r_2^2}{r_1^2}$$

1000*1.3^2/5^2 = 67.60 N

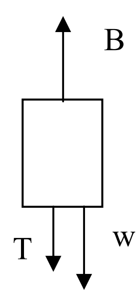
Problem 5. When an object is floating at rest, the buoyant force is _____ the object's weight.

a. greater than
b. less than
c. the same as

Choice c. (from Newton's 2nd Law, object is in equilibrium)

Problem 6. A log of wood of mass 200 kg has a density of 320 kg/m^3. In order to hold the log completely under the water, you use a chain anchored to the bottom of the lake. The tension in the chain is _______ N. Hint: find the volume of the log first.

a. Less than 4130 N
b. 4130 – 4150
c. 4150 – 4170
d. 4170 – 4190
e. 4190 – 4210
f. More than 4210 N



$V_{log} = m_{log} / \rho_{wood}$ = 200 kg/320 kg/m^3 = 0.625 m^3
B – w – T = 0. or T = B - w.
$B = \rho_{fluid} V_{displaced}$ g=1000*0.625*g=6125N
w = mg = 200kg * g = 1960 N
T = B – w = 4165 N

Problem 7. The Empire State building (440 m tall) has a steel frame. If the lowest temperature for a given year was in New York City was -8 °C, and the highest temperature was 40 °C, the change in height of the building over the year was __________ m. The thermal expansion coefficient of steel is 11×10^{-6}/ °C.

a. Less than 0.20 m
b. 0.20 – 0.22
c. 0.22 – 0.24
d. 0.24 – 0.26
e. More than 0.26 m

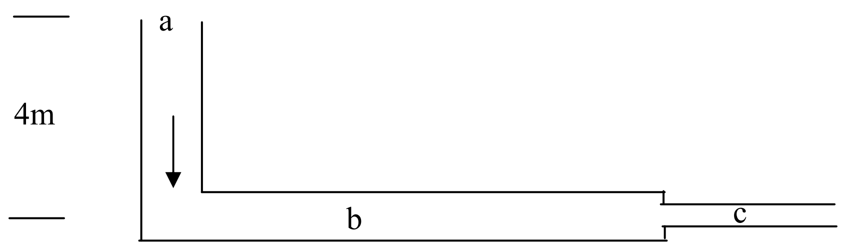
$\Delta L = \alpha L_0 \Delta T$ **= 11 × 10^{-6}/ °C *440 m *(48 °C) = 0.2323 m**

Problem 8. As the building expands on a hot day, a hole drilled in the steel frame:

a. gets bigger
b. gets smaller
c. stays the same

Every size of the structure expands the same fraction, including holes (like a photo enlarger). Choice a

Water in a closed pipe (0.05 m radius) flows from a top floor (position a), at a speed of 3 m/s, to a lower floor 4 m below. It later enters a narrower pipe (0.02 m radius, position c). Neglect any friction.



Problem 9. The pressure is greatest at point:

a. a
b. b
c. c
d. all the same

Pressure is greatest at greater depths and slower speeds. Position b.

Problem 10. The water speed is greatest at position:

a. a
b. b
c. c
d. all the same

Water speed is greatest where area is least. Position c

Problem 11. The absolute pressure at position b is 2.00 x10^5 Pa. The absolute pressure at position a is:

a. Less than 119 kPa
b. 119 – 129
c. 129 – 139
d. 139 – 149
e. 149 – 159
f. More than 159 kPa

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

v is the same between a, b so

$$P_a + \rho g y_a = P_b$$

$$P_a = P_b - \rho g y_a$$

= 2e5 – 1000*g*4 = 160800 Pa.

