Module 3

Temperature and Heat Flow

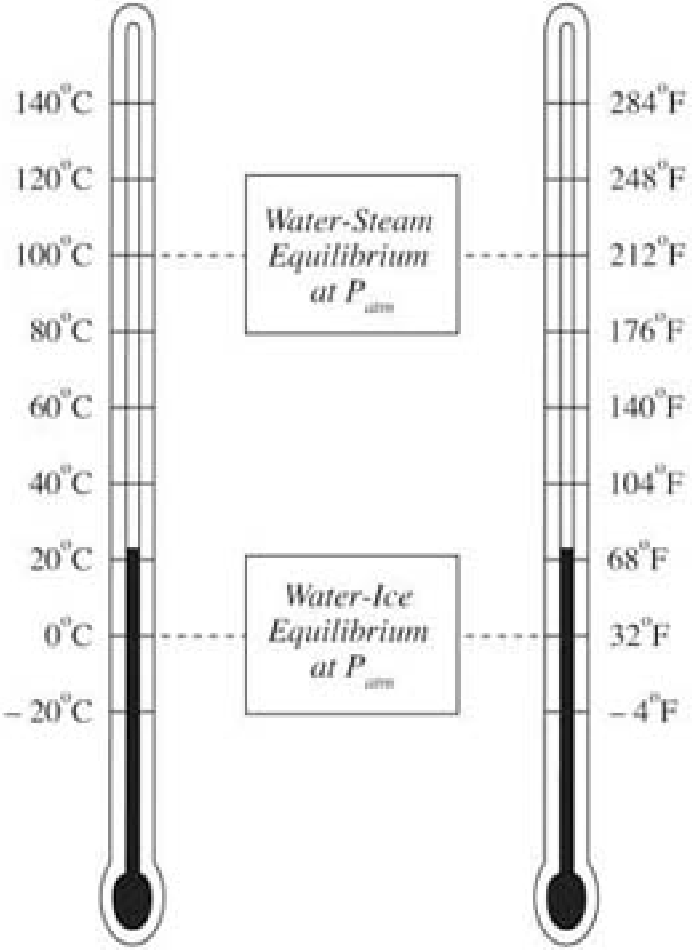
Session Slides with Notes

Converting Celsius and Fahrenheit

$$T_c = \frac{5}{9}(T_f - 32)$$

$$T_f = \frac{9}{5}T_c + 32$$

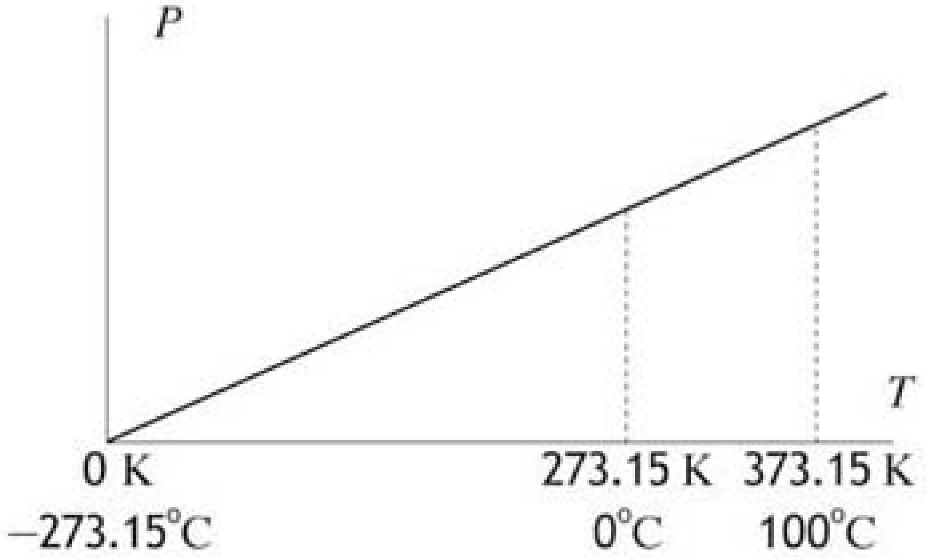
not on MCAT anymore



Kelvin Temperature

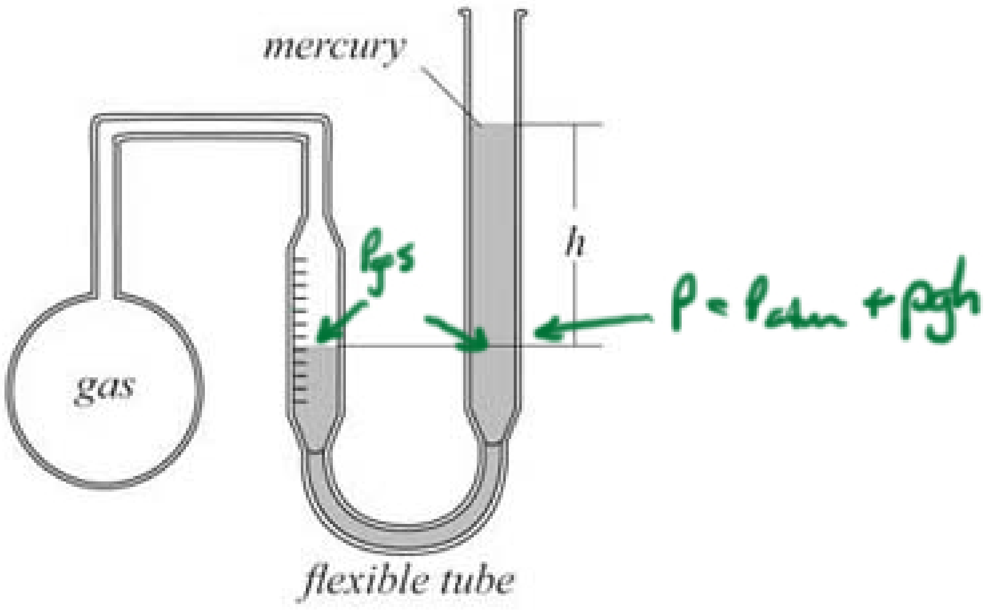
$$T = T_c + 273$$

Convert to Kelvin!



Pressure-Temperature Graph for a Constant Volume Gas Thermometer

How does the constant volume gas thermometer pictured at right measure temperature?



a. It measures the pressure of the gas.

b. It measures changes in the volume of the mercury.

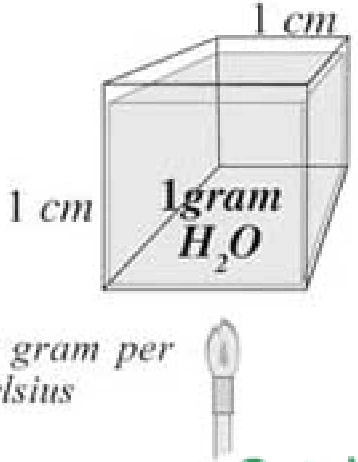
c. It measures the thermal expansion of the gas.

d. It measures the ratio of the density of the mercury to the density of the gas.

Specific Heat

