Solutions

Fall 2013 RED barcode here
Physics 105, sections 1, 2 and 3
Exam 4
Colton

Please write your CID_____

No time limit. No notes. No books. Student calculators only. All problems equal weight, 100 points total.

Constants/Materials parameters:

$g = 9.8$ 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
$\sigma = 5.67 \times 10^{-8}$ W/m^2·K^4
Mass of Sun $= 1.991 \times 10^{30}$ kg
Mass of Earth $= 5.98 \times 10^{24}$ kg

Radius of Earth $= 6.38 \times 10^6$ m
Radius of Earth's orbit $= 1.496 \times 10^{11}$ m
Density of water: 1000 kg/m^3
Density of air: 1.29 kg/m^3
Linear exp. coeff. of copper: 17×10^{-6} /°C
Linear exp. coeff. of steel: 11×10^{-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 alum.: 900 J/kg·°C
Latent heat of melting (water): 3.33×10^5 J/kg
Latent heat of boiling (water): 2.26×10^6 J/kg
Thermal conduct. of alum.: 238 J/s·m·°C
$v_{sound} = 343$ m/s at 20°C

Conversion factors

1 kg = 2.205 lb
1 inch = 2.54 cm
1 mile = 1.609 km
1 m^3 = 1000 L

1 hp = 745.7 W
1 gallon = 3.785 L
1 atm = 1.013×10^5 Pa = 14.7 psi

$T_F = \frac{9}{5}T_C + 32$
$T_K = T_C + 273.15$

Other equations

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$
Surface area of sphere $= 4\pi r^2$
Volume of sphere $= (4/3)\pi r^3$
$$v_{ave} = \frac{v_i + v_f}{2}$$
$v = v_0 + at$
$x = x_0 + v_0 t + \frac{1}{2}at^2$
$v_f^2 = v_0^2 + 2a\Delta x$
$w = mg$, $PE_g = mgy$
$F = -kx$, $PE_s = ½ kx^2$
$f = \mu_k N$ (or $f \le \mu_s N$)
$P = F_{//}v = Fv\cos\theta$
$\vec{F}\Delta t = \Delta\vec{p}$
Elastic: $(v_1 - v_2)_{bef} = (v_2 - v_1)_{after}$
arc length: $s = r\theta$
$v = r\omega$
$a_{tan} = r\alpha$
$a_c = v^2/r$
$$F_g = \frac{GMm}{r^2}, \quad PE_g = -\frac{GMm}{r}$$
$I_{pt\ mass} = mR^2$
$I_{sphere} = (2/5)\ mR^2$
$I_{hoop} = mR^2$

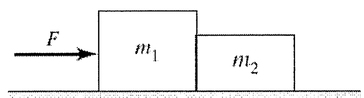
$I_{disk} = (1/2)\ mR^2$
$I_{rod}\ (center) = (1/12)\ mL^2$
$I_{rod}\ (end) = (1/3)\ mL^2$
$L = r_\perp p = rp_\perp = rp\sin\theta$
$P = P_0 + \rho gh$
$VFR = A_1 v_1 = A_2 v_2$
$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$$
$\Delta L = \alpha L_0 \Delta T$
$\Delta V = \beta V_0 \Delta T$; $\beta = 3\alpha$
$$\text{transl.}\ KE_{ave} = \frac{1}{2}mv_{ave}^2 = \frac{3}{2}k_B T$$
$Q = mc\Delta T$; $Q = mL$
$$\frac{\Delta Q}{\Delta t} = kA\frac{T_2 - T_1}{L}$$
$P = e\sigma AT^4$
$|W_{on\ gas}|$ = area under P-V curve
$= |P\Delta V|$ (constant pressure)
$= |nRT\ln(V_2/V_1)|$ (isothermal)
$= |\Delta U|$ (adiabatic)
$$U = \frac{3}{2}Nk_B T = \frac{3}{2}nRT \quad \text{(monatomic)}$$

