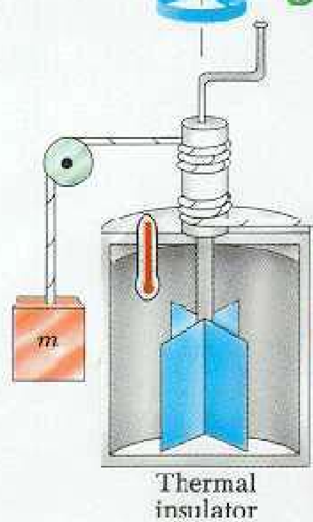
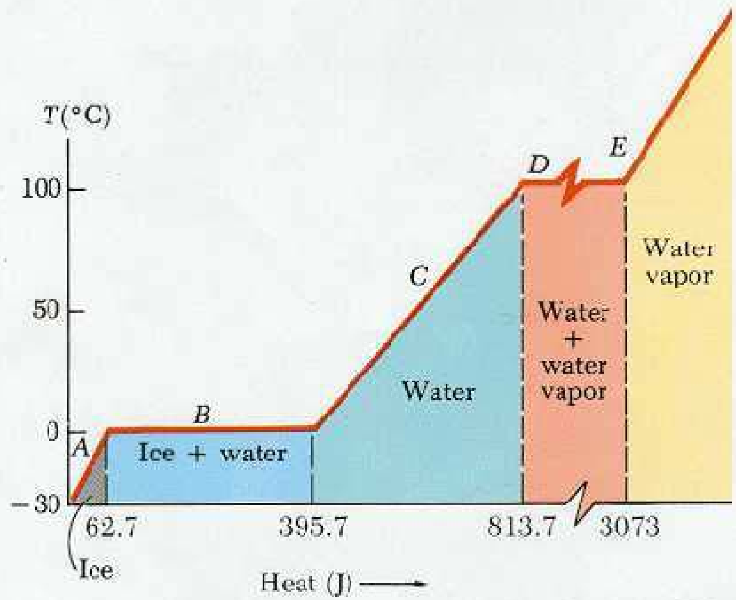
Heat and the First Law of Thermodynamics

HEAT AND THE FIRST LAW OF THERMODYNAMICS





HEAT AND TEMPERATURE

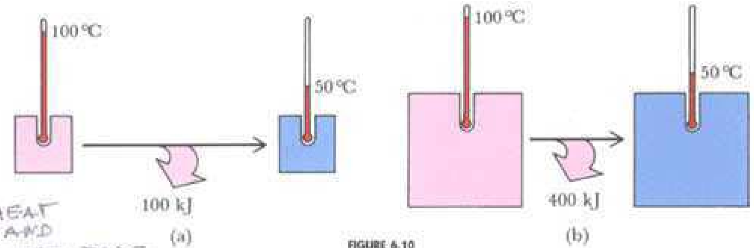


FIGURE 6.10

HEAT Q = ENERGY TRANSFERRED DUE TO TEMPERATURE DIFFERENCE

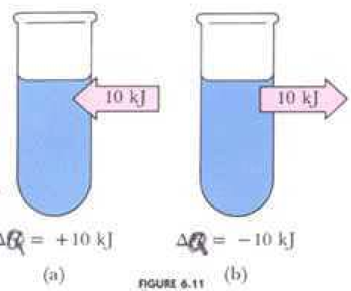


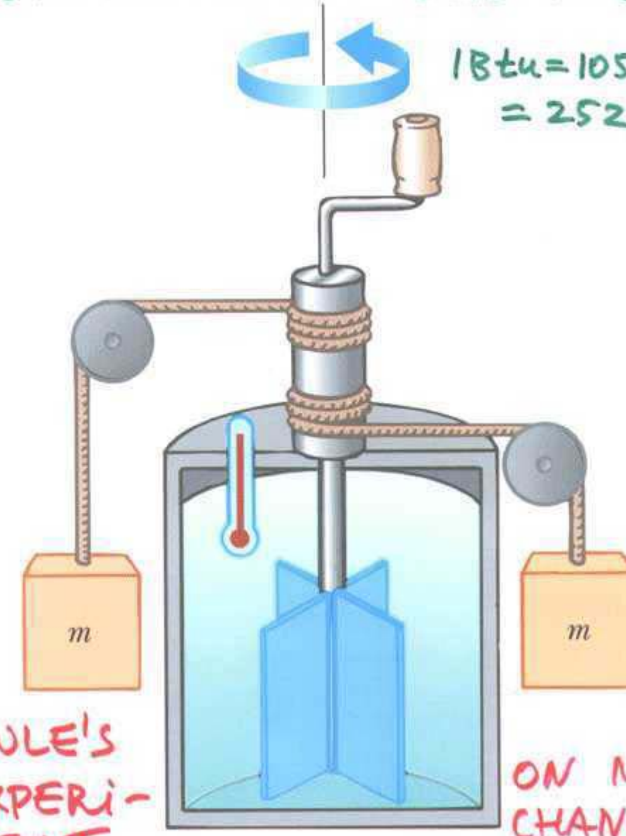
FIGURE 6.11

T-40
FIGURES 6.10, 6.11

HEAT ENTERS AND LEAVES SYSTEM

UNITS OF HEAT: 1 CAL = 4.18 J

1 Btu = 1055 J = = 252 cal.



JOULE'S EXPERIMENT

ON MECHANICAL EQUIVALENT OF HEAT

1 CAL = 4.18 J

Overhead transparencies to accompany Serway/Faughn: *College Physics, 4/e* page 325

Figure 53 Text figure 11.1

Illustration of Joule's experiment for measuring the mechanical equivalent of heat

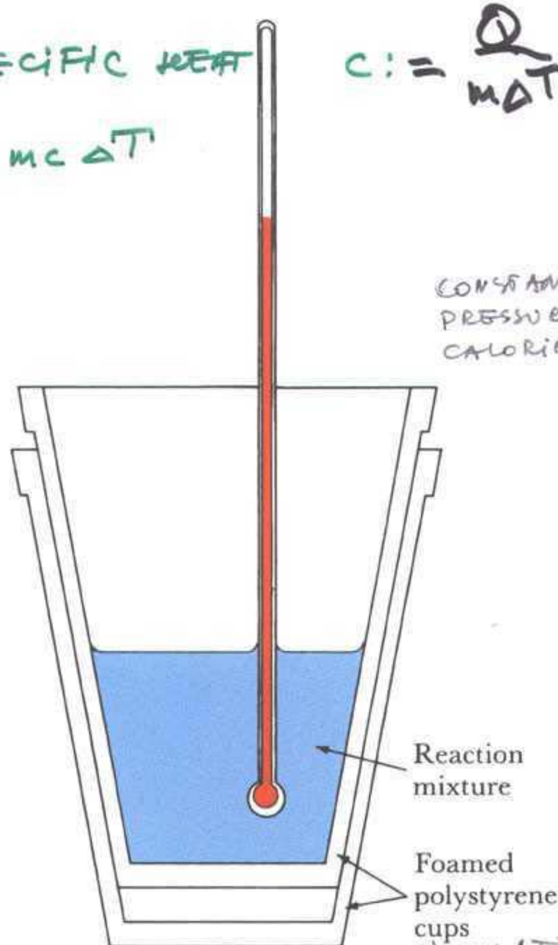
3)

SPECIFIC HEAT

$c := \frac{Q}{m \Delta T}$

$Q = mc\Delta T$

CONSTANT PRESSURE CALORIMETER

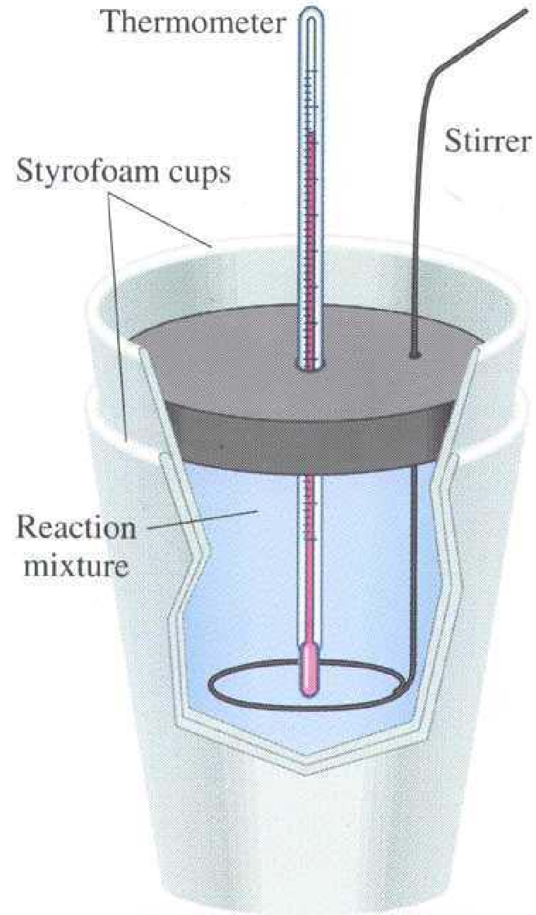


T-37
FIGURE 6.7

Atkins/Beran
GENERAL CHEMISTRY, Second Edition

4)

Figure 6.10



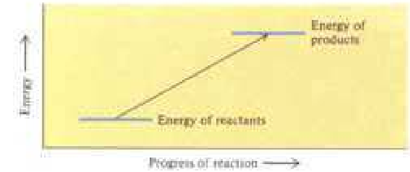
CALORIMETER

5) MADE OF TWO STYROFOAM COFFEE CUP.

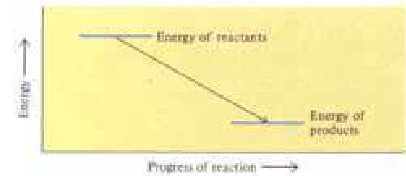
Some Specific Heat Capacities

Substance	C (J/kg - °C)
Solids	
Aluminum	890
Concrete	670
Copper	390
Ice	2,000
Iron and steel	460
Lead	130
Silver	230
Liquids	
Gasoline	2,100
Mercury	140
Seawater	3,900
Water (pure)	4,180

54 (Table 5.3)



(a) An endergonic reaction



(b) An exergonic reaction

Box 4E

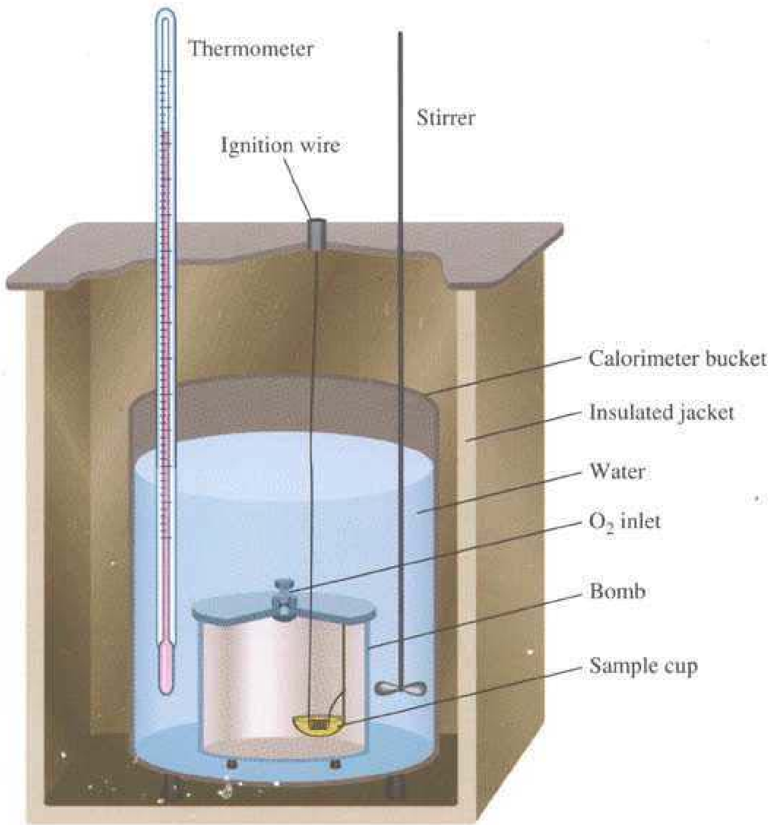
The Caloric Value of Foods

TABLE 4E Caloric Values of Some Foods

Food	Calories	Food	Calories
Milk, 8 oz	165	Apple, 5 oz	70
Swiss cheese, 1 oz	105	Banana, 5 oz	85
Egg, boiled, large	80	Grapefruit, ½ medium	50
Hamburger patty, 3 oz	245	Orange juice, 8 oz	100
Beef, lean, 2 oz	115	Bread, rye, 1 slice	55
Lamb, shoulder, lean, 2 oz	125	Bread, white, 1 slice	60
Haddock, fried, 3 oz	135	Fudge, 1 oz	115
Shrimp, 3 oz	110	Honey, 1 tablespoon	60
Peanuts, roasted, 2 oz	210	Cookie, 3-in	110
Carrot, raw, 8 oz	45	Cornflakes, 1 oz	110
Corn, 5-in ear	65	Noodles, 8 oz	200
Potato, 5 oz	90	Butter, 1 tablespoon	100
Tomato, 5 oz	30	Margarine, 1 tablespoon	100

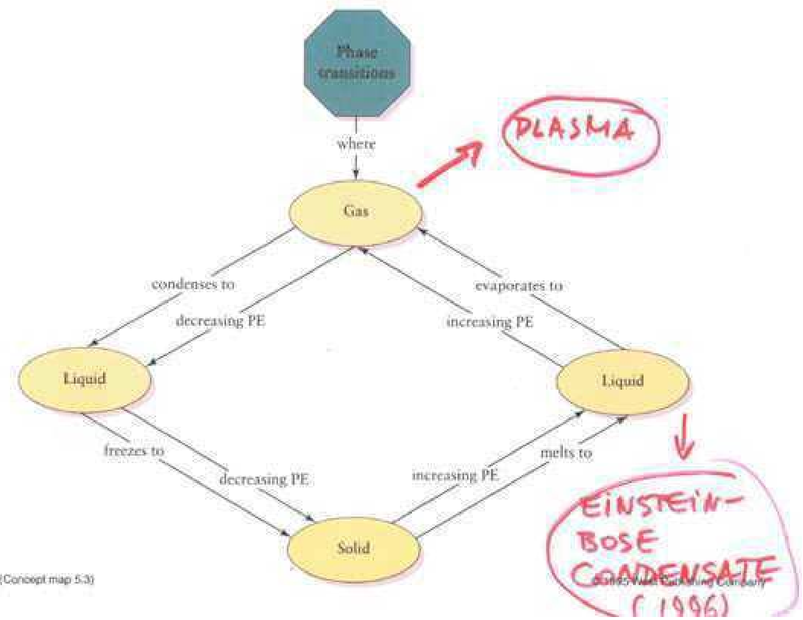
Figure 6.9

CALORiMETER



71)

Phase Transitions



Acetate 67 (Concept map 5.3)

9)