$\frac{cal}{g\,°C}$ or $J/g\,°C$

$c_{H_2O} = \frac{1\,cal}{g\,°C} = \frac{4.18\,J}{g\,°C}$



Heat per gram per degree Celsius

$1\,cal = 4.18\,J$

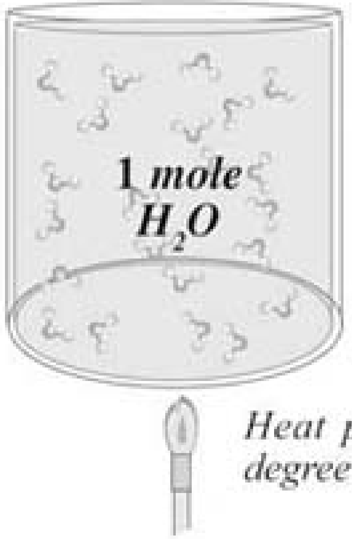
$(50g)\left(\frac{1\,cal}{g\,°C}\right)(30°) = 1500\,cal$

$$Q = m\,c\,\Delta T$$

Q	=	heat flow
m	=	mass
c	=	specific heat
ΔT	=	temperature change

Molar Heat Capacity

$\frac{cal}{mol\,°C}$ $J/mol\,°C$



6.02×10^{23} *molecules*

Heat per mole per degree Celsius

$$Q = n\,C\,\Delta T$$

Q	=	heat flow
n	=	number of moles
C	=	molar heat capacity
ΔT	=	temperature change

According to the *rule of Dulong and Petit* the molar heat capacity of metals with atomic weight above 35 is relatively constant (about 26 J / mole • °C). From the information presented, which of the metals in the table below has the lowest specific heat?

