Physics 23 Practice Problems Chapters 12-13

Chapter 12 Problems

Skip Problems 1-4

5. A 40-gram object at its melting point requires 5000 calories to melt. What is this object's latent heat of melting? What is its latent head of freezing?

6. 6000 calories of heat must be removed from 150 grams of a certain vapor at its condensation point to convert it to liquid at the same temperature. What is that substance's latent heat of condensation?

7. A substance has a specific heat capacity of 0.20 cal/g-C. How much heat (in cal) must be added to 200 grams of this substance at 50 C to raise its temperature to 90 C?

8. Four thousand calories of thermal energy are needed to raise the temperature of 200 grams of a substance from 20 C to 70 C. What is the specific heat capacity of this substance, in cal/g-C?

9. "Chilled to the bone." Suppose equal masses of human tissue (c = 1.00 cal/g-C) and bone (c = 0.10 cal/g-C) lose the same amount of heat over the same time period. If the tissue's temperature drops by 0.3 C, what would be the drop in the bone's temperature?

10. How many calories of heat must be removed from 600 grams of steam at 150 C to convert it to water at 90 C?

11. How many calories of heat must be added to convert 70 grams of ice at 0 C to steam at 100 C?

12. Fifty grams of metal at 300 C are placed in 400 grams of water at 10 C. The specific heat capacity of the metal is 0.25 cal/g-C. What is the approximate equilibrium temperature of the mixture, in degrees Celsius?

13. 100 grams of a substance at 120 C is added to 300 grams of water at 20 C, and after equilibrium is reached, the temperature of the mixture is 30 C. What is the specific heat capacity of the unknown substance?

14. Fifty grams of ice at 0 C is added to 200 grams of water at 70 C. All of the ice melts. What is the equilibrium temperature of the mixture?

15. How many kcals (kilocalories) of heat must be removed from 200 g of steam at 150 C to convert it to 200 g of ice at -20 C?

16. An aluminum bat has a length of 0.86 m at a temperature of 17 C. When the temperature of the bat is raised, the bat lengthens by 1.6×10^{-5} m. Determine the final temperature of the bat. The coefficient of thermal expansion of aluminum is 2.3×10^{-5} C^{-1}.

17. When the temperature of a coin is raised by 75 C, the coin's diameter increases by 2.3×10^{-5} m. If the coin's original diameter was 1.8×10^{-2} m, find the coefficient of linear expansion of the coin's metal.

18. A flask is filled with 1.500 liters (L) of a liquid at 97.1 C. When the liquid is cooled to 15.0 C, its volume is only 1.383 L. Determine the coefficient of volume expansion β of the liquid.

19. For every Cal of work done by the muscles of a human, three joules of heat are generated. In other words, human muscles are only about 25% efficient in doing work. So, to "burn off" four Calories, only one Cal of work needs to be done

Suppose a 75-kg person eats a 140-Cal, chocolate-frosting cupcake. How far up the stairs of a tall building would this person have to climb to burn off the cupcake?

20. 40 grams of ice at -10 C is added to 800 grams of water at 20 C, and 10 grams of steam at 130 C is likewise added to the water. What is the equilibrium temperature?

Chapter 12 Problem Solutions

<table>
<tr><td>5. 5000/40 = 125 cal/g</td><td rowspan="4">9. Values of mass m and heat Q are the same for bone and tissue:

Bone: $\Delta T_1 = Q/(mc_1)$
Tissue: $\Delta T_2 = Q/(mc_2)$
Divide equations:

$\Delta T_1 / \Delta T_2 = c_2/c_1$
$= 1.00/0.10$
$= 10$
$\Delta T_1 = 10\ \Delta T_2$
$= 10\ (0.3)$
$= 3.0$ C
Bone has one-tenth the specific heat capacity of tissue, so bone suffers ten times the temperature drop: -3.0 C</td></tr>
<tr><td>6. 6000/150 = 40 cal/g</td></tr>
<tr><td>7.
$Q = mc\Delta T$
$= 200\ (0.20)(90-50)$
$= 1600$ cal</td></tr>
<tr><td>8.
$\Delta T = 70 - 20$
$= 50$ C

$c = Q/(m\Delta T)$
$= 4000 / [200 \times 50]$
$= 0.40$ cal/g-C</td></tr>
</table>

10.