Problem 12. The absolute pressure at position c is:

a. Less than 28.5 kPa
b. 28.5 – 26.8
c. 26.8 – 27.8
d. 27.8 – 28.8
e. 28.8 – 29.8
f. More than 29.8 kPa

vertical position y is same between b, c, but speeds are different.
$A_a v_a = A_c v_c$ $v_c = v_a (A_a \backslash A_c) = v_a (r_a \backslash r_c)^2$ = 3 * (5cm/2cm)^2=18.75 m/s

$$P_a + \frac{1}{2}\rho v_a^{\ 2} = P_c + \frac{1}{2}\rho v_c^{\ 2}$$

$$P_c = P_a + \frac{1}{2}\rho v_a^{\ 2} - \frac{1}{2}\rho v_c^{\ 2}$$ **= 2e5 + 1/2*1000*(3^2 – 18.75^2) = 28719 Pa**

Problem 13. How long will it take for 5 m^3 of water to flow past any point?

a. Less than 205 s
b. 205 – 215 s
c. 215 – 225
d. 225 – 235
e. 235 – 245
f. Longer than 245 s

volume flow rate: VFR = Av = πr^2 v = pi*(0.05)^2 *3 = 0.0236 m^3/s. So it takes 5/0.0235 = 212.2 sec to get 5 m^3.

Problem 14. Two vandals shoot bullets at a water tower, at the same depth of water. The second bullet makes a slightly larger hole. The hole that has the greatest velocity of water (m/s) flowing out of it is:

a. the large hole
b. the small hole
c. neither; same velocity

Same velocity (but different VFRs). Water from both "falls" the same distance, so it's going the same speed. Or $\frac{1}{2}\rho v_1^{\ 2} = \rho g y_2$, because the pressure is 1 atm at the top and just outside of the hole.

Problem 15. Imagine holding two identical bricks submerged in water. Brick A is just beneath the surface of the water, while brick B is at a greater depth. The force needed to hold brick B in place is __________ the force required to hold brick A in place.

a. larger than
b. smaller than
c. the same as

Pressure depends on depth, but the difference in pressure that gives the buoyant force depends only on the volume of the object submerged.

Problem 16. A 45 g piece of metal at 100°C is put in 100 g of water at 25°C. They are insulated so no heat transfers to/from their surroundings. The water and metal come to equilibrium at 35°C. What was the specific heat of the metal? (c_{water} = 4186 J/kg°C)

a. Less than 1500 J/kg°C
b. 1500 – 1570
c. 1570 – 1640
d. 1640 – 1710
e. 1710 – 1780
f. More than 1780 J/kg°C

$Q_{lost\ by\ metal} = Q_{gained\ by\ water} \rightarrow (mc\Delta T)_{metal} = (mc\Delta T)_{water}$
$45g \times c_{metal} \times 65°C = 100g \times 4186$ J/kg°C $\times 10°C \rightarrow c_{metal}$ =1431 J/kg°C

Problem 17. Nitrogen molecules have a molecular weight of 28 g/mole. Oxygen molecules have a molecular weight of 32 g/mole. How much faster is an average nitrogen molecule going in a typical room (1 atm, 20°C) than an average oxygen molecule?

a. 0-4% faster
b. 4-8%
c. 8-12%
d. 12-16%
e. 16-20%
f. more than 20%
g. none of the above—the oxygen molecule is going faster.

$\frac{1}{2} mv_{ave}$^2 = $3/2\ k_BT \rightarrow$ v = sqrt($3k_BT$/m)
Ratio: k_B and T are the same so v_{N2}/v_{O2} = sqrt(m_{02}/m_{N2}) = 1.069.
Therefore v_{N2} is 6.9% faster than V_{O2}

Problem 18. How much translational kinetic energy does an average nitrogen molecule in the room possess?

a. less than 6.5×10^{-21} J
b. 6.5 – 7.5
c. 7.5 – 8.5
d. 8.5 – 9.5
e. more 9.5×10^{-21} J

$KE_{ave} = 3/2\ k_BT$ = 6.065E-21 J

Problem 19. You put can of water into a fire. The can heats up, and the water remains liquid. Neglecting the tiny change in volume due to thermal expansion, the change in the internal energy of the water is _________ the heat absorbed by the water.