$$U = \frac{5}{2}Nk_B T = \frac{5}{2}nRT \quad \text{(diatomic, around 300K)}$$
$Q_h = |W_{net}| + Q_c$
$$e = \frac{|W_{net}|}{Q_{added}} = 1 - \frac{Q_c}{Q_h}$$
$$e_{max} = 1 - \frac{T_c}{T_h}$$
$$\omega = \sqrt{\frac{k}{m}}, \quad T = 2\pi\sqrt{\frac{m}{k}}$$
$$\omega = \sqrt{\frac{g}{L}}, \quad T = 2\pi\sqrt{\frac{L}{g}}$$
$$v = \sqrt{\frac{T}{\mu}}, \quad \mu = m/L$$
$$\beta = 10\log\left(\frac{I}{I_0}\right) \quad I_0 = 10^{-12}\ \text{W/m}^2$$
$$f' = f\frac{v \pm v_0}{v \pm v_S}$$
$\sin\theta = v/v_s$
o-o/c-c: $f_n = nf_1$; $n = 1,2,3,\ldots$
o-c: $f_n = nf_1$; $n = 1,3,5,\ldots$

Note: the pagination of these solutions is different than the actual exam, but the problems are the same.

Instructions:

- Write your CID at the top of the first page, otherwise you will not get this exam booklet back.
- Circle your answers in this booklet if you wish, but be sure to **record your answers on the bubble sheet.**
- Unless otherwise specified, **ignore air resistance** in all problems.
- Use g = 9.8 m/s^2.
- Many materials parameters such as thermal conductivity, latent heat, etc., are given on pg 1.



1. Two blocks (m_1 = 5 kg, m_2 = 1 kg) sitting on a frictionless table are pushed from the left by a horizontal force as shown, with F = 10 N. They accelerate to the right. What is the magnitude of the force *between* the two blocks?
   - a. Less than 1.6 N
   - b. 1.6 – 1.8
   - c. 1.8 – 2.0
   - d. 2.0 – 2.2
   - e. 2.2 – 2.4
   - f. 2.4 – 2.6
   - g. 2.6 – 2.8
   - h. 2.8 – 3.0
   - i. More than 3.0 N

   Consider group to get acceleration: $\Sigma F_{group} = m_{group}\, a$, $F = (m_1+m_2)\,a$, $a = \frac{F}{m_1+m_2}$

   Then consider m_2 alone: $\Sigma F_{m_2} = m_2 a$, $F_{12} = m_2 \left(\frac{F}{m_1+m_2}\right) = 10\text{N} \cdot \frac{1}{5+1} = \boxed{1.67\text{N}}$

2. On an air track with no friction, a moving cart of mass *m* and velocity of 10 m/s to the right collides with a stationary cart of mass 3*m*. The moving cart bounces backwards at 2 m/s. Which number is closest to the speed with which the larger cart moves off to the right?
   - a. 1 m/s
   - b. 2
   - c. 3
   - d. 4
   - e. 5
   - f. 6
   - g. 7
   - h. 8
   - i. 9
   - j. 10 m/s

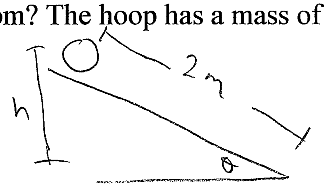
   Before: $\square\!\rightarrow\ \square$ After: $\leftarrow\!\square\ \square\!\rightarrow v = ?$

   $\Sigma p_{bef} = \Sigma p_{aft}$

   $m \cdot 10 = -m \cdot 2 + 3m \cdot v$

   $12 = 3v \rightarrow \boxed{v = 4\,m/s}$

3. A hoop rolls without slipping down a ramp that is 2 m long, with an angle of 30° from horizontal. How fast will the hoop be going at the bottom? The hoop has a mass of 1 kg and a radius of 20 cm.
   - a. Less than 3.0 m/s
   - b. 3.0 – 3.2
   - c. 3.2 – 3.4
   - d. 3.4 – 3.6
   - e. 3.6 – 3.8
   - f. 3.8 – 4.0
   - g. 4.0 – 4.2
   - h. 4.2 – 4.4
   - i. More than 4.4 m/s

   $h = 2m \times \sin\theta$

   $E_{bef} = E_{aft}$

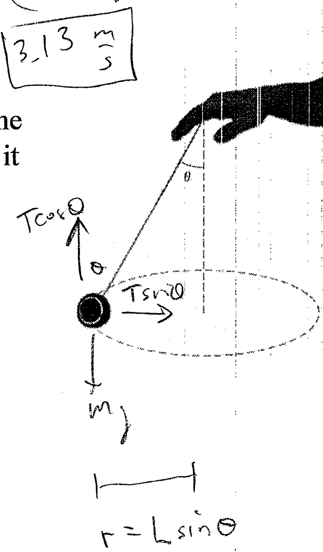
   $mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$, with $I = mr^2$, $\omega^2 = (\frac{v}{r})^2$

