Fall 2008 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>Fundamental constants:</u>

$g = 9.80$ m/s^2

$G = 6.67 \times 10^{-11}$ N·m^2/kg^2

$k_B = 1.381 \times 10^{-23}$ J/K

$N_A = 6.022 \times 10^{23}$

$R = k_B \cdot N_A = 8.314$ J/mol·K = 0.08206 liter·atm/mol·K

$\sigma = 5.67 \times 10^{-8}$ W/m^2·K^4

<u>Conversion factors</u>

1 inch = 2.54 cm

1 m^3 = 1000 L

1 atm = 1.013×10^5 Pa = 14.7 psi

1 cal = 4.186 J

$$T_F = \frac{9}{5} T_C + 32$$

$$T_K = T_C + 273.15$$

Note: all material constants that you should need for the exam are given here (not in the problems).

<u>Material properties</u>

Density of water: 1000 kg/m^3

Density of air: 1.29 kg/m^3

Young's modulus of steel: 20×10^{10} N/m^2

Linear expansion coefficient of brass: 19×10^{-6} /°C

Specific heat of water: 4186 J/kg·°C

Specific heat of ice: 2090 J/kg·°C

Specific heat of steam: 2010 J/kg·°C

Specific heat of aluminum: 900 J/kg·°C

Latent heat of melting (water): 33×10^5 J/kg

Latent heat of boiling (water): 2.26×10^6 J/kg

Thermal conductivity of aluminum: 238 J/s·m·°C

Average molar mass of air molecules: 29 g/mole

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 pressure sensor inside a tub of water is oriented to read the amount of pressure pushing *down* on it. How does the reading change when the sensor is turned upside-down (kept at the same height)?

a. increases
b. decreases
c. stays the same

1. Pressure is exerted in all directions, like in the video we watched. Choice C.

Problem 2. Which exerts more pressure on the ground, a 15000 pound elephant with *four* circular feet (each 12 inches in diameter), or a 150 pound clown standing on *two* stilts (each 2 inches in diameter)?

a. elephant
b. clown
c. same

2. P=F/A → $P_{elephant}/P_{clown} = (15000/(4\pi 6^2))/(150/(2\pi 1^2)) = 1.38$, so $P_{elephant} > P_{clown}$ Choice A.

Problem 3. In the "collapsing can demo", why did the can collapse when the air was pumped out?

a. Too much sucking force pulling on the inside
b. Too much pressure from air on the outside

3. The force was applied by atmospheric pressure. Choice B.

Problem 4. How deep does a scuba diver have to dive before the pressure is 2 atm?

a. Less than 6.8 m
b. 6.8 - 7.8
c. 7.8 - 8.8
d. 8.8 - 9.8
e. 9.8 - 10.8
f. More than 10.8 m

4. $P=P_0+\rho gh$

2 atm=1 atm+(1000)(9.8)h

$(1 \text{ atm})(1.01*10^5 \text{ Pa/atm})=1000*9.8 \text{ h}$

h=10.31 m Choice E

Problem 5. A boat is on a lake. If an anvil (that sinks) is pushed from the boat into the water, will the overall water level of the lake rise, fall or stay the same? (compared to when the anvil was in the boat)

a. rise
b. fall
c. stay the same

5. In the boat, the anvil displaces its weight in water (Archimedes' Principle). Out of the boat, it merely displaces its own volume, which is less. Therefore, the water level falls. Choice B.

Problem 6. If a log (that floats) is pushed from the boat into the water, will the overall water level of the lake rise, fall or stay the same? (compared to when the log was in the boat)

a. rise
b. fall
c. stay the same

6. The log displaces its weight in water both places (because it floats). Choice C.

Problem 7. You make a 50 kg canoe out of a rectangular form: 2.2 m long by 0.7 m wide by 0.6 m deep. Assuming it doesn't tilt over, how much weight can you put in the canoe before it sinks?

a. Less than 830 kg
b. 830 - 840
c. 840 - 850
d. 850 - 860
e. 860 - 870
f. 870 - 880
g. More than 880 kg

7. $\sum F=0 \rightarrow B - (m+50)g=0$

$\rho_{water} vg=(m+50)g$

$m=(1000)(2.2*.7*.6) - 50$

=874 kg Choice F

Problem 8. The pressure above an airplane's wing is ___________ the pressure below the wing. (The airplane is flying at a constant elevation.)