a. greater than
b. less than
c. the same as

$\Delta U = Q_{added} + W_{on} \rightarrow$ if $W_{on} = 0$ (because no volume change), then $\Delta U = Q_{added}$

Problem 20. Actual gases follow the ideal gas law to a good approximation:

a. at high temperatures
b. at low temperatures
c. always

The ideal gas law works well at high temperature because velocities are too high for molecules to stick to each other(does not work when the gas gets close to condensing into a liquid). Choice a

Problem 21. A typical incandescent light bulb puts out 50 W of radiation power. The tungsten filament is at a temperature of 2800 K, and the emissivity of the filament is 0.42. What is the surface area of the filament?

a. Less than 2.5×10^{-5} m^2
b. 2.5 – 3
c. 3 – 3.5
d. 3.5 – 4
e. 4 – 4.5
f. More than 4.5×10^{-5} m^2

$P = e\sigma AT^4 \rightarrow$ 50W = 0.42 × 5.67E-8 W/m^2·K^4 × A × (2800K)^4 $\rightarrow$ A = 3.416E-5 m^2

Problem 22. 151 g of water at 30°C is poured onto a 1400 g iron frying pan that has been heated to 180°C, removed from the stove, and placed in an insulated box that also keeps the steam inside. Everything ends up at 100 °C, including some steam. How much of the water gets vaporized? $L_{vaporization}$ of water = 2.26×10^6 J/kg; c_{iron} = 448 J/kg°C; c_{water} = 4186 J/kg°C

a. Less than 2.1 g
b. 2.1 – 2.4
c. 2.4 – 2.7
d. 2.7 – 3.0
e. 3.0 – 3.3
f. More than 3.3 g

$Q_{\text{lost by frying pan}} = Q_{\text{gained by water}} \rightarrow (mc\Delta T)_{pan} = (mc\Delta T)_{\text{water to }100°} + m_{\text{that gets vaporized}} L_v$
1400 g × 448 J/kg°C × 80°C = 151g × 4186 J/kg°C × 70° + $m_{\text{that gets vaporized}}$ × 2.26×10^6 J/kg
$\rightarrow$ $m_{\text{that gets vaporized}}$ = 2.62 g

Problem 23. 1.53 kg of an ideal gas exists in a 1.18 m^3 container at 273 K and 2 atm absolute pressure. What is the molar mass of the gas?

a. Less than 13.5 g/mole
b. 13.5 – 14.5
c. 14.5 – 15.5
d. 15.5 – 16.5
e. More than 16.5 g/mole

PV = nRT, and n = 1.52kg/MolarMass
$\rightarrow$ 2.02E5 Pa × 1.18m^3 = (1.52kg/MolarMass) × 8.31 J/mol·K × 273K
$\rightarrow$ MolarMass = 0.0146 kg/mol

Problem 24. Which has more effect on the pressure a gas exerts:

a. doubling the number of molecules
b. doubling the mass of each molecule
c. they have the same effect

PV= nRT → doubling n will double P; doubling the mass of each molecule has no effect (they move slower and hit with more mass, but these two effects cancel).

Problem 25. A coal power plant produces 50 megawatts of usable power (mega = 10^6). To do this, it burns coal at 550°C and expels its waste heat into a nearby river at 20°C. What is the theoretical maximum efficiency of the plant?

a. Less than 62 %
b. 62 – 63
c. 63 – 64
d. 64 – 65
e. More than 65 %

$e_{max} = e_C = 1 - T_c/T_h$ = 1 – 293K/823K = 64.4%

Problem 26. The actual efficiency of the plant in the previous problem is 40%. How much heat is expelled to the river each second?

a. Less than 58 J
b. 58 – 62
c. 62 – 66
d. 66 – 70
e. 70 – 74
f. 74 – 78
g. More than 78 J