THE VARIOUS PHASE CHANGES THAT A SUBSTANCE CAN UNDERGO

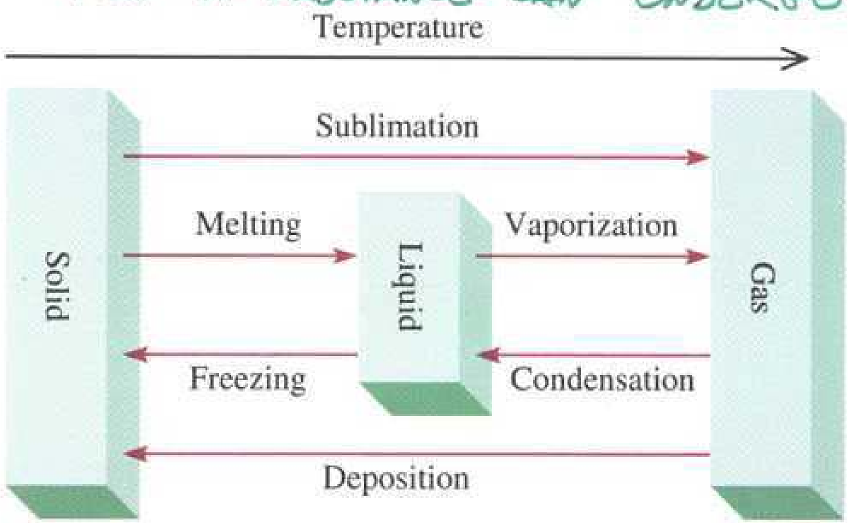


Figure 11.47

10)

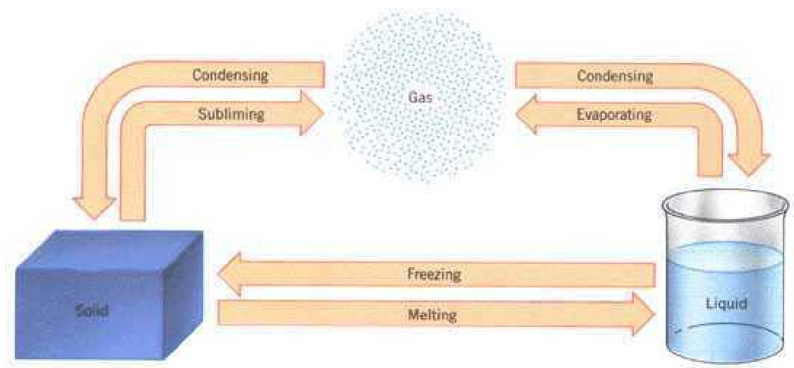


FIGURE 12.23

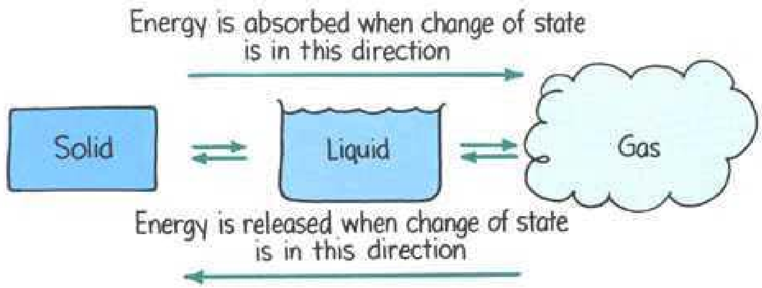
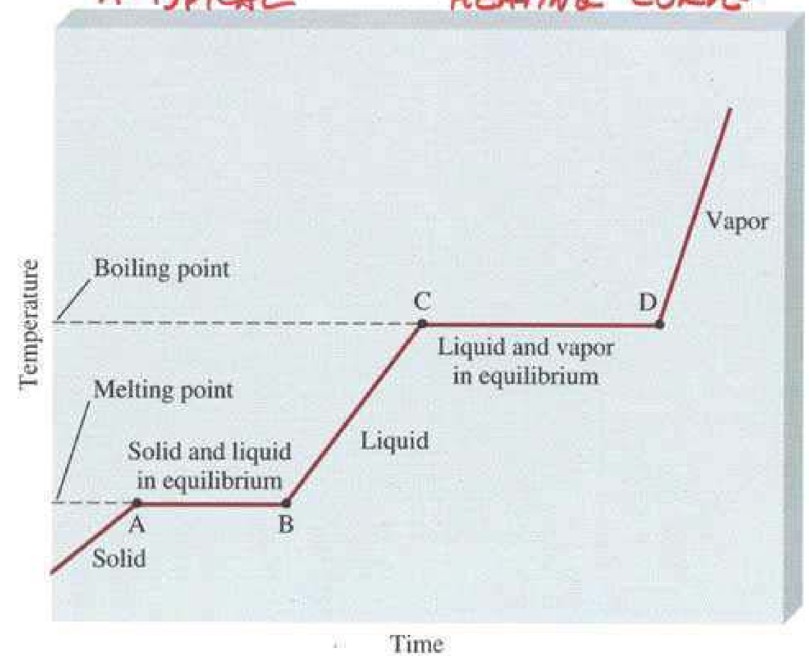


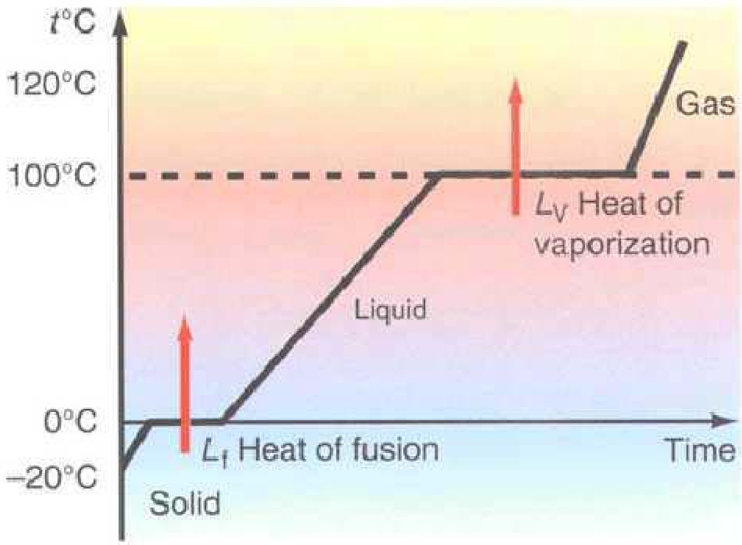
Figure 16.16
Conceptual Physics, Seventh Edition, by Paul G. Hewitt

A TYPICAL HEATING CURVE



128

Figure 11.46



44 Changes of phase
Figure 14.9

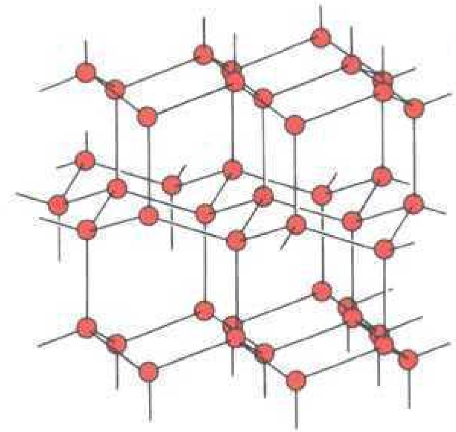


FIGURE 10.20

STRUCTURE OF ICE

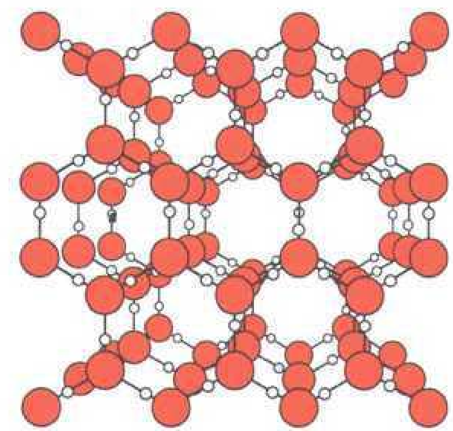
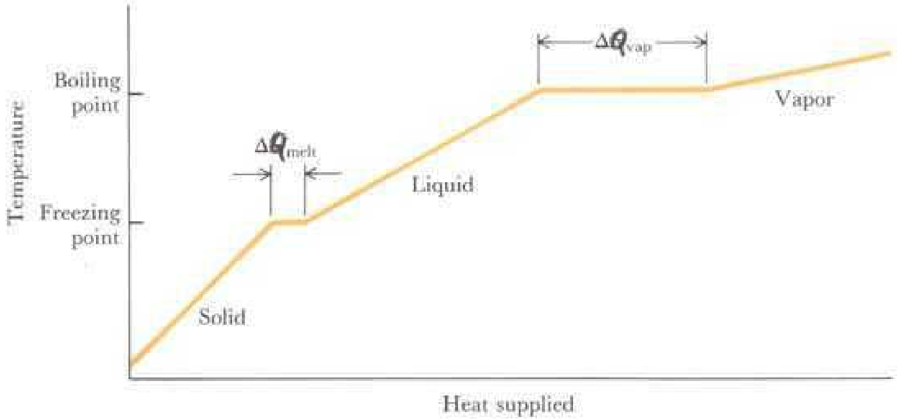


FIGURE 10.44

T-94
FIGURES 10.20, 10.44

12)

(3)



T-44
FIGURE 6.14

A WARMING CURVE
FOR A GENERAL SUBSTANCE

Atkins/Beran
GENERAL CHEMISTRY, Second Edition
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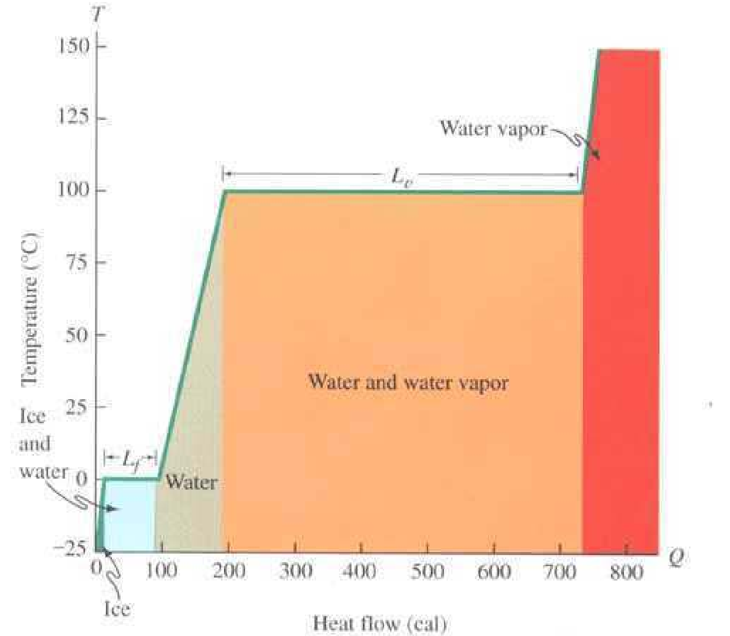
T69 (Figure 18-8) Heat flows in water as its temperature changes

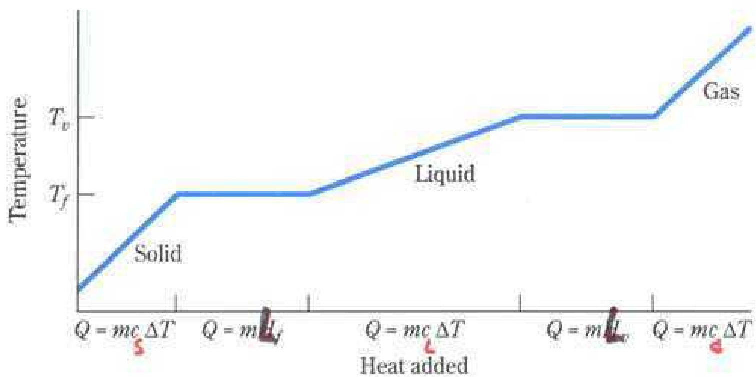


HEATING:
$Q = mc\Delta T$
Specific heat c

MELTING/VAPORIZING
$Q = mL$
LATENT HEAT L

PHYSICS FOR SCIENTISTS
AND ENGINEERS
by Fishbane/Gasiorowicz/Thornton

14)



34

Fig. 11.7

TABLE 10.2 Normal melting and boiling points of ionic solids

Ionic solid	Melting point, °C	Boiling point, °C
LiF	842	1676
LiCl	614	1382
NaCl	801	1413
KCl	776	1500*s**
$MgCl_2$	708	1412
MgO	2800*s*	3600
$CaCl_2$	782	2000
Al_2O_3	2015	2980

*The *s* indicates that the solid sublimes.

T-86
TABLE 10.2, FIGURE 10.2

SPECIFIC HEAT, J/kg-C°

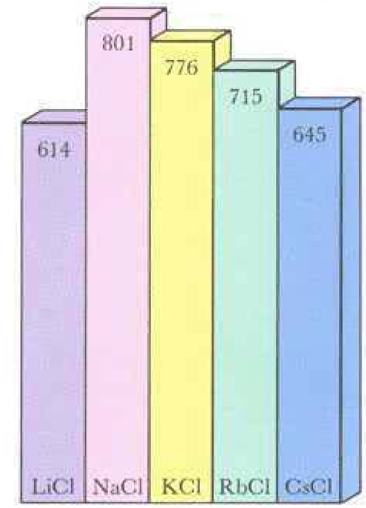
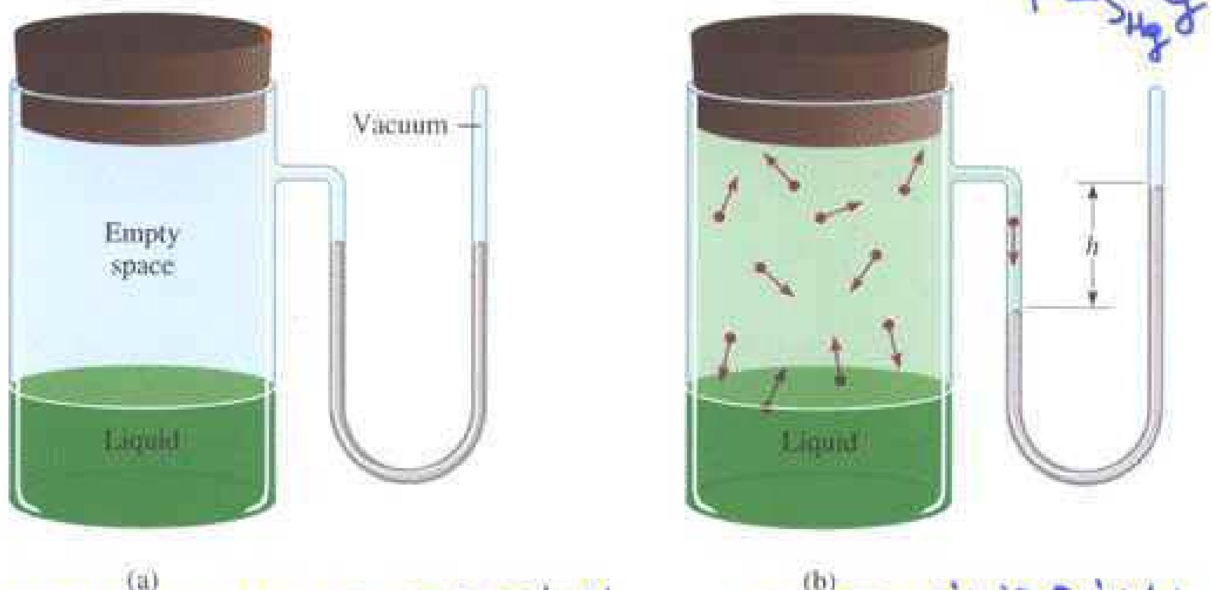


FIGURE 10.2

8)