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

8. Air above the wing travels faster → less pressure. (Thus generating "lift".) Choice B.

Problem 9. Which balloon will have the greatest relative change in volume when immersed in liquid nitrogen: one filled with helium, or one filled with air?

a. helium
b. air
c. same change

9. Like the demo in class, the *air* in the balloon will condense into liquid and have *very* little volume. The helium gas will shrink some, about 25% its original volume, but not nearly as much as the air. Choice B.

Problem 10. Actual gases follow the ideal gas law to a good approximation:

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

10. Gases are only "ideal" far from the condensing point. Choice A.

Problem 11. You mix some helium and neon gas together in the same container so they are at the same temperature. The average translational kinetic energy per helium atom is ____ the average kinetic energy per neon atom. (Neon atoms are more massive than helium atoms.)

a. greater than
b. less than
c. equal to

11. Equipartition Theorem: $KE=3/2k_BT$. Doesn't depend on mass. Choice C.

Problem 12. The fact that desert sand is very hot in the day and very cold at night is evidence that sand has a

a. low specific heat
b. high specific heat

12. $Q=mc\Delta T$ → a small c will allow temperature to change a lot for a given Q. Choice A.

Problem 13. The first law of thermodynamics is a statement of:

a. conservation of energy
b. conservation of (regular) momentum
c. conservation of angular momentum
d. conservation of mass/volume
e. none of the above

13. Choice A.

Problem 14. The 2nd law of thermodynamics is a statement of:

a. conservation of energy
b. conservation of (regular) momentum
c. conservation of angular momentum
d. conservation of mass/volume
e. none of the above

14. It's a statement of probability. Choice E.

Problem 15. It is possible to compress an ideal gas without increasing its temperature.

a. true
b. false

15. Sure—just remove the right amount of heat at the same time. Choice A.

Problem 16. A 10.4 N weight hangs from a 2 m long, 3 mm diameter steel wire. How much does the wire stretch?
a. Less than 0.011 mm
b. 0.011 - 0.012
c. 0.012 - 0.013
d. 0.013 - 0.014
e. 0.014 - 0.015
f. More than 0.015 mm

16. y=stress/strain=(F/A)/(ΔL/L)
$\Delta L = FL/AY = ((10.4)(2))/(\pi(.0015)^2(20*10^{10})) = 1.47*10^{-5}$m=.0147mm Choice E

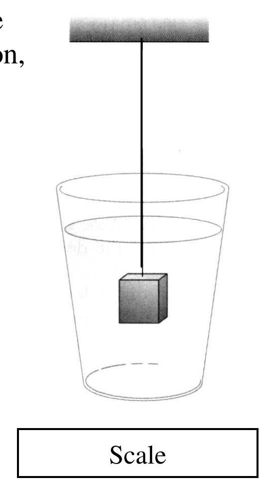
Problem 17. In an experiment with a brass ball and ring, the ring is heated to allow the ball to pass through. If the ball is 1.0000 cm in diameter and the hole in the ring has a diameter of 0.9992 cm, how hot (ΔT) does the ring need to be heated?
a. Less than 41° C
b. 41 - 42
c. 42 - 43
d. 43 - 44
e. 44 - 45
f. 45 - 46
g. More than 46° C

17. $\Delta L = \alpha L \Delta T$ hole in ring must increase by .0008 cm
$.0008 = (19*10^{-6})(.9992)\Delta T$ (cm units cancel out)
ΔT=42.1°C Choice C

Problem 18. Water in a closed pipe (5 cm in radius) flows at a speed of 3 m/s. How long will it take for 5 m^3 of water to flow past any point?
a. Less than 130 s
b. 130 - 150
c. 150 - 170
d. 170 - 190
e. 190 - 210
f. More than 210 s