$e = |W_{net}|/Q_h$ → each second W_{net} = 50E6 J, so $Q_h = |W_{net}|/0.4$ = 125 MJ.
$Q_l = Q_h - |W_{net}|$ = 75 MJ

Problem 27. An office window is 3 m^2 in area. If it is a single-pane window with 1 cm thick glass, at what rate would heat would be lost from the room through the window in the winter, when T_{inside} = 21°C and $T_{outside}$ = -9°C? (The thermal conductivity of glass is 0.84 W/m·°C.)

a. Less than 7500 J/s
b. 7500 – 7600
c. 7600 – 7700
d. 7700 – 7800
e. Faster than 7800 J/s

Q/time = kAΔT/L = 0.84 W/m·°C × 3 m^2 × 30°C /0.01 m = 7560 W

Problem 28. If no heat is added to a system, its temperature cannot be increased:

a. True
b. False

You can do work on it to increase the internal energy. The "setting a wad of cotton on fire" demo was an excellent counterexample. Choice b.

Problem 29. You have 30 moles of a monatomic ideal gas at 400K. You expand the gas from 1 m^3 to 3 m^3 in an isothermal process, and in the expansion the gas does 109,554 J of work. Was heat added or removed from the gas during this process?

a. added
b. removed
c. neither; no heat was exchanged

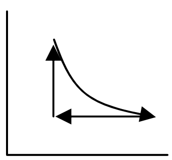
$\Delta U = Q + W_{on}$ → $Q = \Delta U - W_{on}$ which = $-W_{on}$, since $\Delta U = 0$ for an isothermal process
$W_{on\ gas}$ = negative, since the gas expanded, so Q = positive, i.e. heat was added

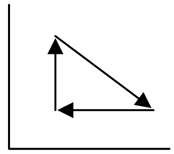
Problem 30. What was the original pressure of the gas?

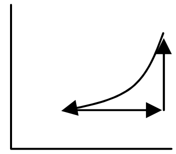
a. Less than 93.4 kPa
b. 93.4 – 95.4
c. 95.4 – 97.4
d. 97.4 – 99.4
e. More than 99.4 kPa

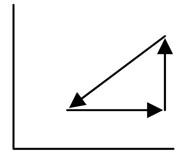
PV = nRT → P (1m3) = 30 mol (8.314 J/mol·K) (400K) → P=99768 Pa

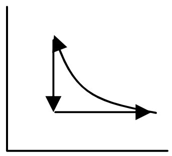
Problem 31. After the isothermal expansion in the problem above, the gas is compressed at constant pressure back to 1 m^3, after which the gas is heated up at constant volume until it reaches the original pressure again. Which of the following diagrams best represents the total process on a standard P-V diagram?

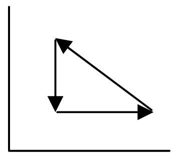
1) 

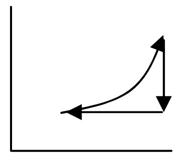
2) 

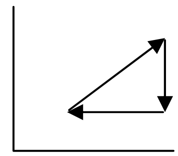
3) 

4) 

5) 

6) 

7) 

8) 

The only choice that is an isothermal expansion, then constant P compression, then heating up at constant V, is #1.

Problem 32. What was the $|W_{net}|$ done by the gas during the whole cycle?

a. Less than 41.7 kJ
b. 41.7 – 43.7
c. 43.7 – 45.7
d. 45.7 – 47.7
e. More than 47.7 kJ

First solve for P_b; one way is to use a ratio: $\frac{P_bV_b}{P_aV_a}=\frac{nRT_b}{nRT_a}$ → **$P_b = P_a V_a/V_b$ = 33240 Pa.**

Then $|W_{net}| = |W_{a\ to\ b}| - |W_{b\ to\ c}|$ = 109554 J – 33240 Pa (3 m^3 – 1 m^3) = 43074 J.