APPARATUS FOR MEASURING THE VAPOR PRESSURE OF A LIQUID

$P = \rho_{Hg} g h$

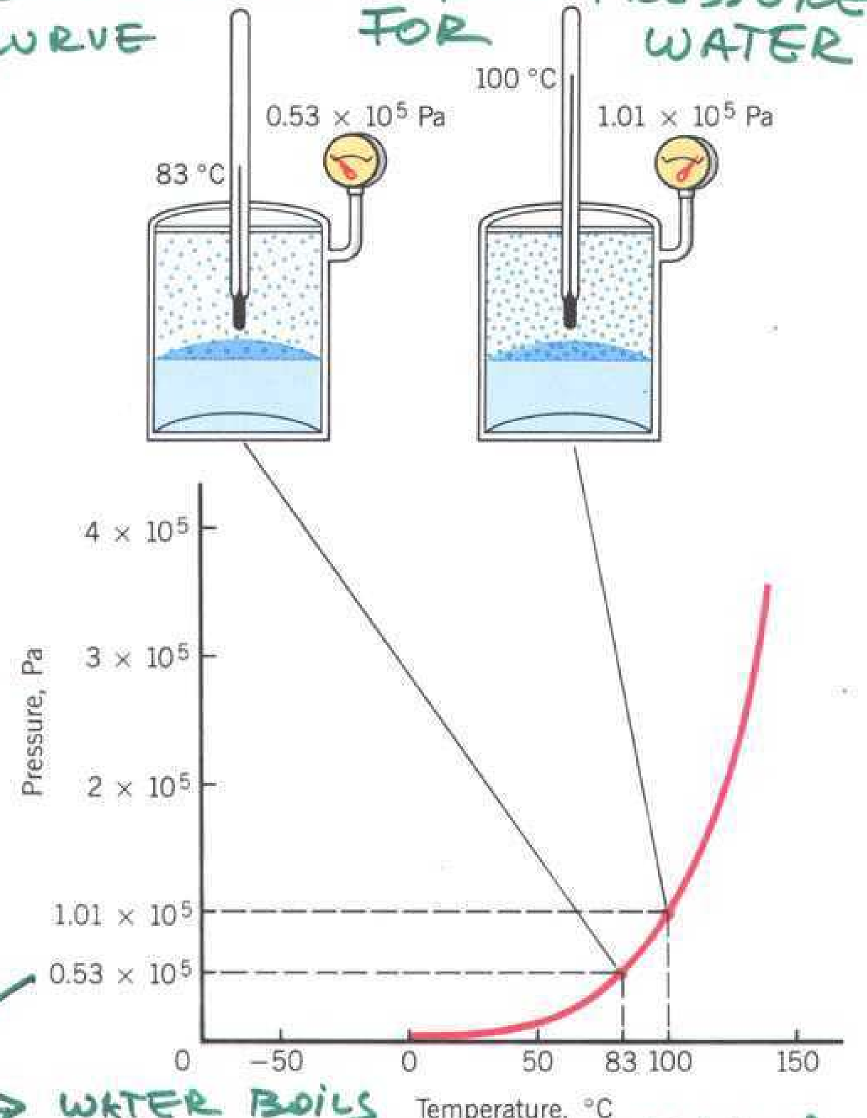


(a) BEFORE THE EVAPORATION BEGINS

(b) AT EQUILIBRIUM THE NUMBER OF MOLECULES LEAVING AND RETURNING TO THE LIQUID IS THE SAME

Figure 11.40

EQUILIBRIUM VAPOR PRESSURE CURVE FOR WATER

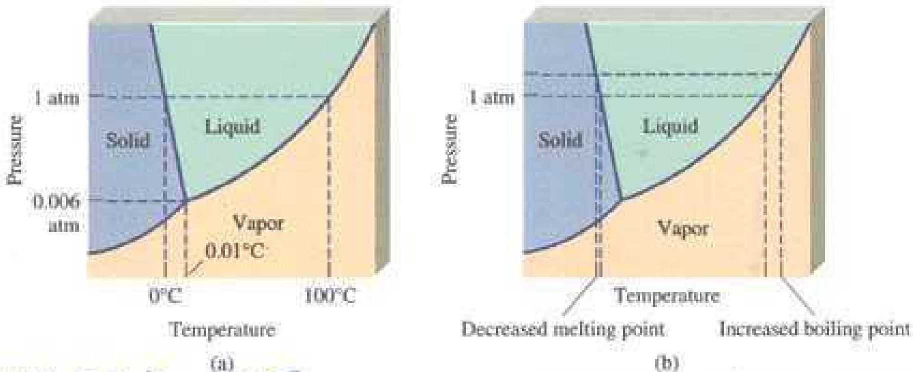


→ WATER BOILS AT 83°C ON THE MOUNTAIN OF ALTITUDE ~ 5 KM, WHERE $P \simeq 0.53 \times 10^5$ PA

17)

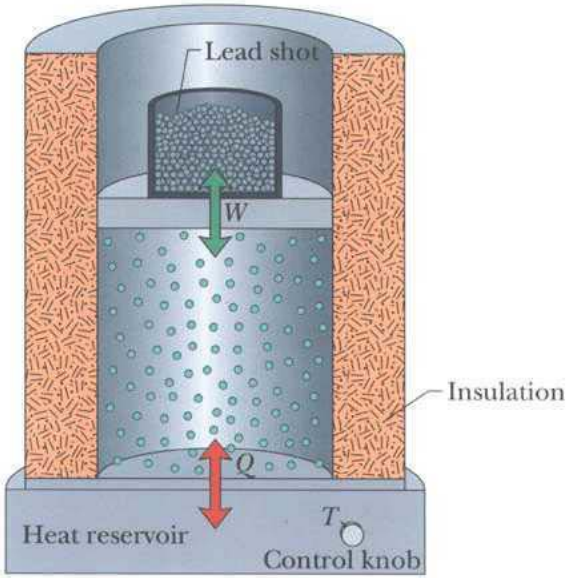
FIGURE 12.26

THE PHASE DIAGRAM OF WATER



EACH SOLID LINE REPRESENTS T, P AT WHICH TWO PHASES ARE AT EQUILIBRIUM; AT THE TRIPLE POINT ALL 3 PHASES ARE IN EQUIL.

INCREASING THE PRESSURE ON ICE LOWERS ITS MELTING TEMP., AND INCREASING PRESSURE ON WATER RAISES ITS BOILING POINT

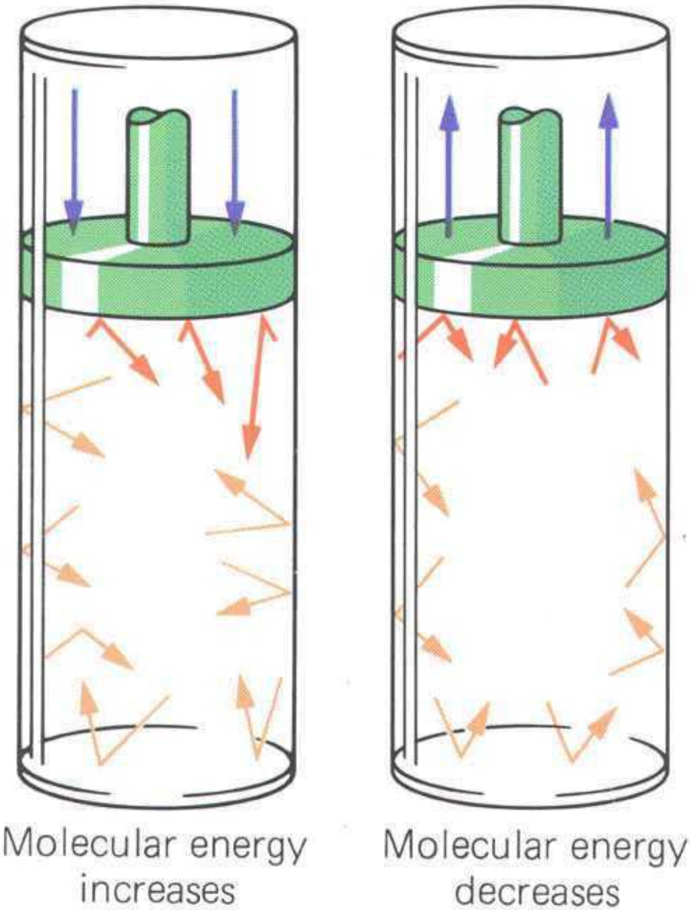


ENERGY TRANSFER TO/FROM THE GAS: HEAT OR WORK

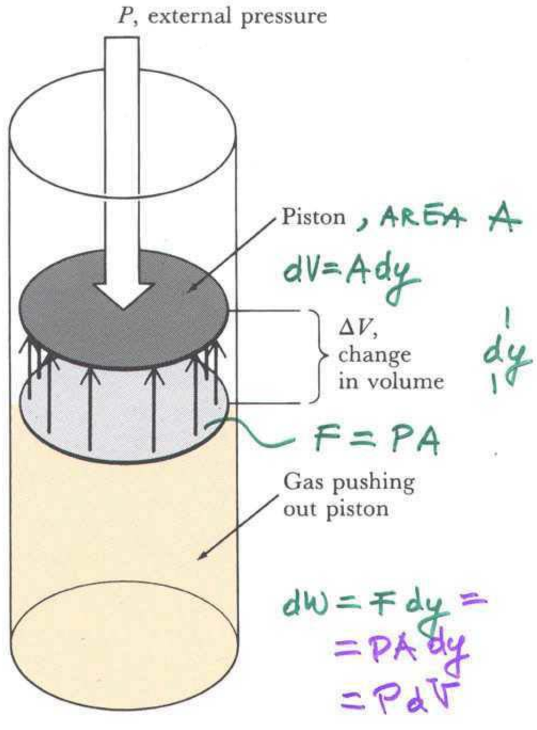
(18)

FIGURE 20-3

Figure 4-21



18')



T-146
FIGURE 16.1

THE GAS IS DOING WORK W>0 ON THE PISTON

(9)

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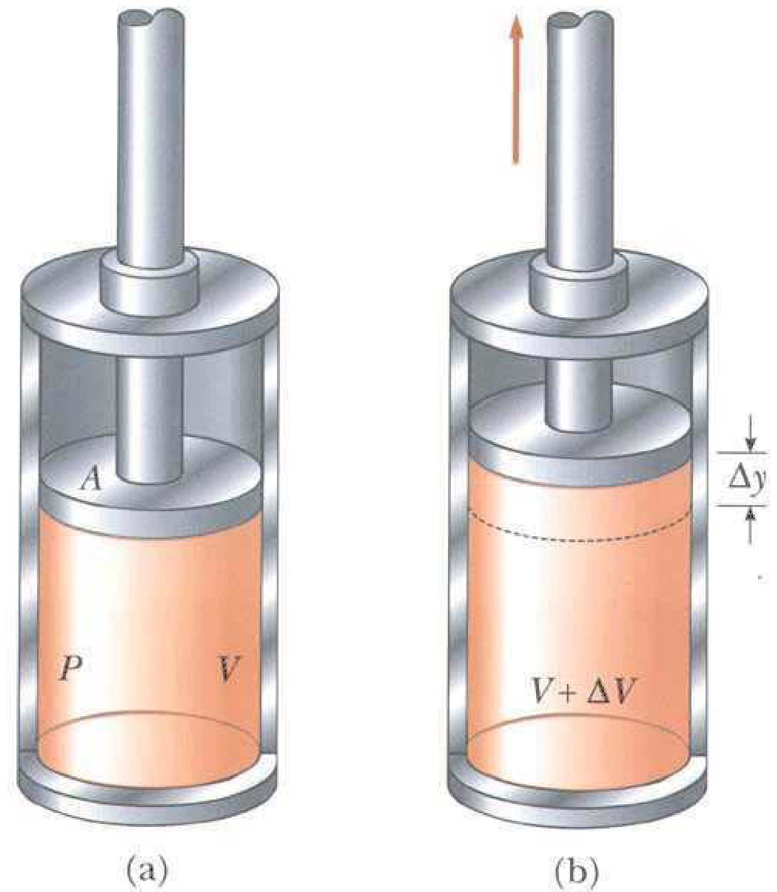
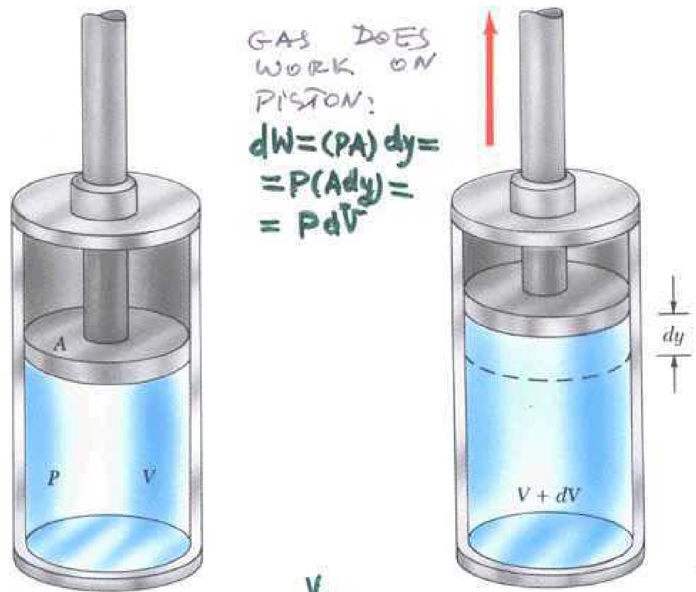


Overhead transparencies to accompany Serway/Faughn: *College Physics, 4/e*
Figure 57 Text figure 12.2 page 355
(9') Gas contained by a cylinder with a movable piston

20')

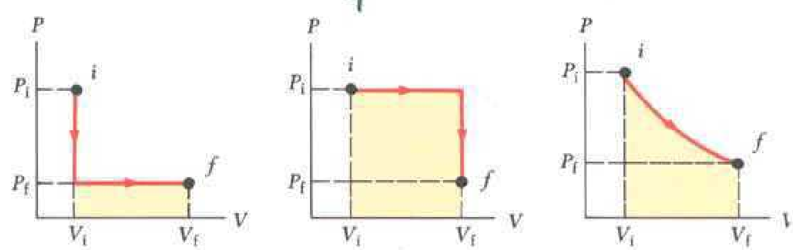


(a) (b)

GAS DOES WORK ON PISTON:

$dW = (PA)\,dy =$
$= P(A\,dy) =$
$= P\,dV$

$$W = \int_{V_1}^{V_2} P\,dV = \text{AREA UNDER P-CURVE}$$



(a) (b) (c)

57. Serway Fig. 20.3, Fig. 20.5

20)

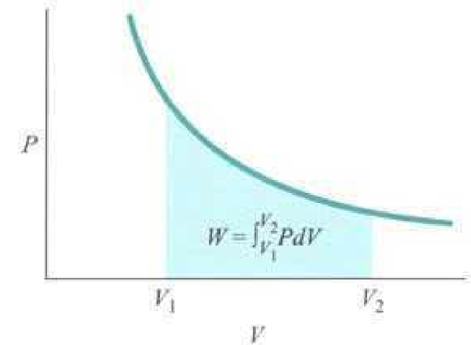
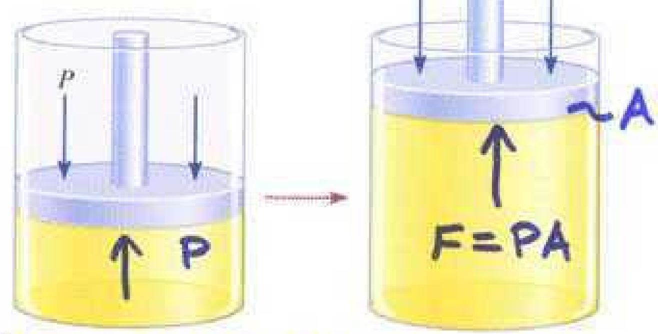