18. Volume flow rate=A*velocity
Volume/Time=A*v→ time = Volume/(A*v)
$=5m^3/(\pi(.05m)^2*3m/s) = 212.2s$ Choice F

Problem 19. An open beaker of water is resting on a spring scale. A hanging mass is immersed in the water. The reading on the scale will _______. (A free-body diagram will be required for this situation, in problem 32.)
a. increase
b. decrease
c. stay the same



19. The Newton's 3rd Law partner force of the buoyant force pushes *down* on the *water* (because buoyant force pushes *up* on the *mass*). I.e. $F_{mass-water} = -F_{water-mass}$
Choice A

Problem 20. Same situation. The hanging mass is a 5 kg cube of metal, 10 cm on each edge. What will be the tension in the wire supporting the mass? (A free-body diagram will be required for this situation, in problem 32.)

a. Less than 39.5 N
b. 39.5 - 40.5
c. 40.5 - 41.5
d. 41.5 - 42.5
e. 42.5 - 43.5
f. 43.5 - 44.5
g. More than 44.5 N

20. $\sum F_{mass}=0 \rightarrow T+B-mg=0$

$T=mg-B$

$=5(9.8)-(1000)(.1)^3(9.8)$

$=39.2$ **N** **Choice A**

Problem 21. An old-fashioned 1 liter glass milk jug is "empty" (still has air inside), at 20° C. You seal it, then put it into a fire at 500° C. The jug does not burst. What is the final pressure in the jug?

a. Less than 2.6 atm
b. 2.6 - 2.7
c. 2.7 - 2.8
d. 2.8 - 2.9
e. 2.9 - 3.0
f. More than 3.0 atm

21. $P_1\cancel{V_1}/P_2\cancel{V_2}=\cancel{nR}T_1/\cancel{nR}T_2 \rightarrow P_2=P_1(T_2/T_1)$

$=1$ **atm(773K/293K)**

$=2.64$ **atm** **Choice B**

Problem 22. If instead of being totally empty the jug had one mole of water molecules in it (18 g), how much pressure would they exert after being vaporized? (The jug still does not break; neglect pressure from any air molecules left inside.)

a. Less than 60 atm
b. 60 - 61
c. 61 - 62
d. 62 - 63
e. 63 - 64
f. More than 64 atm

22. $PV=nRT \rightarrow P=nRT/V$

$=((1\ \text{mol})(8.31\ \text{J/mol*K})(773\ \text{K}))/.001\text{m}^3$

$=6.4*10^6\ \text{Pa}=63.6\ \text{atm}$ **Choice E**

Problem 23. Water at 100° C is cooled to 0° C. The same amount of heat loss that it took to cool the ice could be used to freeze what percentage of the water?

a. Less than 5%
b. 5 - 7
c. 7 - 9
d. 9 - 11
e. 11 - 13
f. More than 13 %

23. $Q=m_1c\Delta T \rightarrow$ **heat to cool** $(\Delta T=100)$ $Q=m_2L \rightarrow$ **heat to freeze**

$m_2L=m_1c\Delta T$

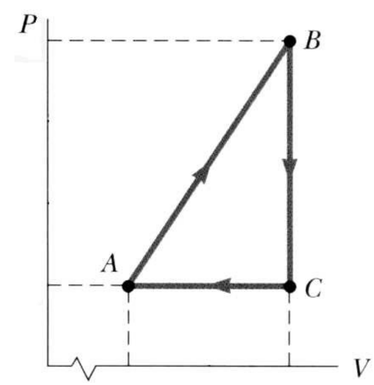
$m_2/m_1=((4186\text{J/kg*°C})(100\text{°C}))/33*10^5\text{J/kg}=.127=12.7\%$ **Choice E**

Problem 24. What mass of steam that is initially at 120° C is needed to warm 1500 g of water in a light insulated container from 30° C to 45° C?

a. Less than 28 g
b. 28 - 30
c. 30 - 32
d. 32 - 34
e. 34 - 36
f. 36 - 38
g. More than 38 g

24. $\mathbf{Q_{lost\ by\ steam} = Q_{gained\ by\ water}}$
$\mathbf{(mc\Delta T)_{steam} + mL + (mc\Delta T)_{water\ that\ was\ steam} = (mc\Delta T)_{water}}$
$\mathbf{m[(2010*20)+(2.26*10^6)+(4186*55)]=(1500g)(4186)(15)}$
m= 37.22 g **Choice F**

For the next three problems, consider the cyclic process described by the figure.