   $mgh = \frac{1}{2}mv^2 + \frac{1}{2}mv^2$

   $gh = v^2$

   $v = \sqrt{gh} = \sqrt{(9.8\frac{m}{s^2})(2m \sin 30°)} = \boxed{3.13\ \frac{m}{s}}$

4. Barney swings a 0.2 kg yo-yo around in a horizontal circle, as shown. The angle θ in the picture is 30°, and the length of the string is 0.5 m. What must the yo-yo's speed be as it goes around the circle?
   - a. Less than 1.00 m/s
   - b. 1.00 – 1.05
   - c. 1.05 – 1.10
   - d. 1.10 – 1.15
   - e. 1.15 – 1.20
   - f. 1.20 – 1.25
   - g. 1.25 – 1.30
   - h. More than 1.30 m/s

   $\Sigma F_y = 0$: $T\cos\theta = mg$

   $\Sigma F_x = ma_c$: $T\sin\theta = \frac{mv^2}{r}$

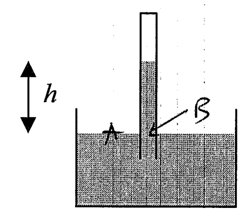
   divide: $\frac{T\sin\theta}{T\cos\theta} = \frac{mv^2/r}{mg}$

   $\tan\theta = \frac{v^2}{rg}$

   $v = \sqrt{rg\tan\theta} = \sqrt{(.5\sin 30°)(9.8)\tan 30°}$

$= \boxed{1.189\ m/s}$

5. A barometer is created using water as the liquid instead of mercury. If the atmospheric pressure is 0.85 atm, how high up will the water rise in the column (i.e. the distance h)? Remember the top of the column is vacuum.



a. Less than 8.0 m
b. 8.0 – 8.3
c. 8.3 – 8.6
d. 8.6 – 8.9
e. 8.9 – 9.2
f. 9.2 – 9.5
g. 9.5 – 9.8
h. 9.8 – 10.1
i. More than 10.1 m

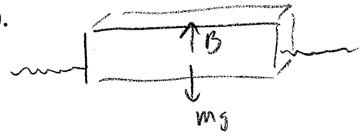
$P_A = P_B$

$P_{atm} = \rho g h$

$h = \frac{P_{atm}}{\rho g} = \frac{(.85)(1.01\cdot 10^5)}{(1000)(9.8)}$

$\boxed{h = 8.76\,m}$

6. Suppose you could bathe in a pool of mercury (density = 13,534 kg/m^3). As you lie there, what fraction of your body's volume would be submerged? Approximate yourself as a rectangular solid made out of water (the exact dimensions don't matter).



a. Less than 7.0%
b. 7.0 – 7.5
c. 7.5 – 8.0
d. 8.0 – 8.5
e. 8.5 – 9.0
f. 9.0 – 9.5
g. 9.5 – 10.0
h. More than 10.0%

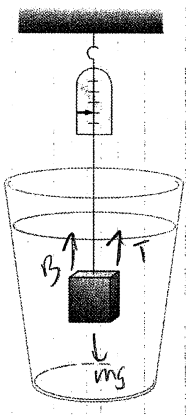
$\Sigma F = 0 \rightarrow B = mg$

$\rho_{fl} V_{obj\ submerged}\, \cancel{g} = \rho_{obj} V_{obj\ total}\, \cancel{g}$

$\frac{V_{submerged}}{V_{total}} = \frac{\rho_{obj}}{\rho_{fluid}} = \frac{1000}{13534} = \boxed{7.39\%}$

7. A 5 kg block of metal is suspended from a spring scale and immersed in water as shown in the figure. The dimensions of the block are 12 cm × 10 cm × 6 cm. What will be the reading of the spring scale?

tension



a. Less than 42 N
b. 42 – 43
c. 43 – 44
d. 44 – 45
e. 45 – 46
f. 46 – 47
g. 47 – 48
h. More than 48 N

$\Sigma F = 0 \rightarrow B + T - mg = 0$

$T = mg - B$

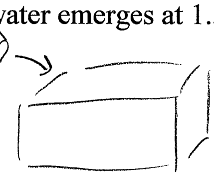
$= mg - \rho_{fl} V_{obj}\, g$

$= (5)(9.8) - (1000)(.12 \times .10 \times .06)(9.8)$

$= \boxed{41.94\,N}$

8. A cowboy at a dude ranch fills a horse trough that is 1.5 m long, 0.6 m wide, and 0.5 m deep. He uses a 3 cm diameter hose from which water emerges at 1.5 m/s. How long does it take him to fill the trough?