Figure 21-10
Physics for Scientists and Engineers, Second Edition
by Richard Wolfson and Jay M. Pasachoff

2a)

$$W=\int_{V_1}^{V_2} P\,dV = P\int_{V_1}^{V_2} dV = P(V_2-V_1)$$



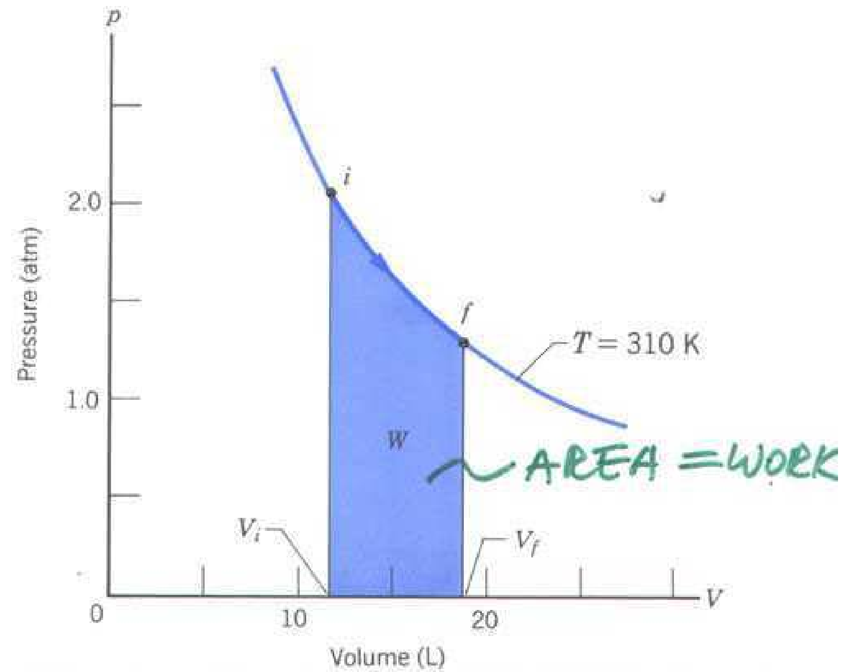
THE EXPANSION OF A GAS AGAINST A CONSTANT EXTERNAL PRESSURE P - ISOBARIC PROCESS

WORK OF GAS

$$W = P\Delta V$$

Figure 6.16

WORK IN ISOTHERMAL EXPANSION



GAS DOES POSITIVE W>0 WORK ON THE PISTON

A pV diagram.

22)

 FIG. 21.2

23)

$$P = \frac{nRT}{V} = \frac{\text{CONST}}{V}$$

ISOTHERMS

IDEAL GAS $PV = nRT$

$$W = \int_{V_1}^{V_2} P\,dV = nRT \int_{V_1}^{V_2} \frac{dV}{V} = nRT \ln \frac{V_2}{V_1}$$

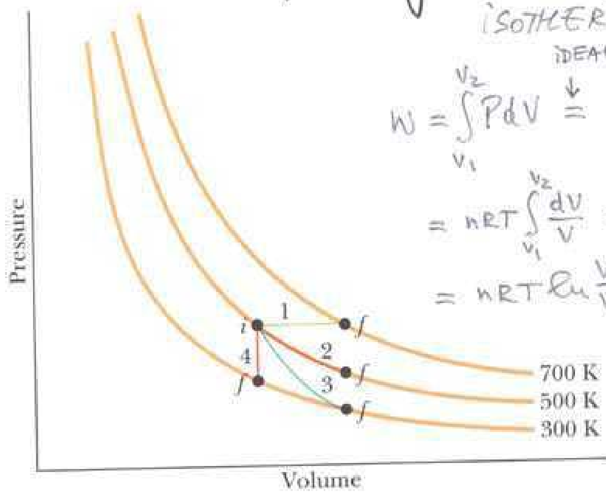
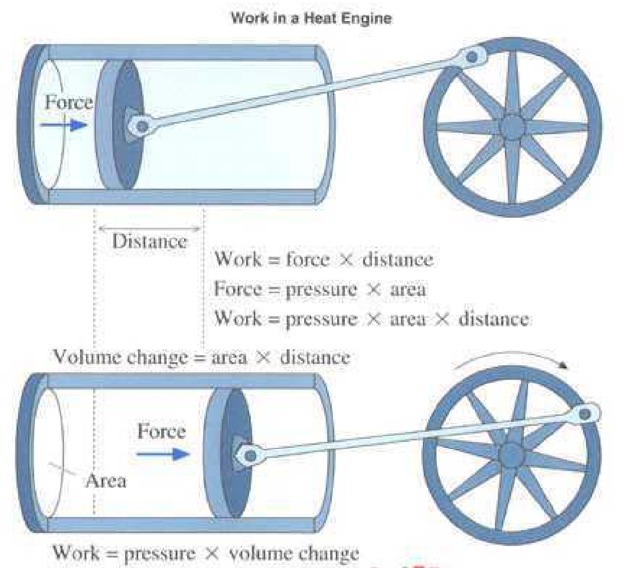


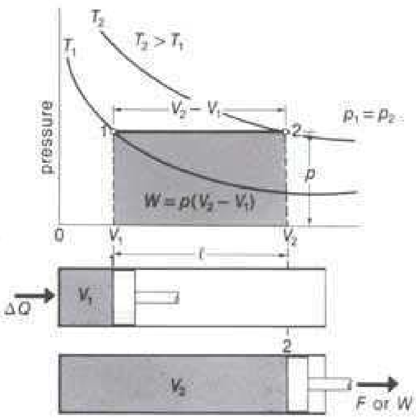
FIGURE 21-15 74

24)

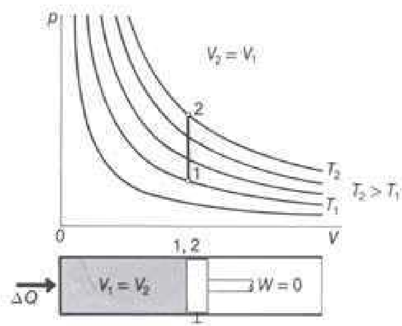


Acetate 8-2 (Figure 8.10)

$W = P\Delta V$ OR $dW = PdV$



ISOBARIC



ISOVOLUMETRIC

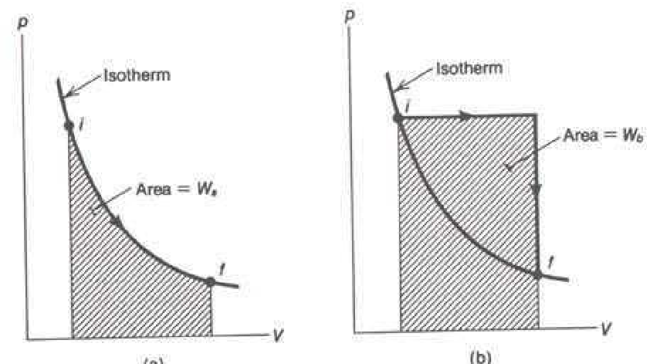


Figure 20-11

26)

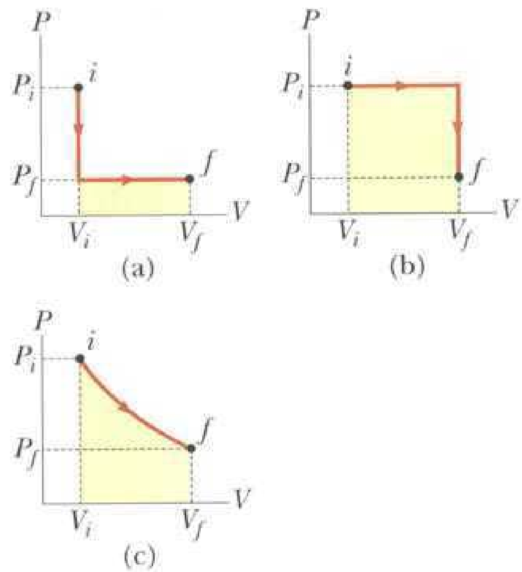


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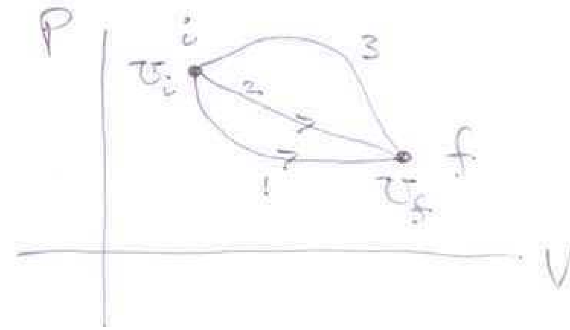
Figure 58 Text figure 12.4 page 356
Work done by a gas between initial state and final state

THE FIRST LAW OF THERMODYNAMICS



EXPER.: $Q_1 - W_1 = Q_2 - W_2 = Q_3 - W_3 = \dots$

$Q - W$ = THE SAME FOR DIFFERENT TRANSITIONS BETWEEN SAME i, f STATES.

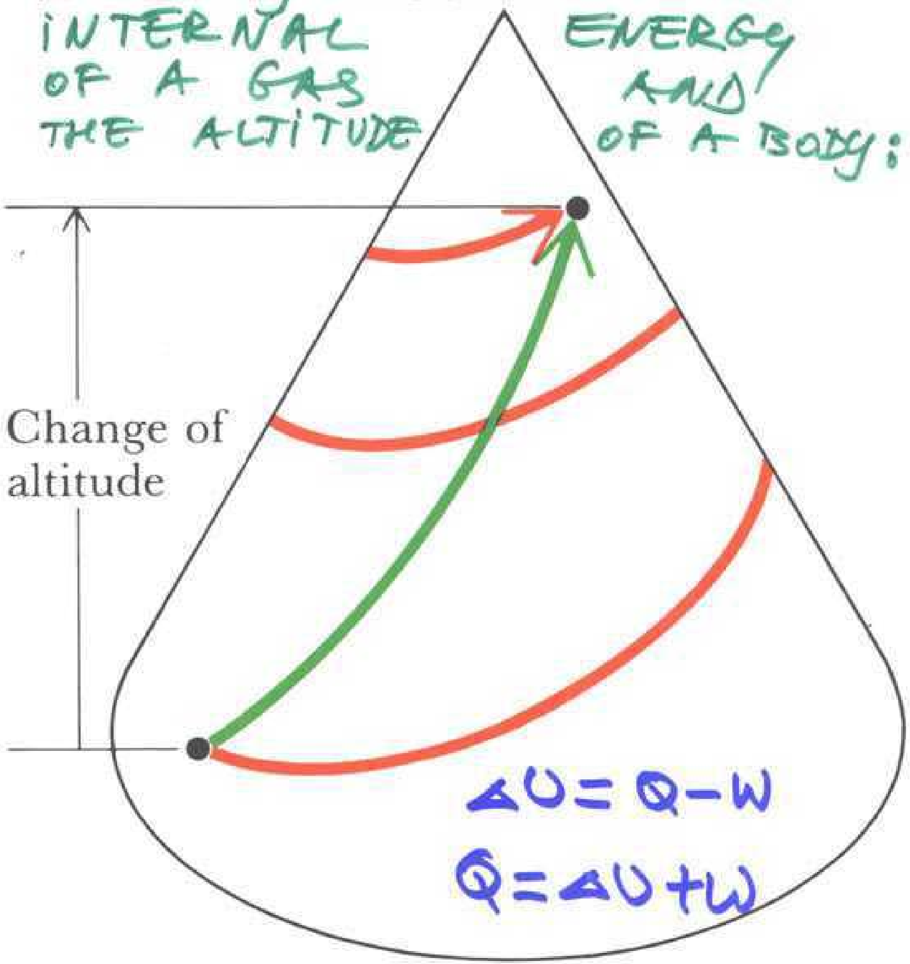
CONCLUSION: $\Delta U = U_f - U_i$

THERE EXISTS A QUANTITY U, CHARACTERIZING THE STATE OF THE BODY; WE DEFINE THE CHANGE IN U TO BE

$$\boxed{\Delta U = Q - W}$$ 1st LAW

27) ENERGY CONSERV.! U = INTERNAL ENERGY

ANALOGY BETWEEN INTERNAL ENERGY OF A GAS AND THE ALTITUDE OF A BODY:

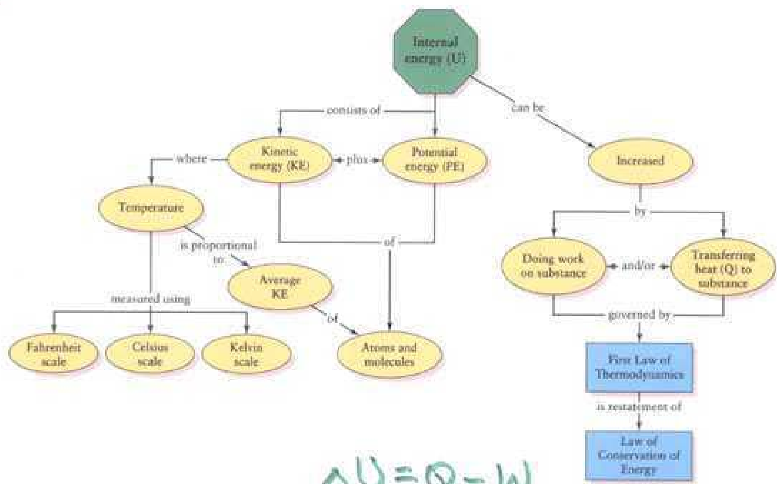


ALTITUDE IS A STATE PROPERTY; ITS CHANGE IS PATH-INDEPENDENT, GIVEN INIT. AND FINAL POINTS.