Cool the steam: $mc\,\Delta T = (600)(0.5)(-50)$
$= \mathbf{-15{,}000\ cal}$

Condense the steam: $-mL = -(600)(540)$
$= \mathbf{-324{,}000\ cal}$

Cool the water: $mc\,\Delta T = (600)(1.0)(-10)$
$= \mathbf{-6{,}000\ cal}$

Total: Q $= \mathbf{-345{,}000\ cal}$

11.

Melt the ice:	70(80) = 5600 cal
Warm the water:	70(1.0)(100) = 7000 cal
Vaporize the water:	70(540) = 37,800 cal
Total:	Q = 50,400 cal

12.
Sum of the Q's equals zero:

$50(0.25)(T - 300) + 400(1.0)(T - 10) = 0$
$T = 18.79$ C

13.

$(100)(c)(30-120) + 300(1.0)(30-20) = 0$
$c = 0.33$ cal/g-C

14.

Q for melting ice: 50(80) = 50 (80)

Q for warming the melted ice water = 50 (1.0) (T - 0)

Q for cooling the warm water = 200 (1.0) (T - 70)

Sum of Q's = zero:

4,000 + 50 (1.0) (T - 0) + 200 (1.0) (T - 70) = 0

T = 40 C

15.

Cool the steam:	200 (0.5)(-50)	= -5,000 cal
Condense the steam:	200 (540)	= -108,000 cal
Cool hot water:	200 (1.0) (0 - 100)	= -20,000 cal
Freeze cold water:	-200 (80)	= -16,000 cal
Cool the ice:	200 (0.5) (-20)	= <u>- 2,000 cal</u>
Total Q		= -151,000 cal

151 kcal must be removed

16.

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

$\Delta T = \Delta L / \alpha L_o$

$= 1.6 \times 10^{-5} / [23 \times 10^{-6} (0.86)]$

$= 0.81$ C

$T = T_o + \Delta T$

$= 17 + 0.81$

$= 17.81$ C

17.

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

$\alpha = \Delta L / (L_o \Delta T)$

$= 2.3 \times 10^{-5}$ m / [1.8×10^{-2} m x 75 C]

$= 1.7 \times 10^{-5}$ C^{-1}

18.

$\Delta V = 1.383 - 1.500$

$= - 0.117$ L

$\Delta T = 15.0 - 97.1$

$= -82.1$ C

$\beta = (\Delta V/V_o)/\Delta T$

$= (-0.117/1.500) / (-82.1)$

$= 9.5 \times 10^{-4}$ C^{-1}

19.

This person needs to do ¼ (140) = 35 Cal of work.

35 Cal = 35,000 cal
$= (35{,}000 \text{ cal}) (4.19 \text{ J/cal})$
$= 1.47 \times 10^5$ J

$W = 1.47 \times 10^5$ J

The work done equals the increase in her gravitational energy:

$W = mgh$
$= (75)(9.8)\, h$
$= 735\, h$

$735\, h = 1.47 \times 10^5$
$h = 200$ m

Average stair-step height is 0.20 m, so the number of steps the person needs to take is:

200 / 0.20 = 1000

At about one second per step, the person would be climbing for 1000 seconds, or about 17 minutes, to work off that cupcake.

20.

40 grams of ice at -10 C and 10 grams of steam at 130 C are added to 800 grams of water at 20 C. What is the equilibrium temperature?

Heat gained by warming ice:	40(0.5)[0 - (-10)]	= 200
Heat gained in melting ice:	40 (80)	= 3200
Heat gained by warming cold water:	40 (1.0)(T - 0)	= 40 T
Heat lost by cooling steam:	10 (0.5) (100-130)	= -150
Heat lost by condensing steam:	-10 (540)	= -5400
Heat lost by cooling hot water:	10 (1.0) (T - 100)	= 10 T - 1000
Heat gained or lost by 800 g of water:	800 (1.0) (T - 20)	= 800 T - 16,000

Sum of Q's is zero:
200 + 3200 + 40 T - 150 - 5400 + 10 T - 1000 + 800 T - 16,000 = 0
T = 22.53 C

Chapter 13

1. The rate at which heat passes through a living room wall facing the outdoors is 6000 W. Its thickness is 0.10 m, and the outside temperature is 20 C lower than the inside temperature. The wall has an area of 24 m^2. What is the thermal conductivity of the wall?