Problem 25. For A to B: is $W_{on\ gas}$ positive or negative?

a. positive
b. negative
c. neither ($W_{on\ gas} = 0$)

25. The gas expands, so $\mathbf{W_{by\ gas}}$**=positive.**
Therefore $\mathbf{W_{on\ gas}}$**=negative** **Choice B**

Problem 26. For C to A: does the internal energy increase or decrease?

a. increase
b. decrease
c. neither ($\Delta U = 0$)

26. The gas decreases in temp (goes "down the mountain"), therefore U decreases. **Choice B**

Problem 27. For B to C: is heat added or taken away from the gas? (Hint: think of the 1st Law.)

a. added
b. taken away
c. neither ($Q_{added} = 0$)

27. $\mathbf{\Delta U = Q_{added} - W_{on}}$
$\mathbf{Q_{added} = \Delta U - W_{on}}$ **ΔU negative since T decreases;** $\mathbf{W_{on}=0}$ **since no volume change**
=negative **Choice B**

Problem 28. You have 30 moles of a monatomic ideal gas at 400K. The gas expands from 1 m^3 to 3 m^3 in an *adiabatic* process; as the gas expands, the pressure decreases from 99.7 kPa to 15.98 kPa. How much work was done by the gas during the expansion? (Hint: start with the 1st Law.)

a. Less than 66 kJ
b. 66 - 68
c. 68- 70
d. 70 - 72
e. 72 - 74
f. 74 - 76
g. More than 76 kJ

28. $\mathbf{\Delta U = Q_{added} + W_{on}}$
$\mathbf{W_{on} = \Delta U - Q_{added}}$**;** $\mathbf{\Delta U = 3/2 nR\Delta T}$ **(monatomic ideal gas), Q=0(adiabatic)**
$\mathbf{W_{by} = |W_{on}| = 3/2(30)(8.31)(400 - T_f)}$**;** $\mathbf{T_f = P_f V_f / nR = 192.3K}$
$\mathbf{W_{by}}$**=77.67 kJ** **Choice G**

Problem 29. A power plant has an electrical power output of 800 MW (M = "mega", million) and operates with an efficiency of 35%. If the excess energy is carried away from the plant by a river with a mass flow rate of 2×10^6 kg/s, what is the rise in temperature of the flowing water?

a. Less than 0.16° C
b. 0.16 - 0.18
c. 0.18 - 0.20
d. 0.20 - 0.22
e. 0.22 - 0.24
f. 0.24 - 0.26
g. More than 0.26° C

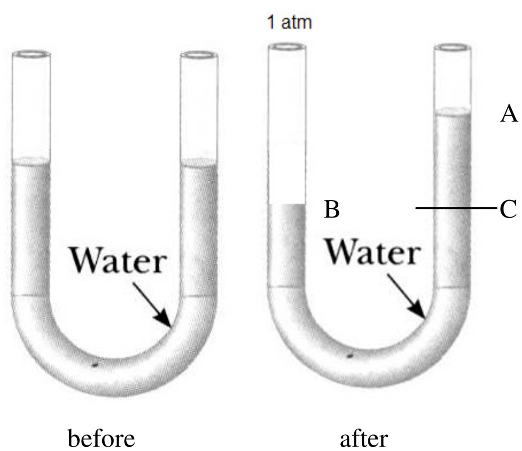
29. $e=|W_{net}|/Q_h=|W_{net}|/(|W_{net}|+Q_c)$ → (a little algebra) → $Q_c=|W_{net}|*(1-e)/e$
Q_c/time=$800*10^6$ J/s *((1-.35)/.35) = $1.486*10^9$ J/s
$Q=mc\Delta T$ → (Qc/time) = (m/time)$c\Delta T$
$1.486*10^9$ J/s = ($2*10^6$kg/s)(4186J/kg°C)ΔT
ΔT=0.177°C Choice B