$r = .015m$



a. Less than 5.0 min
b. 5.0 – 5.5
c. 5.5 – 6.0
d. 6.0 – 6.5
e. 6.5 – 7.0
f. 7.0 – 7.5
g. 7.5 – 8.0
h. 8.0 – 8.5
i. More than 8.5 min

$VFR = Av$

$\frac{Vol}{time} = Av \rightarrow time = \frac{Volume}{Av}$

$= \frac{1.5m \times .6m \times .5m}{\pi (.015m)^2 (1.5\,m/s)}$

$= 424.4\,sec \times \frac{1\,min}{60\,s}$

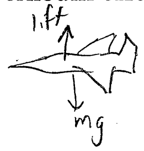
$= \boxed{7.07\,min}$

9. Bernoulli's Law is a statement of:

a. conservation of energy
b. conservation of linear momentum
c. conservation of angular momentum
d. conservation of mass
e. conservation of volume
f. probability

$\rightarrow \Sigma F = 0$

10. A certain model airplane (m = 3 kg) is being tested in a wind tunnel; it's hovering in mid air. It has two wings (as usual), and each wing has a horizontal area of 0.070 m^2. The wings are shaped so that the air is traveling faster above the wing than below in order to generate lift (as usual). Suppose the air above each wing is moving at 45 m/s. If all of the lift is explained by the Bernoulli effect, how fast must the air below the wing be moving? Use 1.29 kg/m^3 as the density of air.



$\Sigma F = 0 \rightarrow$ lift $= mg$

lift $= (P_{\text{below wing}} - P_{\text{above wing}}) \times$ area   since $P = F/A$

from Bernoulli: $P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2$

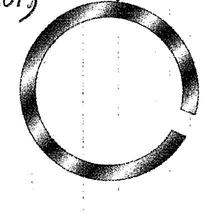
$P_{\text{below}} - P_{\text{above}} = \frac{1}{2}\rho_{air}(v_{above}^2 - v_{below}^2)$

Piecing together, $mg = \frac{1}{2}\rho_{air}(v_{above}^2 - v_{below}^2)(\text{area})$

$v_{below} = \sqrt{v_{above}^2 - \frac{2mg}{\rho_{air} \cdot A}} = \sqrt{45^2 - \frac{2(3)(9.8)}{1.29(2 \cdot .07)}} = \boxed{41.22 \frac{m}{s}}$

- a. Less than 39.0 m/s
- b. 39.0 – 39.5
- c. 39.5 – 40.0
- d. 40.0 – 40.5
- e. 40.5 – 41.0
- f. 41.0 – 41.5
- g. 41.5 – 42.0
- h. 42.0 – 42.5
- i. More than 42.5 m/s

11. A copper ring has a gap in it, as shown in the figure. The gap width is 1.6000 cm when the temperature is 30°C. What will the gap width be when the temperature is 122°C?



$\alpha = 17 \cdot 10^{-6} /°C$

$\Delta L = \alpha L \Delta T$

$L_{new} = L + \Delta L = L + \alpha L \Delta T$

$= L(1 + \alpha \Delta T)$

$= (1.6)(1 + (17 \cdot 10^{-6})(122 - 30))$

$= \boxed{1.6025 \text{ cm}}$

- a. Less than 1.5980 cm
- b. 1.5980 – 1.5985
- c. 1.5985 – 1.5990
- d. 1.5990 – 1.5995
- e. 1.5995 – 1.6000
- f. 1.6000 – 1.6005
- g. 1.6005 – 1.6010
- h. 1.6010 – 1.6015
- i. 1.6015 – 1.6020
- j. More than 1.6020 cm

12. A bimetallic strip has copper on the left side and steel on the right side. It's initially uncurved. Which direction will it curve when it is heated up?