T-41
FIGURE 6.12

29)

Internal Energy



$\Delta U = Q - W$

Acetate 62 (Concept Map 5.1)

DIFFERENT PROCESSES **AND I LAW:**

- ISOTHERMAL : $T = \text{const}$
- ADIABATIC : $Q = 0$

  1ST LAW: $\Delta U = \cancel{Q} - W$

  $\Delta U = -W$
- ISOBARIC : $P = \text{const}$

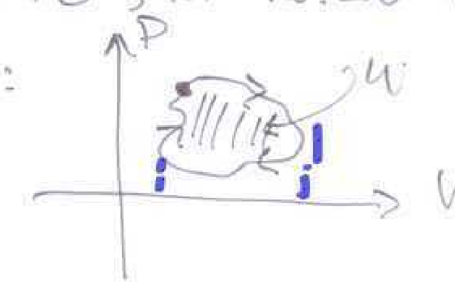
  $\text{WORK} = \int P\,dV \overset{\downarrow}{=} P\Delta V$
- ISOVOLUMETRIC : $V = \text{const}$

  $W = 0$; 1ST LAW: $\Delta U = Q$
- CYCLIC :

  $\Delta U = 0 \rightarrow$

  1ST LAW:

  $Q = W$

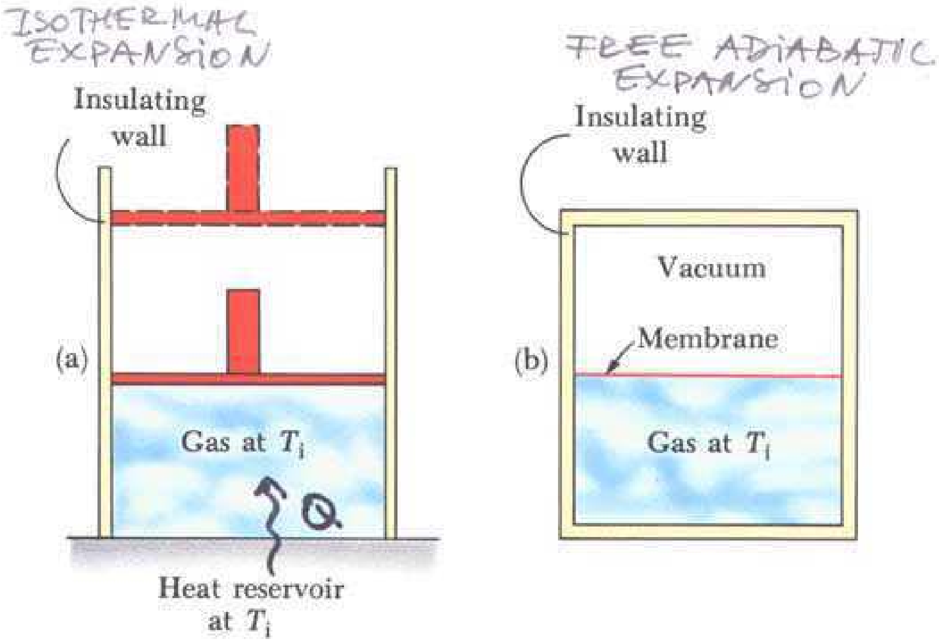


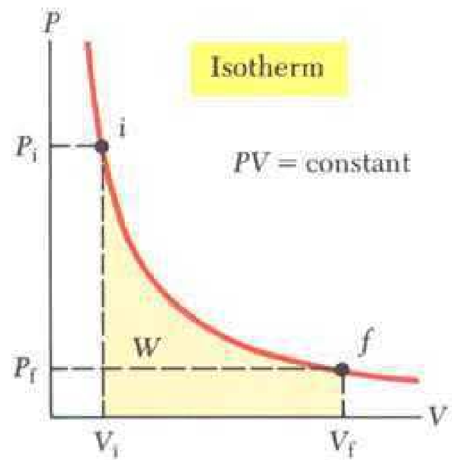
- FREE EXPANSION, ADIABATIC :

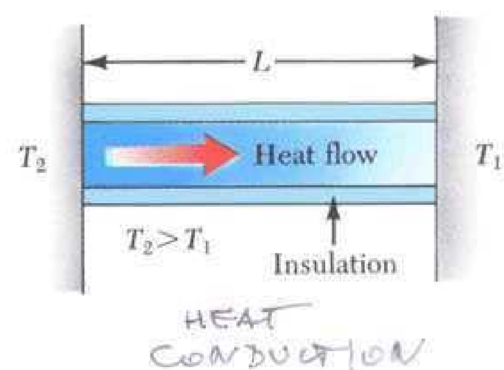
  $Q = 0$, $W = 0$

  1ST LAW: $\Delta U = 0$

30)


ISOTHERMAL EXPANSION
Insulating wall
(a)
Gas at T_i
Q
Heat reservoir at T_i
FREE ADIABATIC EXPANSION
Insulating wall
Vacuum
Membrane
(b)
Gas at T_i


P
Isotherm
P_i
i
PV = constant
W
f
P_f
V
V_i
V_f


L
T_2
Heat flow
T_1
$T_2 > T_1$
Insulation
HEAT CONDUCTION

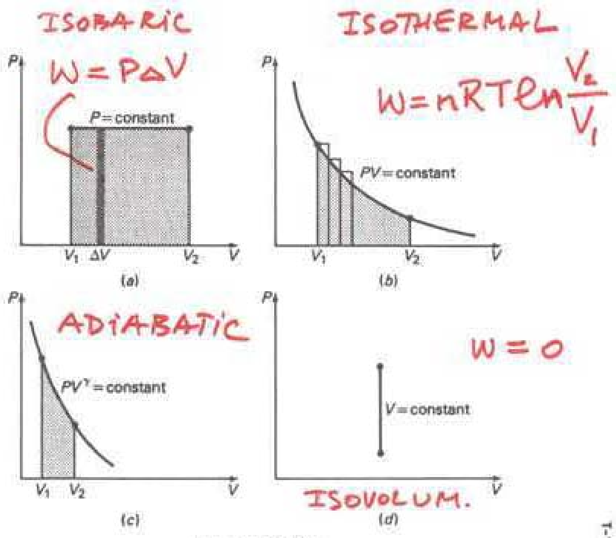
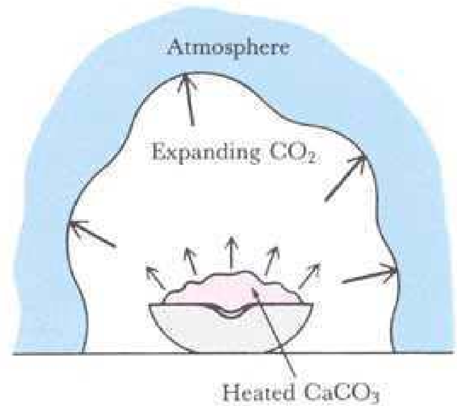


Figure 13.3 (p. 291)

T-11

ISOBARIC



P = CONST.

FIGURE 16.2

T-147
FIGURES 16.2, 16.3

WORK DONE AGAINST THE ATMOSPHERE

ISOVOLUMETRIC

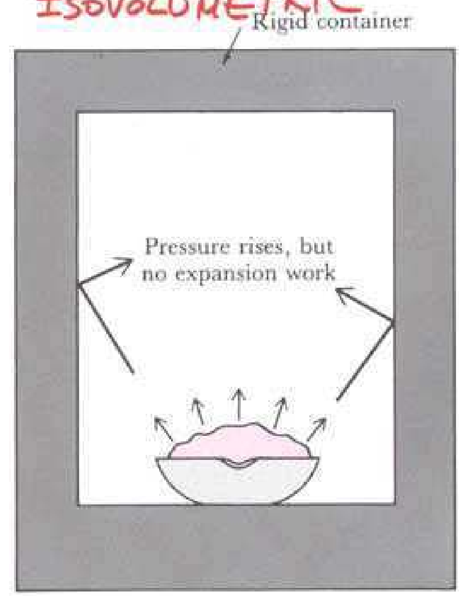


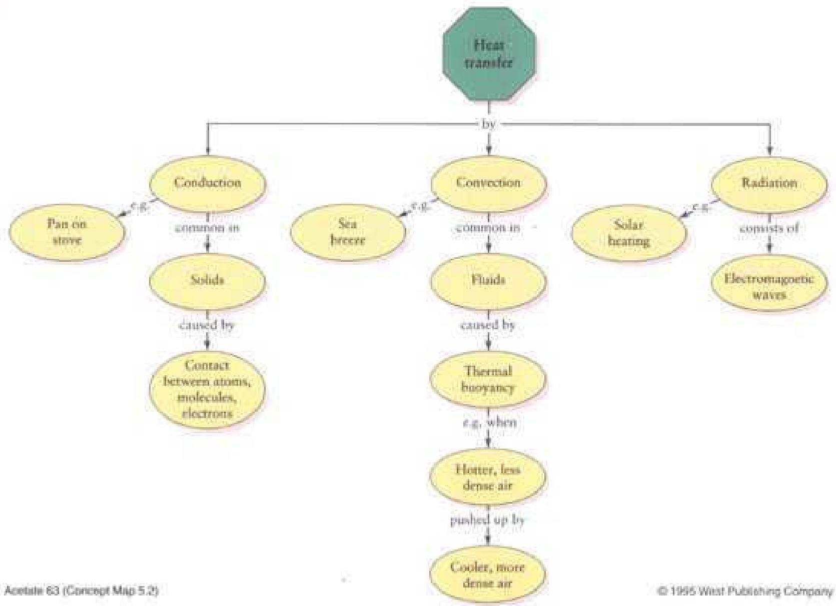
FIGURE 16.3

NO WORK DONE

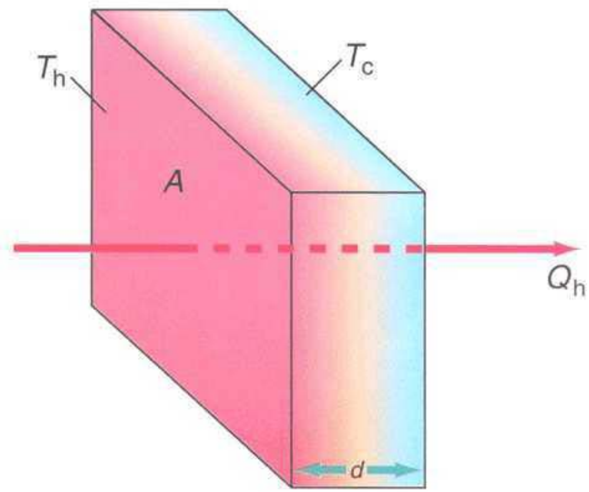
V = CONST.

34)

Mechanisms of Heat Transfer



Acetate 63 (Concept Map 5.2)

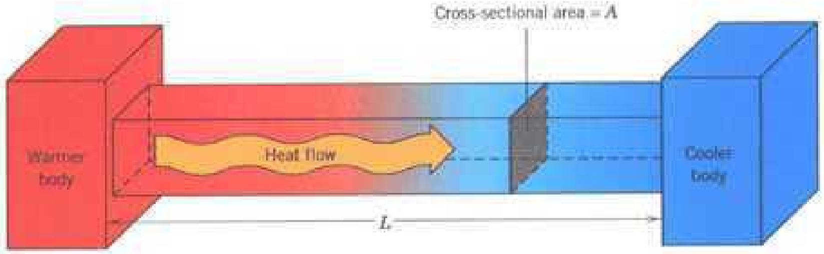


34')

48 **Heat conduction through a slab**
Figure 16.6

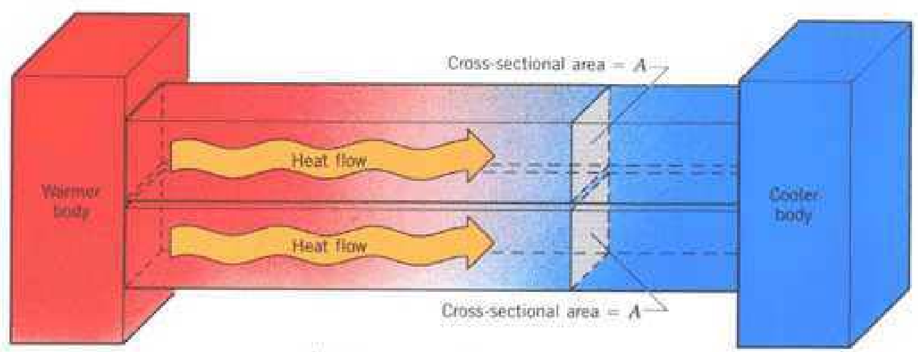
35

HEAT IS CONDUCTED THROUGH THE BAR WHEN THE ENDS OF THE BAR ARE MAINTAINED AT DIFFERENT TEMPERATURES.



36

TWICE AS MUCH HEAT FLOWS THROUGH TWO IDENTICAL BARS AS THROUGH ONE BAR:



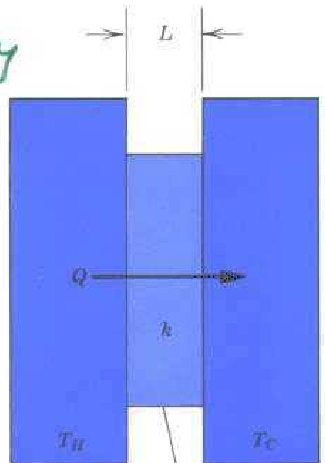
$$\frac{dQ}{dt} \sim A$$

FIGURE 13.9

HEAT TRANSFER BY CONDUCTION:

$$\mathcal{H} \equiv \frac{dQ}{dt} = k A \frac{\Delta T}{L}$$

K = THERMAL CONDUCTIVITY



$T_H > T_C$

$\Delta T = T_H - T_C$

Thermal conduction.

37)

 FIG. 20.8

37)

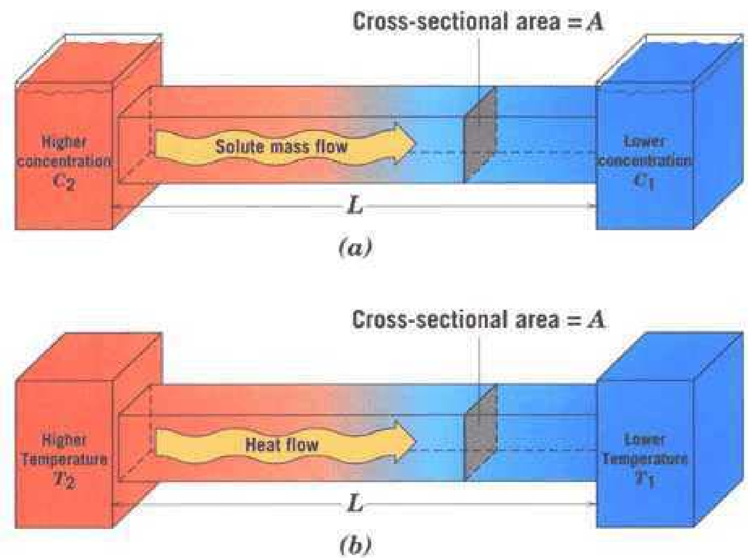


FIGURE 14.14

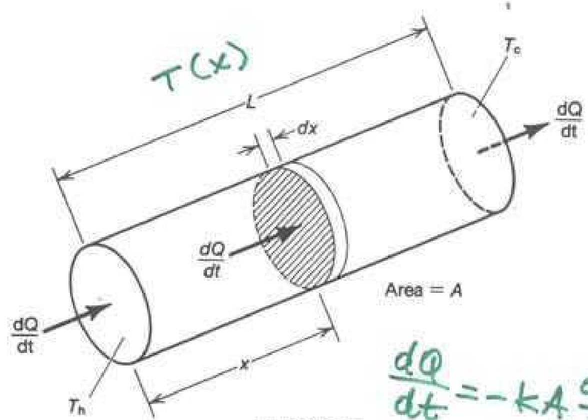
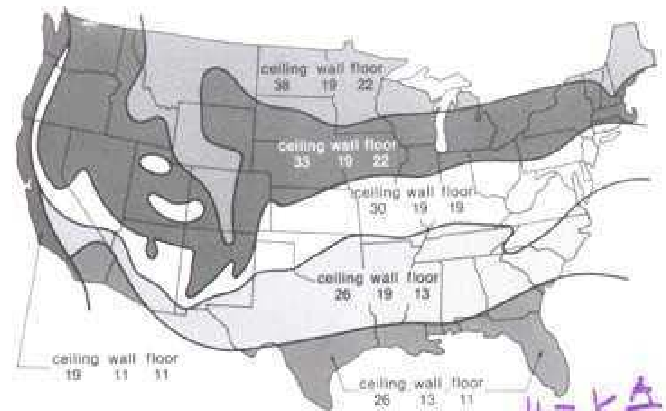