2. A wall consists of two layers of different thermal conductivities and thicknesses. The thinner layer has a thickness of 0.01 m and a thermal conductivity of 0.09 W/m-C. The thicker layer has a thickness of 0.03 m and a thermal conductivity of 0.05 W/m-C. The thin layer faces a room whose air temperature is 20 C, and the thicker layer faces the outdoor air, whose temperature is -4 C. What is the temperature of the interface?

3. The rate at which heat passes through a wall is 4200 W. If the wall's thickness were tripled, its area cut in half, and its thermal conductivity reduced to one tenth of its previous value, what then would be the rate at which heat passes through the wall?

4. A solid cylinder's radius is the same as its height.
(a) What is the surface area of the cylinder?
(b) If the cylinder is cut in half, creating two smaller cylinders,
what will be the total surface area?

5. A solid cylinder whose height equals its radius is radiating 8000 W. If it's cut in half, creating two smaller cylinders, what will be the total rate at which the two cylinders is radiating infra-red?

6. At what Kelvin temperature must the surface of a sphere of radius 0.40 m be in order that it emit 20,000 watts of IR radiation? (Assume e = 1.)

7. An object with emissivity 0.40 has a surface area of 1.3 m^2. Its surface temperature is 300 K. What would be the net loss in energy in two hours if it were submerged in water at 280 K?

8. If a spherical star is radiating infra-red at a rate 8.0×10^{24} W, what would be the radiation rate if the star collapsed to a radius one-fourth of the original radius, and its Kelvin temperature tripled?

9. The table below shows the mass per cubic meter of water vapor that "saturates" the air at various temperatures.

Suppose the current temperature is 20 C, and the water vapor content is 11 grams/m^3.

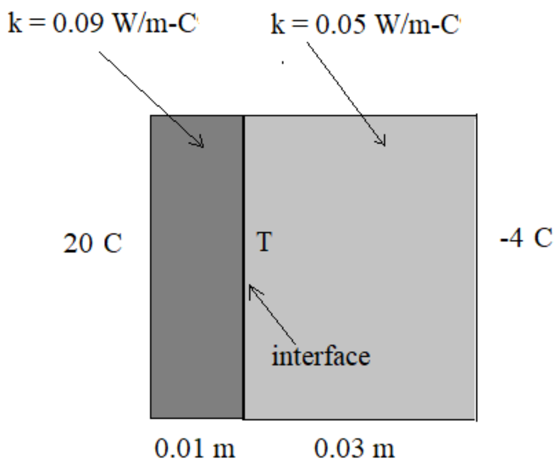
(a) What is the humidity? (b) What will be the humidity if the water vapor content doesn't change and the temperature later rises to 25 C? (c) If the temperature falls to 10 C, how many grams of water vapor per cubic meter will condense?

T (C)	M (g/m^3)
10	8
20	17
25	20
30	30

Chapter 13 Problem Solutions

1. k (24) 20 / 0.10 = 6000
   k = 1.25 W/m-C

2.



Whatever flows through the left layer must flow through the right layer: The two rates are the same:

Rate for the left layer:
0.09 A (20 - T) / 0.01

Rate for the right layer:
0.05 A [T - (- 4)]/ 0.03

Equate the two rates and solve for T:

0.09 A (20 - T) / 0.01 = 0.05 A [T - (-4)] / 0.03
T = 16.25 C

The temperature is less than 20 C, and greater than -4 C, as expected.

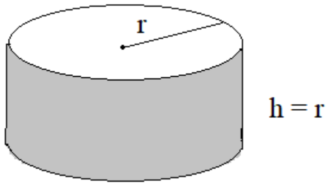
3.