$\alpha = 17 \cdot 10^{-6} /°C$ $\alpha = 11 \cdot 10^{-6} /°C$

copper expands more than steel

- a. Like this:)
- b. Like this: (
- c. It will stay uncurved

13. Actual gases follow the ideal gas law to a good approximation:
- a. at high temperatures (far from their condensing point)
- b. at low temperatures (close to their condensing point)
- c. always

14. In my lab, I have a vacuum pump which can get my vacuum chamber to a pressure of 0.4 milliPascal. That's 250 million times less pressure than 1 atm! The vacuum chamber has a volume of 20 L. How many gas molecules are still inside the chamber when it reaches that very low pressure? (The chamber is at 300K.)

$.020 \text{ m}^3$

$PV = N k_B T$

$N = \frac{PV}{k_B T} = \frac{(.4 \cdot 10^{-3})(.02)}{(1.38 \cdot 10^{-23})(300)}$

$= \boxed{1.93 \cdot 10^{15}}$

- a. Less than 1.8×10^{15}
- b. 1.8 – 2.0
- c. 2.0 – 2.2
- d. 2.2 – 2.4
- e. 2.4 – 2.6
- f. 2.6 – 2.8
- g. 2.8 – 3.0
- h. 3.0 – 3.2
- i. More than 3.2×10^{15}

15. You have a balloon filled with helium gas, having a volume V. It's initially at 300K. If you cool the gas down to liquid nitrogen temperature (77K), what will the volume become? Pressure stays constant!

a. Less than 0.12 V
b. 0.12 – 0.15
c. 0.15 – 0.18
d. 0.18 – 0.21
e. 0.21 – 0.24
f. 0.24 – 0.27
g. 0.27 – 0.30
h. 0.30 – 0.33
i. More than 0.33 V

$$\frac{\cancel{P}_1 V_1 = \cancel{nR} T_1}{\cancel{P}_2 V_2 = \cancel{nR} T_2}$$

$$V_2 = V_1 \frac{T_2}{T_1} = V \cdot \frac{77\text{K}}{300\text{K}} = \boxed{.257\ V}$$

16. Air can be thought of as a diatomic gas having a molar mass of 28.97 g/mol. That is basically a weighted average of the molar masses of all of molecules found in air (primarily nitrogen and oxygen, which are diatomic). Using that molar mass, what is the density of air at 350 K? .02897 kg/mol

a. Less than 1.05 kg/m^3
b. 1.05 – 1.10
c. 1.10 – 1.15
d. 1.15 – 1.20
e. 1.20 – 1.25
f. 1.25 – 1.30
g. 1.30 – 1.35
h. 1.35 – 1.40
i. More than 1.40 kg/m^3

$$PV = nRT \qquad n = \frac{m}{MM}$$

$$\frac{m}{V} = \frac{P \cdot MM}{RT} = \frac{(1.01\cdot 10^5)(.02897)}{(8.31)(350)} = \boxed{1.006\ \frac{\text{kg}}{\text{m}^3}}$$

17. Gas A is made from atoms that are twice as massive as the atoms in Gas B. However, gas A is monatomic while gas B is diatomic. How do the speeds of the molecules compare at 300K?

a. $v_A < v_B$
b. $v_A = v_B$
c. $v_A > v_B$
d. the relationship between speeds cannot be determined

$$\tfrac{1}{2}mv^2 = \tfrac{3}{2}k_BT \rightarrow v = \sqrt{\frac{3k_BT}{m}}$$

← m is the mass of a molecule, which is the same! T also the same! So v = the same!

18. Same situation. How does the total kinetic energy per molecule of gas A compare to gas B?

a. $KE_A < KE_B$
b. $KE_A = KE_B$
c. $KE_A > KE_B$
d. the relationship between KEs cannot be determined

$\frac{3}{2}k_BT$ for monatomic

$\frac{5}{2}k_BT$ for diatomic ← diatomic is bigger.

19. You take an 80 g piece of aluminum out of your freezer (at -18°C) and add it to 250 g of water in an insulated cup (at 30°C). The insulated cup itself has negligible mass. How cold does the aluminum get the water?