Figure 21-5

$$\frac{dQ}{dt} = -kA\frac{dT}{dx}$$



(a)

$$H = k\frac{A}{L}\Delta T$$

INSULATION R NUMBERS,

$$R = \frac{L}{k}$$

$$H \left(= \frac{dQ}{dt}\right) = \frac{A\Delta T}{R}$$

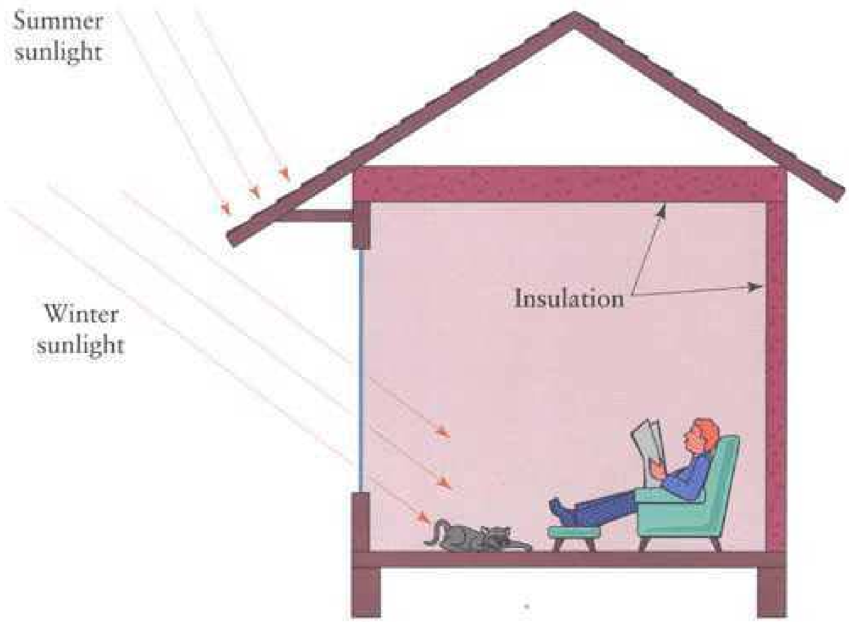
UNIT OF R:

$$\frac{ft^2 \cdot F^\circ \cdot h}{BTU}$$

(b)

(40)

Home Heat Transfer Considerations



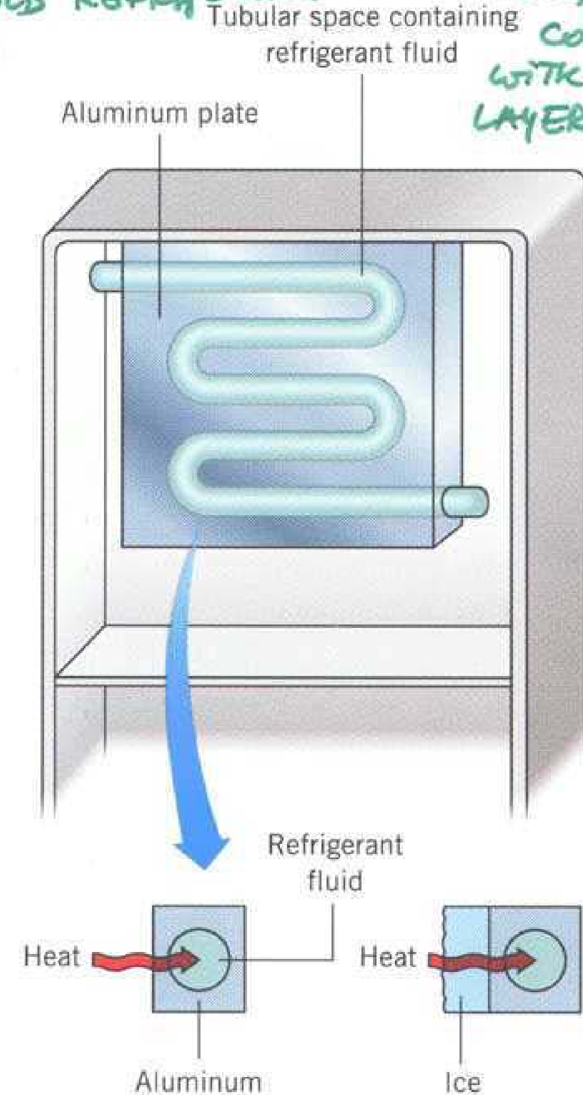
Acetate 60 (Figure 5.26)

IN A REFRIGERATOR, COOLING IS ACCOMPLISHED BY A COLD REFRIGERANT FLUID.

IT WORKS LESS WELL, WHEN COATED WITH A LAYER OF ICE:

$K_{ice} = 2.2$

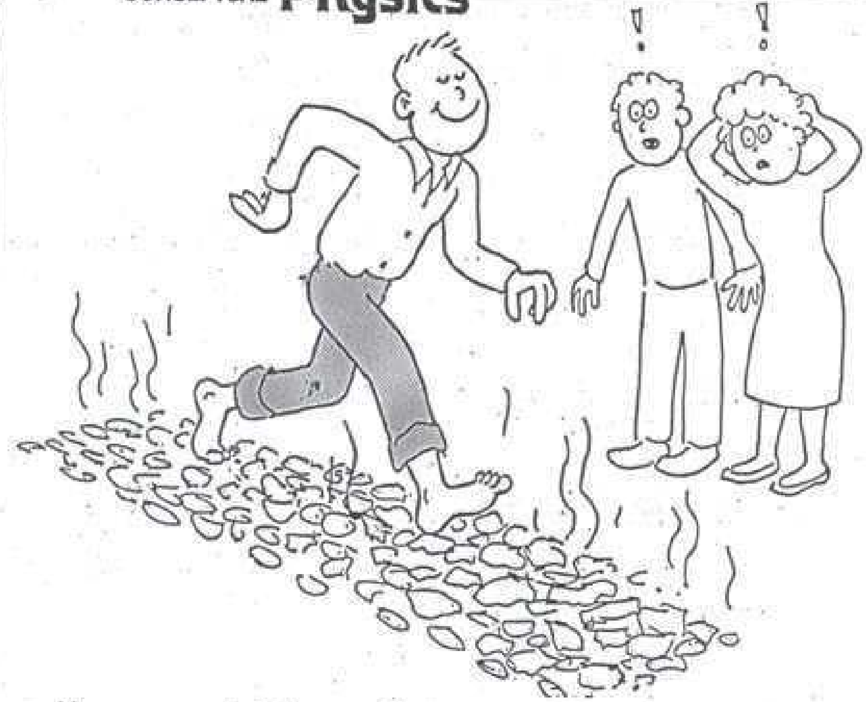
$K_{Al} = 240$



4D

FIGURE 13.11

CONCEPTUAL **Physics**



He can quickly walk barefoot across red hot coals of wood without harm because of

a) mind of matter

b) reasons that are outside mainstream physics

c) basic physics concepts

Hewitt Drew It!

42)

CONCEPTUAL **Physics**

He can quickly walk barefoot across red hot coals of wood without harm because of

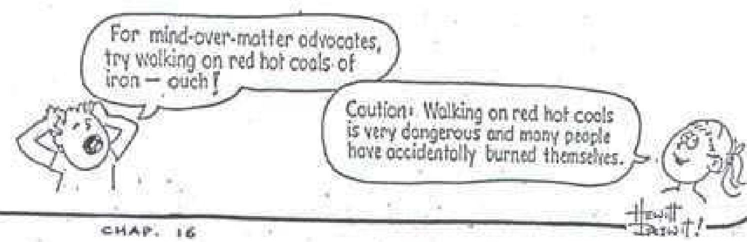
a) mind of matter

b) reasons that are outside mainstream physics

c) basic physics concepts

The answer is c:

First of all, the coals are wood, a very poor conductor of heat. Wood is a poor conductor even when it's hot, which is why wooden handles are used on cookware. Even when the wood is red hot, its poor conductivity allows quick steps without the transfer of very much heat. High temperature and how much heat transfers are entirely different physics concepts. Secondly, if your feet are damp because of perspiration or wet surrounding grass, even less heat is transferred to your feet. Why? Two reasons: Some of the heat energy goes into evaporating the moisture that would otherwise burn you — and when the moisture turns to vapor it provides an insulating blanket. This is why you wet your finger before touching a hot clothes iron.



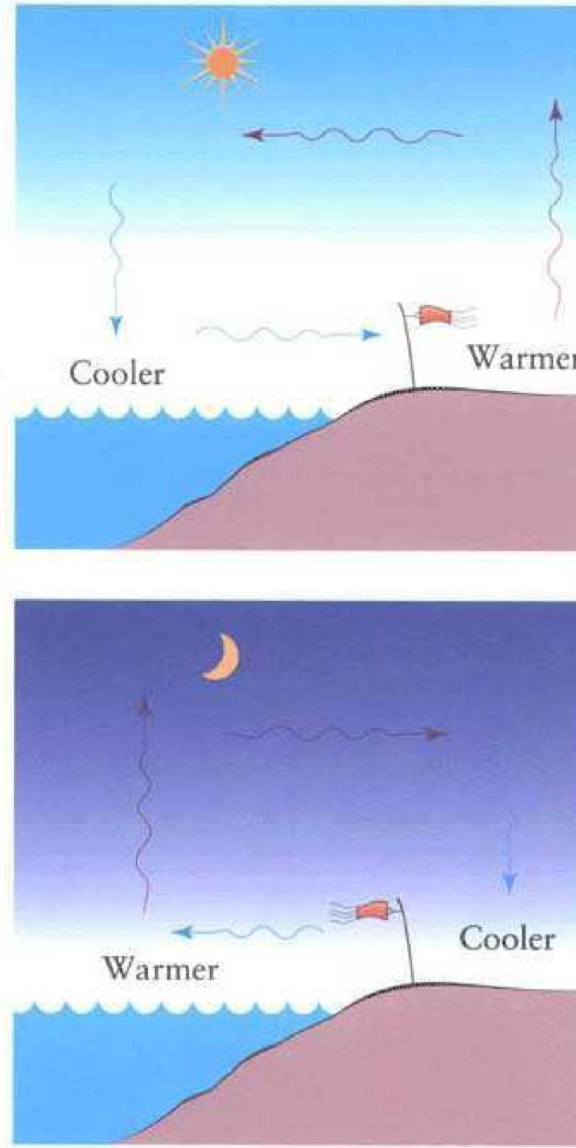
43)

CONVECTION

BETWEEN TWO PLATES OF DIFFERENT TEMPERATURE

CONVECTION:

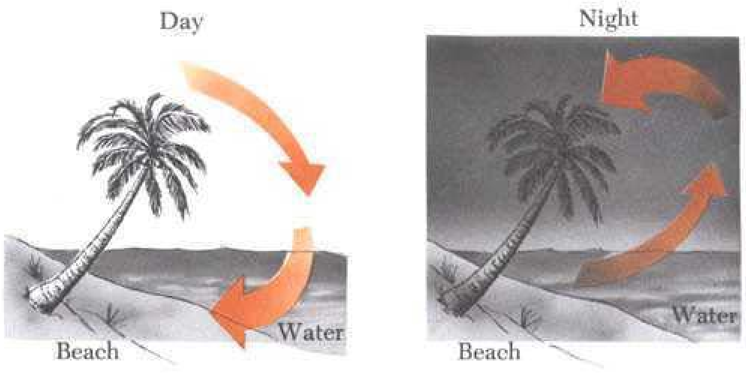
Sea Breeze and Land Breeze



WARMER AIR RISES FROM THE HEATED LAND, CAUSING COOLER AIR TO BE DRAWN IN FROM THE SEA.

THE LAND COOLS AT NIGHT, SO THE FLOW IS REVERSED.

e 5.23)



(a) (b)

Fig. 12-1

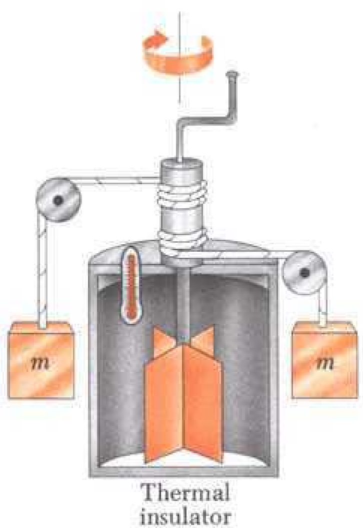
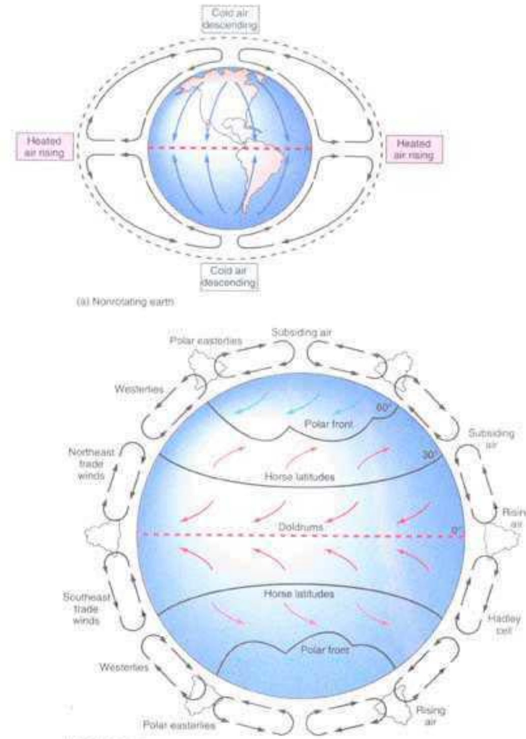


Fig. 12-2

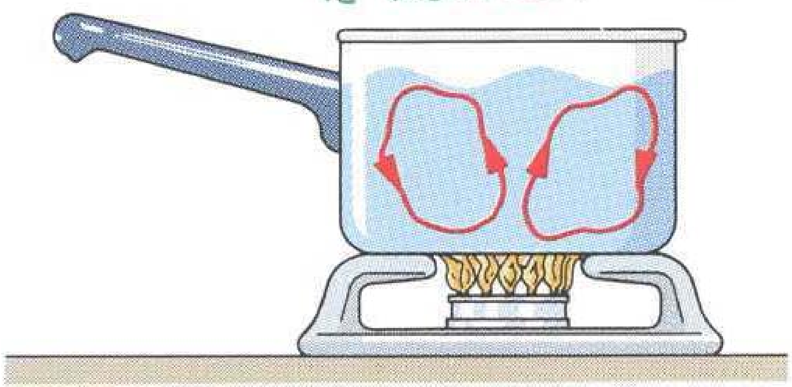


(a) Nonrotating earth

(b) Rotating earth

47 (45) Convection in the atmosphere
Figure 16.2

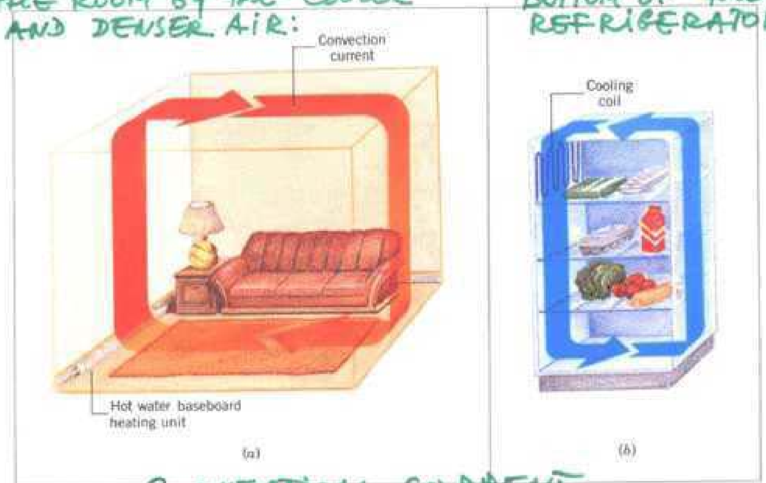
CONVECTION CURRENTS ARE SET UP WHEN A PAN OF WATER IS HEATED:



4.7)

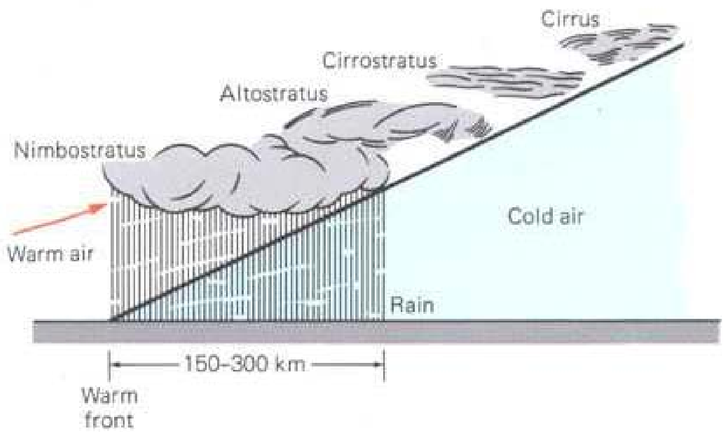
AIR WARMED BY THE HEATING UNIT IS PUSHED TO THE TOP OF THE ROOM BY THE COOLER AND DENSER AIR:

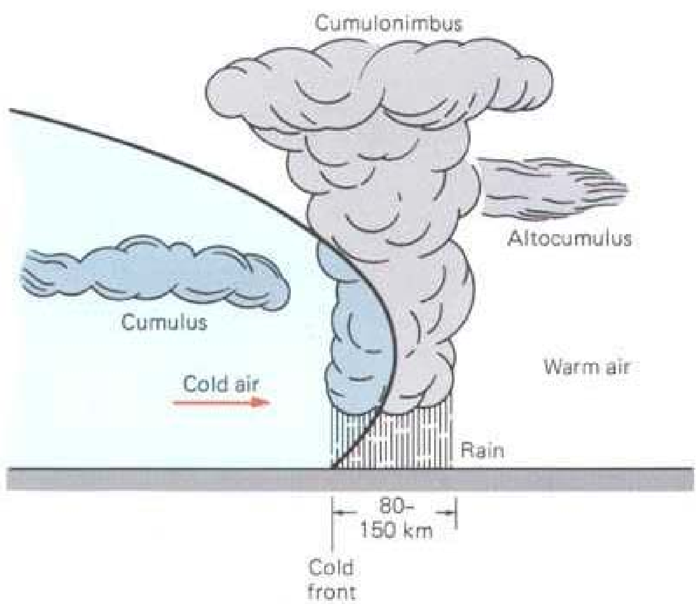
AIR COOLED BY THE COOLING COIL SINKS TO THE BOTTOM OF THE REFRIGERATOR:

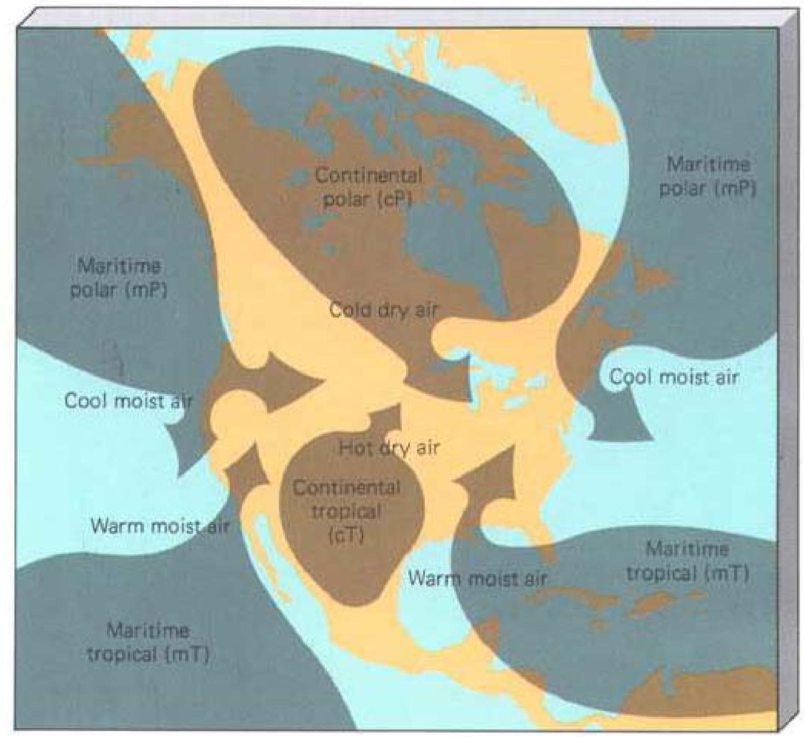


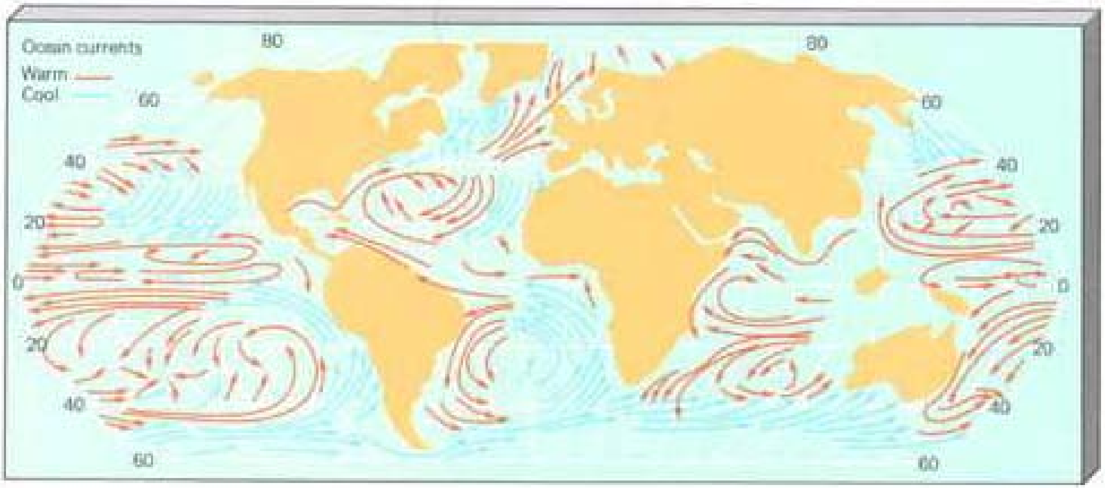
CONVECTION CURRENT IS ESTABLISHED.

FIGURE 13.3 115

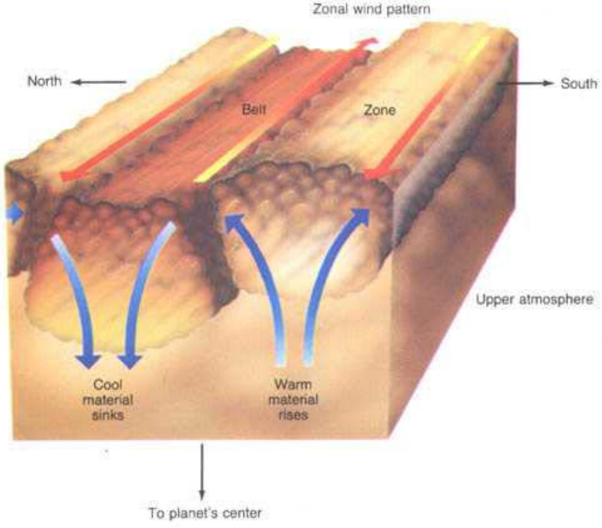

Cirrus
Cirrostratus
Altostratus
Nimbostratus
Warm air
Cold air
Rain
150-300 km
Warm front
(a)


Cumulonimbus
Altocumulus
Cumulus
Cold air
Warm air
Rain
80-150 km
Cold front
(b)

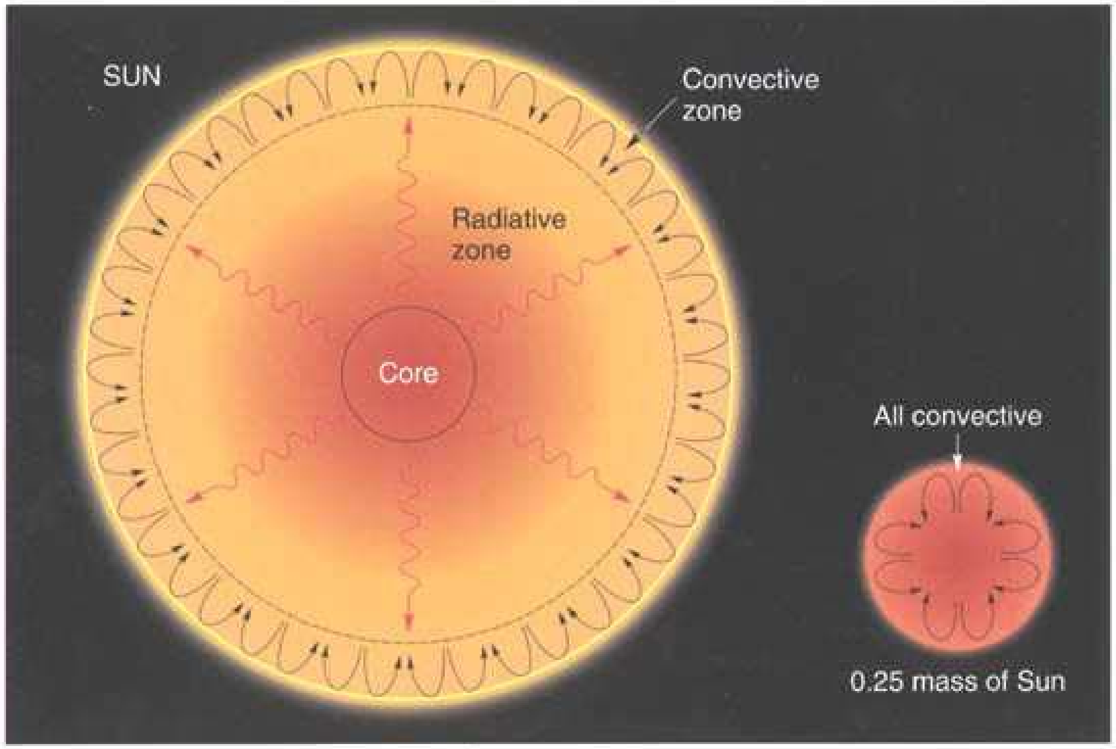

Continental polar (cP)
Maritime polar (mP)
Maritime polar (mP)
Cold dry air
Cool moist air
Cool moist air
Hot dry air
Continental tropical (cT)
Warm moist air
Warm moist air
Maritime tropical (mT)
Maritime tropical (mT)



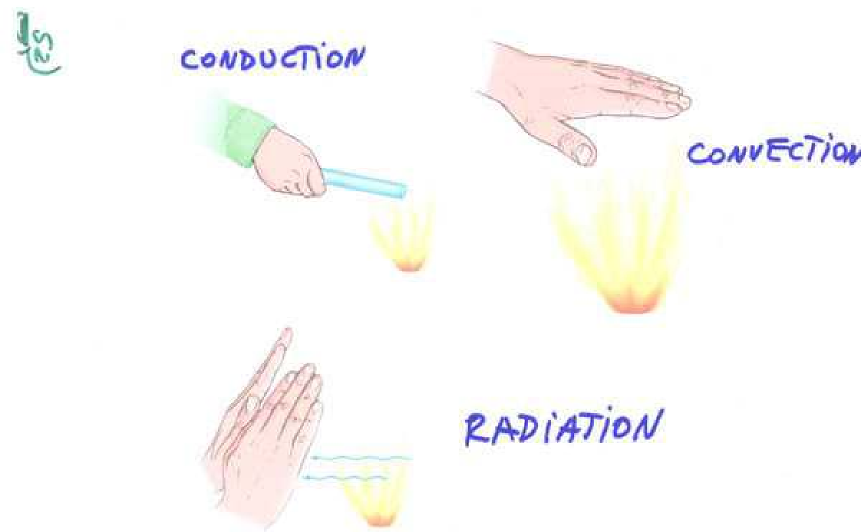
T 13-4 Zones and bands in Jupiter's atmosphere



Interior of the Sun and a flyweight star

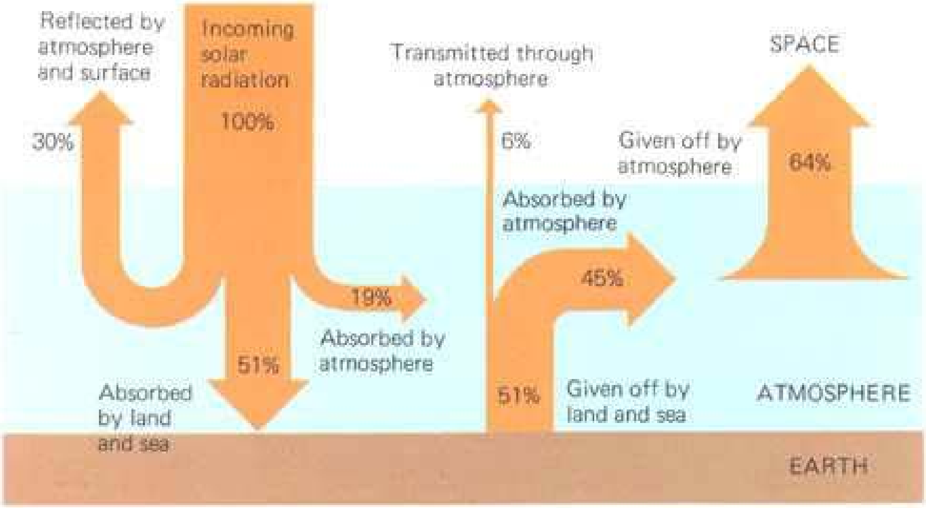


Acetate 172 (Figure 14-7)



Overhead transparencies to accompany Serway/Faughn: *College Physics, 4/e*
Figure 55 Text figures 11.4, 11.7, & 11.9 pages 334, 337, & 338
Conduction, convection, and radiation

Figure 13-7


Reflected by atmosphere and surface
30%
Incoming solar radiation
100%
Transmitted through atmosphere
6%
SPACE
Given off by atmosphere
64%
Absorbed by atmosphere
45%
19%
Absorbed by atmosphere
51%
Absorbed by land and sea
51%
Given off by land and sea
ATMOSPHERE
EARTH