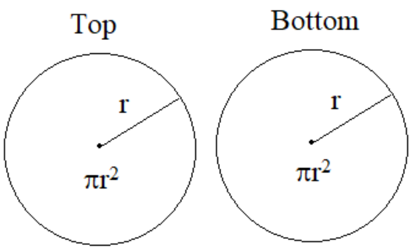
$R = kA|\Delta T|/x$
$= 4200$ W

$x = 3\ x_o$
$A = ½\ A_o$
$k = 1/10\ k_o$

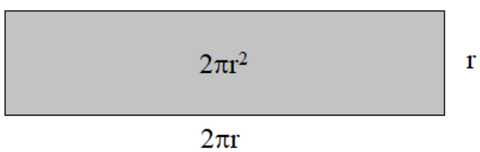
$R/R_o = (k/k_o)\ (A/A_o)\ /\ (x/x_o)$
$= (1/10)\ (1/2)\ /\ 3$
$= 1/60$
$R = (1/60)\ R_o$
$= (1/60)\ 4200$
$= 70$ W

4. (a)



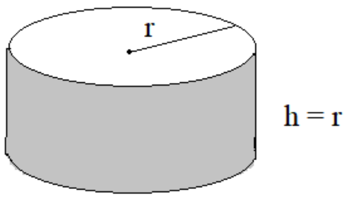


Rectangular Area:

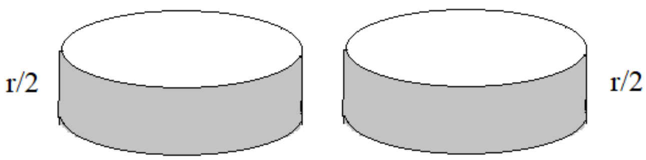


$$\text{Initial Surface Area} = \pi r^2 + \pi r^2 + 2\pi r^2$$
$$= 4\pi r^2$$

4. (b)



A cut through the mid-section of the cylinder above creates the two smaller cylinders below, which opens up two more circular areas to be added to the area that existed before the cut.



$$\begin{aligned}\text{New area} &= \text{Old Area} + 2\pi r^2 \\ &= 4\pi r^2 + 2\pi r^2 \\ &= 6\pi r^2\end{aligned}$$

5.

$R_o = \sigma e A_o T_o^4$
$\quad = 8000$ W
$R = \sigma e A T_o^4$
$A_o = 4\pi r^2$
$A = 6\pi r^2$

$R/R_o = A/A_o$
$\quad = 6/4$

New Rate = (6/4) 8000
$\quad$ = 12,000 W

6. $A = 4\pi\ (0.40)^2$ $= 2.01\ m^2$ $5.67 \times 10^{-8}\ (1.0)\ (2.01)\ T^4 = 20{,}000$ W $T = 647$ K	7. $5.67 \times 10^{-8}\ (0.40)\ (1.3)\ (280^4 - 300^4) = -57.60$ W Two hours = 7200 s: $Q = (-57.60\ J/s)\ (7200\ s)$ $= -4.15 \times 10^5$ J
8. $R_o = \sigma e A_o T_o^4$ $= \sigma e\ (4\pi)\ r_o^2 T_o^4$ $= 8.0 \times 10^{24}$ watts $r = ¼\ r_o$ $T = 3\ T_o$ $R/R_o = \sigma e\ (4\pi)\ r^2 T^4 / [\sigma e\ (4\pi)\ r_o^2 T_o^4]$ $= r^2 T^4 / r_o^2\ T_o^4$ $= (r/r_o)^2\ (T/T_o)^4$ $= (1/4)^2\ (3)^4$ $= 5.06$ $R = 5.06\ R_o$ $= 5.06\ (8.0 \times 10^{24}\ W)$ $= 40.5 \times 10^{24}$ W	9. (a) (11/17) 100% = 64.7% (b) (11/20) 100% = 55.0% (c) At 10 C only 8 grams per cubic meter are allowed, but there are 11 grams present, so three grams condense, leaving behind 8 grams per cubic meter, which saturates the air (100% humidity) at this temperature.