c = 900 J/kg°C (aluminum) c = 4186 J/kg°C (water)

a. Less than 20°C
b. 20 – 21
c. 21 – 22
d. 22 – 23
e. 23 – 24
f. 24 – 25
g. 25 – 26
h. 26 – 27
i. More than 27°C

$$Q_{\text{lost by water}} = Q_{\text{gained by Al}}$$

$$(mc\Delta T)_{\text{water}} = (mc\Delta T)_{Al}$$

← I'm guessing the water doesn't freeze

$$(250\cancel{g})(4186)(30 - T_f) = (80\cancel{g})(900)(T_f - -18)$$

$$250\cdot 4186\cdot 30 - 250\cdot 4186\cdot T_f = 80\cdot 900\cdot T_f + 80\cdot 900\cdot 18$$

$$250\cdot 4186\cdot 30 - 80\cdot 900\cdot 18 = 250\cdot 4186\cdot T_f + 80\cdot 900\cdot T_f$$

$$T_f = \frac{250\cdot 4186\cdot 30 - 80\cdot 900\cdot 18}{250\cdot 4186 + 80\cdot 900} = \boxed{26.91\,°C}$$

my assumption was warranted

$c = 4186 \frac{J}{kg°C}$

mL, $L = 333000\,J/kg$

20. An ice cube is in an insulated container, right at its melting point of 0°C. The ice is then melted by transferring in the minimum possible amount of heat energy. That is, after the ice melts, the water (that used to be ice) is still right at 0°C. Then, that exact same amount of energy is transferred again into the container, causing the water to increase in temperature. What is the final temperature of the water?
    a. Less than 77°C
    b. 77 – 79
    c. 79 – 81
    d. 81 – 83
    e. 83 – 85
    f. 85 – 87
    g. 87 – 89
    h. 89 – 91
    i. More than 91°C

$Q = mc\Delta T$

$\cancel{m}L = \cancel{m}c\Delta T$

$\Delta T = \frac{L}{c} = \frac{333000\,J/kg}{4186\,J/kg°C} = \boxed{79.55°C}$

21. A certain amount of heat (Q) flows over the course of one second from the inside of a house at 20°C through a wall to the outside air at 10°C. How much heat will flow through the wall during a one second interval at night, when the outside air is -10°C? The inside stays at 20°C. (Assume thermal conduction through the walls is the only source of heat loss.)
    a. 0
    b. 0.5 Q
    c. Q
    d. 1.5 Q
    e. 2 Q
    f. 2.5 Q
    g. 3 Q
    h. 3.5 Q
    i. 4 Q

$\frac{Q}{t} = \frac{kA}{l} \cdot \Delta T$

$Q \sim \Delta T$

case 1: $\Delta T = 10°C$

case 2: $\Delta T = 30°C$

→ 3× more Q for case 2

$k = 238\,J/s\,m\,°C$

22. Water is being boiled in an open kettle that has a 0.5 cm thick circular aluminum bottom with an area of 0.008 m². If the water boils away at a rate of 0.4 kg/min, what is the temperature of the lower surface of the bottom of the kettle? Assume that the top surface of the bottom of the kettle is at 100°C (the temperature of the boiling water).
    a. Less than 103°C
    b. 103 – 104
    c. 104 – 105
    d. 105 – 106
    e. 106 – 107
    f. 107 – 108
    g. 108 – 109
    h. 109 – 110
    i. More than 110°C

$\frac{m}{t} = \frac{.4\,kg}{60\,sec}$

Actual Exam Choice: E

$\frac{Q}{t} = \frac{kA}{l}\Delta T$

boiling: $Q = mL$ (w/ $L = 2260{,}000\,J/kg$)

$\frac{mL}{t} = \frac{kA}{l} \cdot \Delta T$

$\Delta T = \left(\frac{m}{t}\right) \cdot \frac{L \cdot l}{kA} = \frac{\left(\frac{.4\,kg}{60\,sec}\right)\left(2260000\,\frac{J}{kg}\right)(.005\,m)}{\left(238\,\frac{J}{sec\,m\,°C}\right)(.008\,m^2)} = 39.6\,°C$

since $T_{top} = 100\,°C$

$\boxed{T_{bottom} = 139.6°C}$

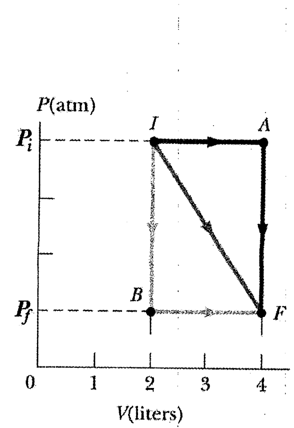
23. The first law of thermodynamics is a statement of:
    a. conservation of energy
    b. conservation of linear momentum
    c. conservation of angular momentum
    d. conservation of mass
    e. conservation of volume
    f. probability

24. If no heat is added to a system, its temperature cannot be increased:
    a. True
    b. False

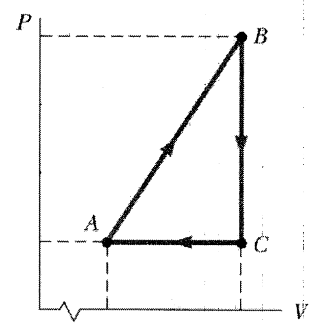
Adiabatic changes can change temperature.