Problem 30. You very foolishly decide to build the walls of your new house out of solid aluminum, 5 cm thick. As a result, in the wintertime heat leaks out like a sieve. How much money does this cost you each *day*? The inside temp is 70° F (21.1° C), the average outside temperature is 25° F (-3.9° C), and your new house has a surface area of 280 m^2. The gas company charges you $0.89 per "therm" ($1.055 \times 10^8$ J). Ignore heat loss through the ground and through radiation & convection effects.

a. Less than $19,000
b. $19K - 20K
c. $20K - 21K
d. $21K - 22K
e. $22K - 23K
f. $23K - 24K
g. $24K - 25K
h. More than $25,000

30. Q/time=$kA\Delta T/L$=((238J/s*m*°C)(280m^2)(21.1-(-3.9)))°C/0.05m
=$3.332*10^7$ J/s
1 day=24 hours*3600s/1 hr*$3.332*10^7$J/1 sec=$2.879*10^{12}$ J in one day
$2.879*10^{12}$J*$0.89/$1.055*10^8$J=$24,286 for one day of heating. Yikes! Choice G

Problem 31. A U-tube open at both ends is partially filled with water. Air is blown over the right end; this causes the water on the left to fall by 3 cm and the water on the right to rise by 3 cm. (That is, the total difference in height is now 6 cm.) The pressure at the left end stays at 1 atm. How fast was the air going over the right end? Note we have two densities here: water and air; don't get them confused in your equations.



a. Less than 29 m/s
b. 29 - 30
c. 30 - 31
d. 31 - 32
e. 32 - 33
f. 33 - 34
g. 34 - 35
h. More than 35 m/s

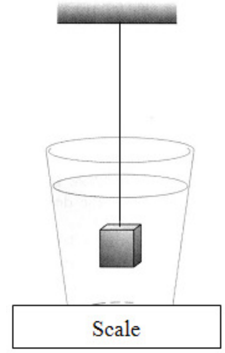
31. Pressure at A reduced due to wind
Pressure at C=pressure at B (Pascal's principle), also equals $P_A+\rho_w gh$
1 atm=$P_A+\rho_w gh$
P_A = 1 atm-$\rho_w gh$
From Bernoulli:
P_A+~~$\rho_{air}gh_A$~~$+1/2P_{air}v_A^2=P_B+$~~$\rho_{air}gh_B+1/2\rho_{air}v_B^2$~~
(difference between $\rho_{air}gh_A$ and $\rho_{air}gh_B$ is insignificant; also, v_B=0)
$P_A+1/2\rho_{air}v_A^2=P_B$
(1 atm-$\rho_w gh$)+$1/2\rho_{air}V_A^2$=1atm
$1/2\rho_{air}v_A^2=\rho_w gh$
$v_A=\sqrt{(2gh(\rho_w/\rho_{air}))}=\sqrt{(2(9.8)(.06)100/1.29)}$
=30.19 m/s Choice C

Write your CID separately on this sheet to guarantee your free body diagram doesn't get lost:

CID: __________

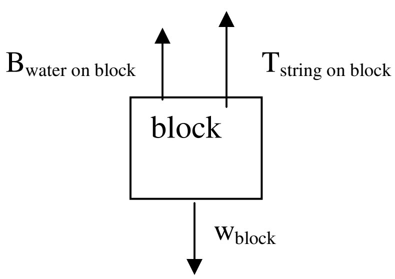
This problem is worth 4 pts; the rest of the exam is worth 96 points

Problem 32. For the situation of problems 19 and 20, draw free body diagrams for (a) the block, and (b) the cup of water.



In your diagrams, label the gravitational forces e.g. as "w_{object}" ("weight of object"). For all other forces, label what is producing the force and on what it is acting. Do so like this: use "F_{1on2}" to mean "Force produced by object 1 acting on object 2", or e.g. "N_{1on2}" for "normal force of object 1 on object 2".

(a) Free body diagram for block



(b) Free body diagram for cup of water