THE GREENHOUSE EFFECT

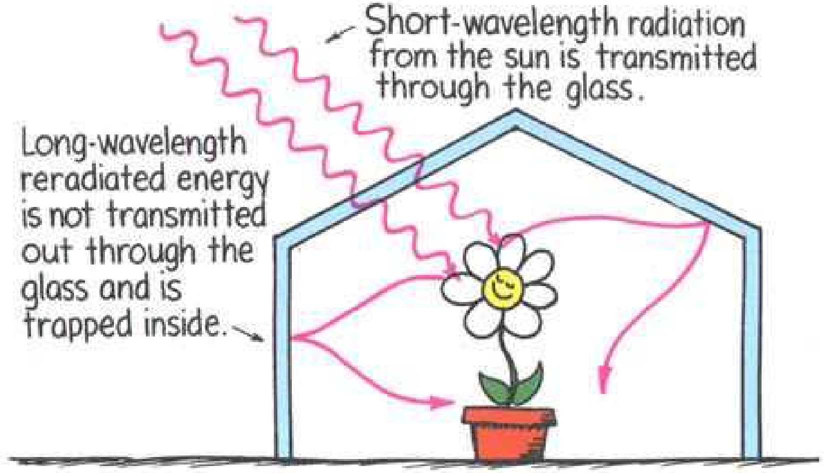
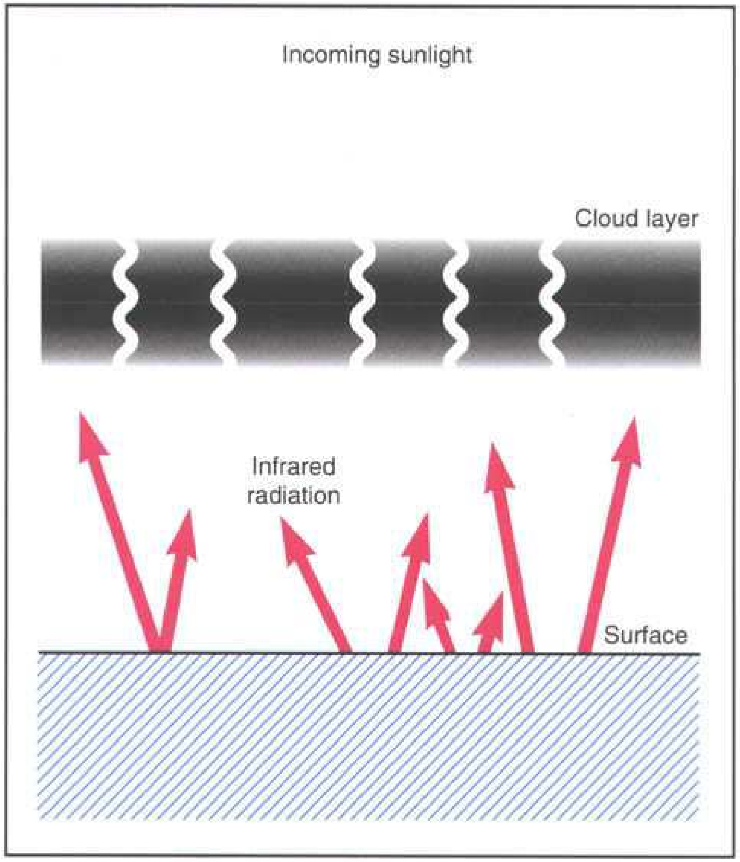


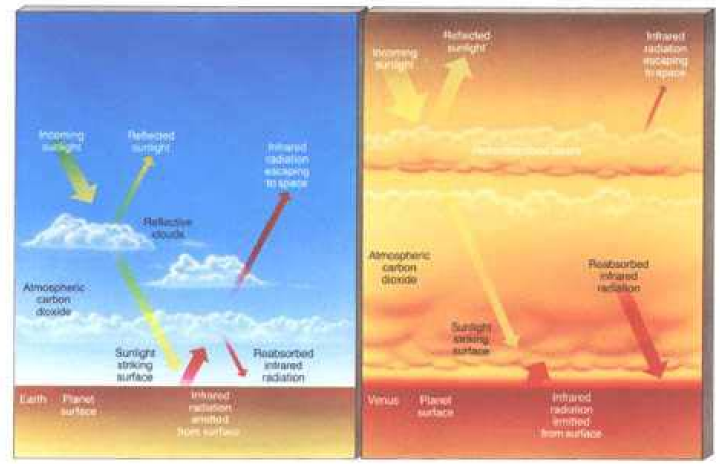
Figure 15.17
Conceptual Physics, Seventh Edition, by Paul G. Hewitt

The greenhouse effect



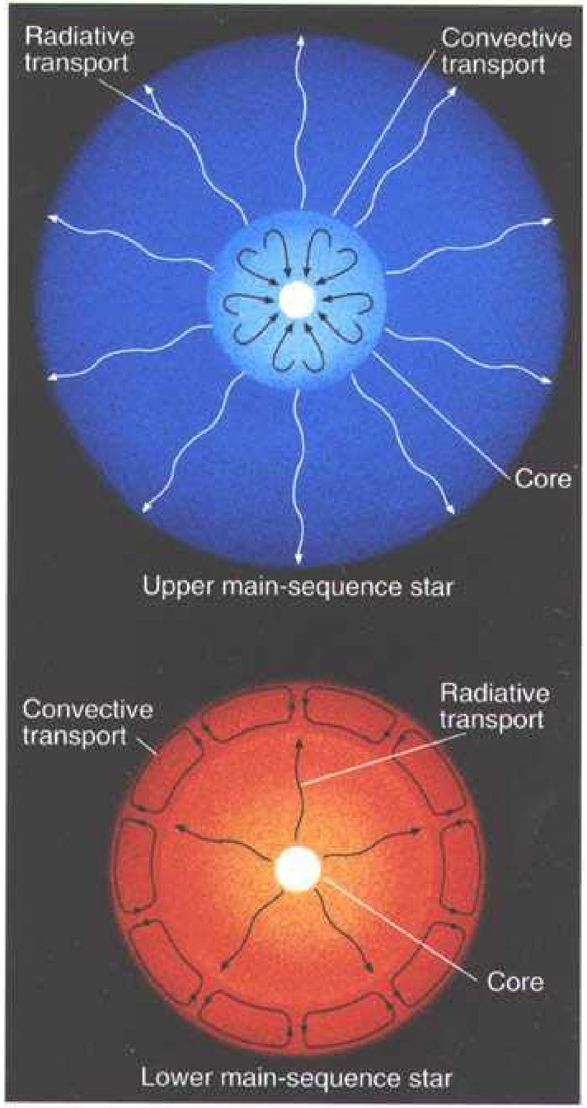
54)

T 11-2 Greenhouse effect on Earth and Venus



ASTRONOMY TODAY / (Chaisson/McMillan)

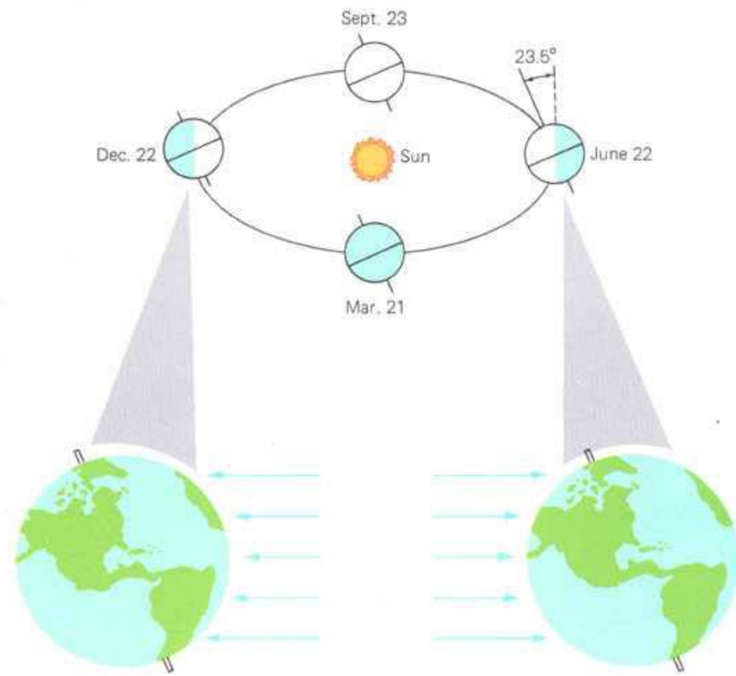
Energy Transport Inside Stars



Transparency 72 (Figure 13.5)

8)

Figure 13-10



57)

HEAT TRANSFER

CONDUCTION

CONVECTION

RADIATION:

$$P = \sigma e A T^4$$

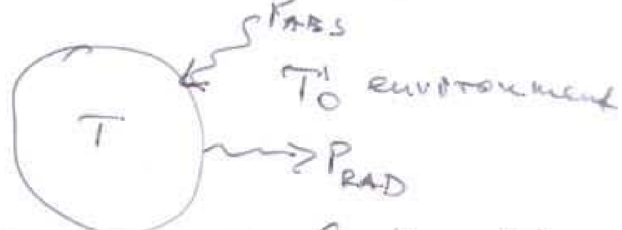
Stefan's law

σ – universal constant

e – emissivity

T – Body's temp. (Kelvin)

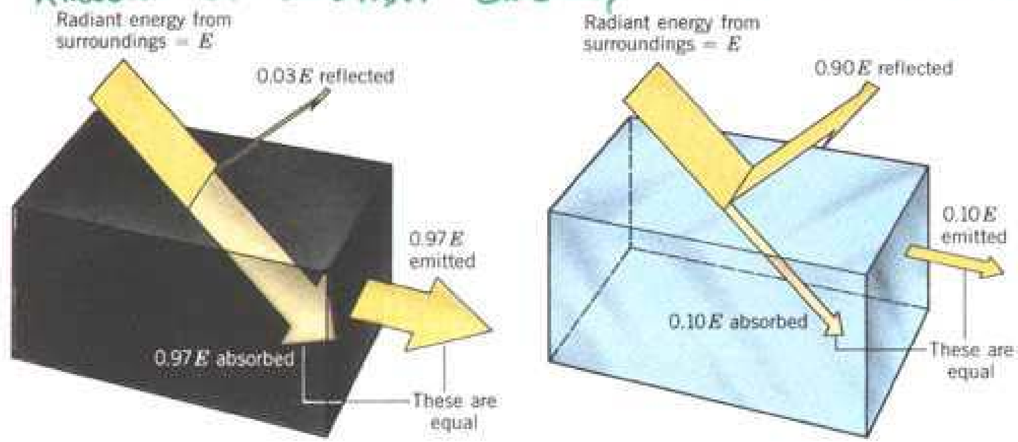
$0 \leq e \leq 1$



$$P_{NET} = \sigma A e (T^4 - T_0^4)$$

59, 60)

WHEN THE BLOCK AND ITS SURROUNDINGS HAVE THE SAME $T = T_0$, THE BLOCK EMITS THE SAME AMOUNT OF RADIANT ENERGY THAT IT ABSORBS



(a) Lampblack-coated block (b) Silver-coated block

$e = 0.97$ $e = 0.10$

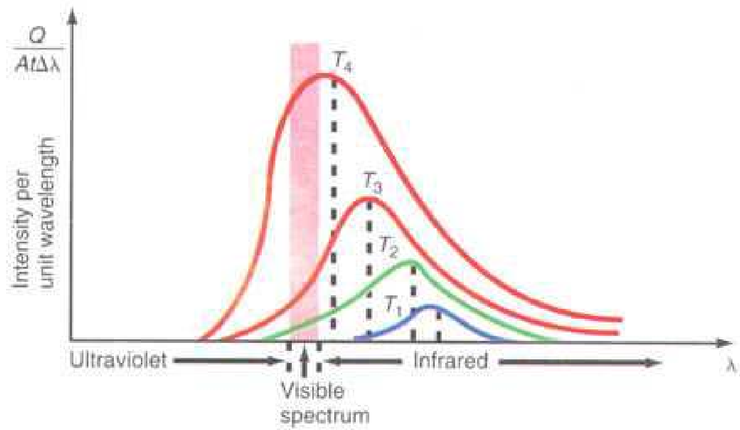
ALMOST PERFECT → REFLECTOR

ORBER

FIGURE 13.15 120

THE INTENSITY OF BLACKBODY RADIATION AS A FUNCTION OF WAVELENGTH AND TEMPERATURE

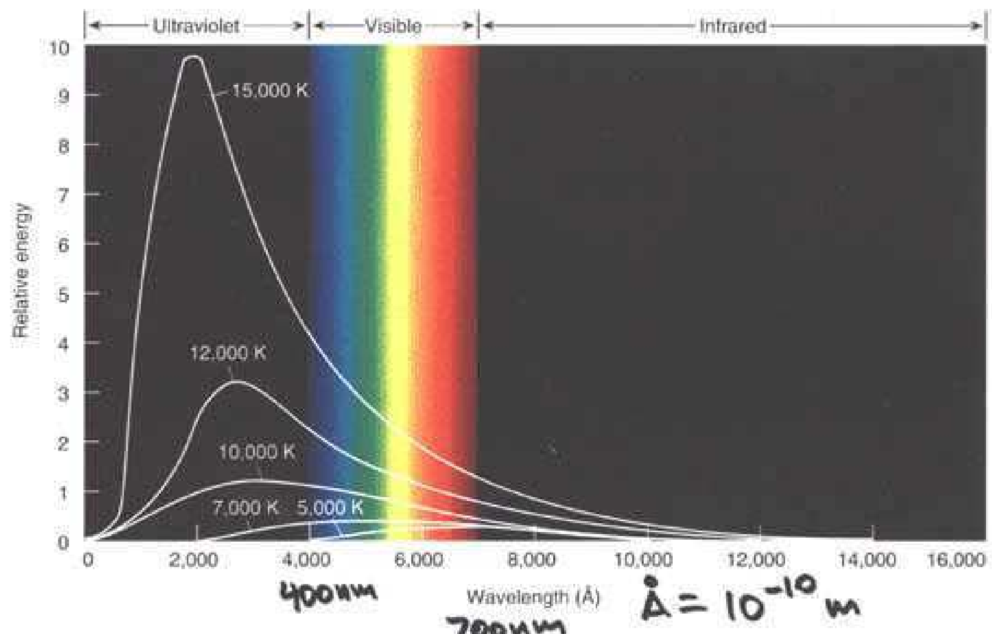
$T_4 > T_3 > T_2 > T_1$



49 **The intensity of blackbody radiation as a function of wavelength and temperature**
Figure 16.10

6)

Continuous spectra for objects of different temperatures



Transparency 28 (Figure 4.7)

62)

THE DESIGN OF A HOT WATER SOLAR COLLECTOR TAKES INTO ACCOUNT ENERGY TRANSFER VIA: CONVECTION, CONDUCTION AND RADIATION

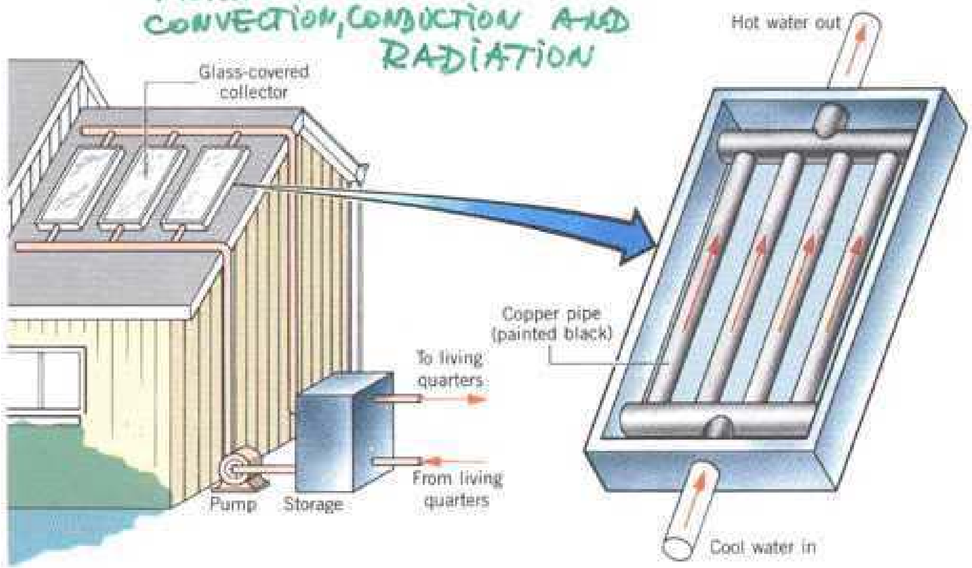


FIGURE 13.18