25. In the figure, $P_i = 4$ atm and $P_f = 1$ atm. A monatomic gas can be taken from state I to state F via state A (path IAF), or via state B (path IBF). Which path results in the greater change in internal energy?
    a. IAF
    b. IBF
    c. Same

same T_i and same T_f



26. Consider the cyclic process described by the figure. For A to B: is $W_{on\ gas}$ positive, negative, or zero?



   a. Positive
   b. Negative
   c. Zero
   d. Can't tell without more details

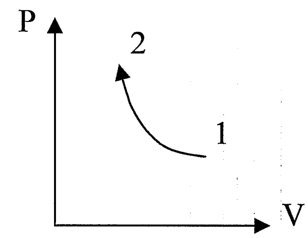
gas is expanding so $W_{by\ gas}$ = pos.
$W_{on\ gas}$ = neg.

27. Same situation. For C to A: is heat added or taken away from the gas?
   a. Added
   b. Taken away
   c. Neither ($Q_{added} = 0$)

$\underset{\text{negative}}{\Delta U} = Q + \underset{\text{positive}}{W_{on}}$

Q must be negative

28. A diatomic ideal gas is compressed isothermally from state 1 (100 kPa, 0.008 m^3, 300 K) to state 2 (200 kPa, 0.004 m^3, 300 K). Was heat added or taken away from the gas?



   a. Added
   b. Taken away
   c. Neither ($Q_{added} = 0$)

$\underset{\text{zero}}{\Delta U} = Q + \underset{\text{positive}}{W_{on}}$

Q must be negative

29. Same situation. How much heat flowed into or out of the gas during the process (magnitude)? ~~Hint: diatomic gases have a different value of internal energy than monatomic gases~~.
   a. Less than 520 J
   b. 520 – 540
   c. 540 – 560
   d. 560 – 580
   e. 580 – 600
   f. 600 – 620
   g. 620 – 640
   h. 640 – 660
   i. More than 660 J

$Q = -W_{on}$ since $\Delta U = 0$
$= -(-nRT \ln V_f/V_i)$
$= nRT \ln\left(\frac{V_2}{V_1}\right)$
$= P \cdot V \ln\left(\frac{V_2}{V_1}\right)$
$= (100 \cdot 10^3)(.008) \ln\left(\frac{.004}{.008}\right) = \boxed{-554.5\text{ J}}$
(Negative, as expected)

30. A coal power plant produces 800 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 60°C. What is the theoretical maximum efficiency of the plant?

823K   333K

   a. Less than 58%
   b. 58 – 60
   c. 60 – 62
   d. 62 – 64
   e. 64 – 66
   f. 66 – 68
   g. 68 – 70
   h. 70 – 72
   i. More than 72%

$e_{max} = 1 - \frac{T_c}{T_h}$
$= 1 - \frac{333K}{823K}$
$= \boxed{59.5\%}$

31. Suppose the actual efficiency of the plant in the previous problem is 35%. How much heat is expelled to the river each second?
   a. Less than 1200 ~~J~~ MJ
   b. 1200 – 1250
   c. 1250 – 1300
   d. 1300 – 1350
   e. 1350 – 1400
   f. 1400 – 1450
   g. 1450 – 1500
   h. 1500 – 1550
   i. 1550 – 1600
   j. More than 1600 ~~J~~ MJ

$e = \frac{|W_{net}|}{Q_h}$

$Q_h \rightarrow |W_{net}|$, Q_c

$Q_h = |W_{net}| + Q_c$

$e = \frac{|W_{net}|}{|W_{net}| + Q_c}$

$|W_{net}| + Q_c = |W_{net}|/e$

$Q_c = \frac{|W_{net}|}{e} - |W_{net}|$

$= \frac{(800\text{ MJ})}{.35} - 800\text{ MJ} = \boxed{1485\text{ MJ}}$