Element	Atomic Weight	Molar Heat Capacity at STP	
Ni	58.70	26.0	J / mole • °C
Ag	107.868	25.5	
Cd	112.40	26.0	
Pb	207.2	26.8	

a. Ni

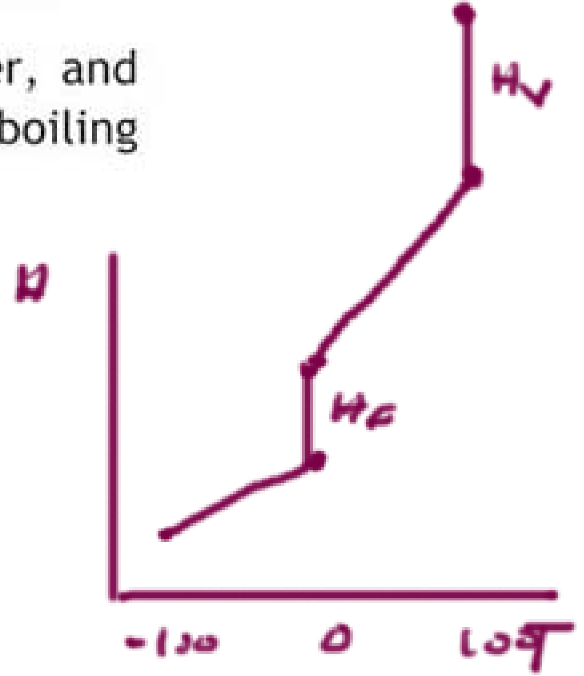
b. Ag

c. Cd

d. Pb

The table below gives the heat capacities of ice, liquid water, and steam as well as the heats of transformation for melting and boiling water (P = 1atm).

C_{ice} (cal/g $\cdot$ °C)	Latent Heat of Fusion (cal/g)	C_{water} (cal/g $\cdot$ °C)	Latent Heat of Vaporization (cal/g)	C_{steam} (cal/g $\cdot$ °C)
0.5	80	1	540	0.48



How much heat must be added to transform 1g of ice at -100°C into steam?

$Q = mc\Delta T$

a. 48 cal

b. 580 cal

c. 621.5 cal

d. 770 cal

The easiest path has four steps: 1) heating the ice from -100°C to 0°C; 2) melting the ice; 3) heating the liquid water from 0°C to 100°C; and finally, 4) boiling the water. The amount of heat which must be added for temperature change equals the product of the mass, specific heat and temperature change. For the phase changes, the amount of heat equals the product of the mass and the heat of transformation. Here are the computations for each of the four steps:

$$Q_{-100^\circ C \to 0^\circ C} = (1\ g)(.50\ \frac{cal}{g\ ^\circ C})(100^\circ C) = 50\ cal$$

$$Q_{fusion} = (1\ g)\ (80\ \frac{cal}{g}) = 80\ cal$$

$$Q_{0^\circ C \to 100^\circ C} = (1\ g)\ (1\ \frac{cal}{g\ ^\circ C})(100^\circ C) = 100\ cal$$

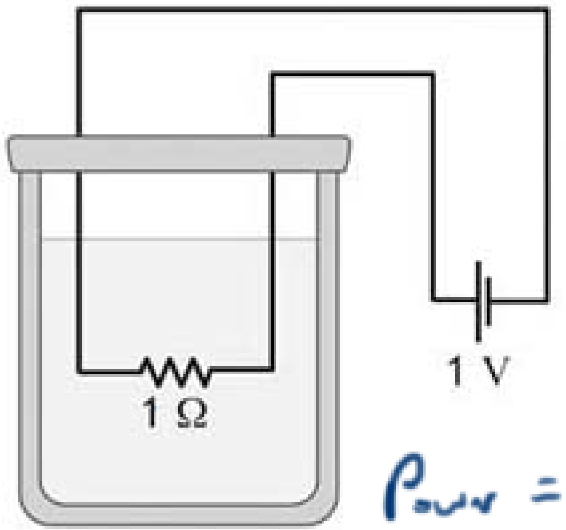
$$Q_{vaporization} = (1\ g)\ (540\ \frac{cal}{g}) = \underline{540\ cal}$$

$$sum = 770\ cal$$

THIS IS A VERY COMMONLY OCCURING TYPE OF PROBLEM. (ALTHOUGH THE COMPUTATIONS HERE ARE SUPPOSED TO BE EASY ENOUGH TO DO IN YOUR HEAD, IT'S A GOOD IDEA IN A TEST ENVIRONMENT TO WRITE THE COMPUTATIONS DOWN TO AVOID MISTAKES.

The Dewar flask at right contains 100ml of water at 25°C.

After a 1 volt (1 joule per coulomb) battery begins to deliver 1 ampere (1 coulomb per second) of current through the resistance immersed in the water, approximately how long does it take the water temperature to reach 35°C?



$c_{H_2O} = \frac{1 \text{ cal}}{g\,°C}$

$Q = (100 g)(\frac{1 cal}{g °C})(10°C)$

$= 1000$ cal

$P_{ower} = 1 \text{ J/s}$

$P = VI$

1000 cal = 4200 J

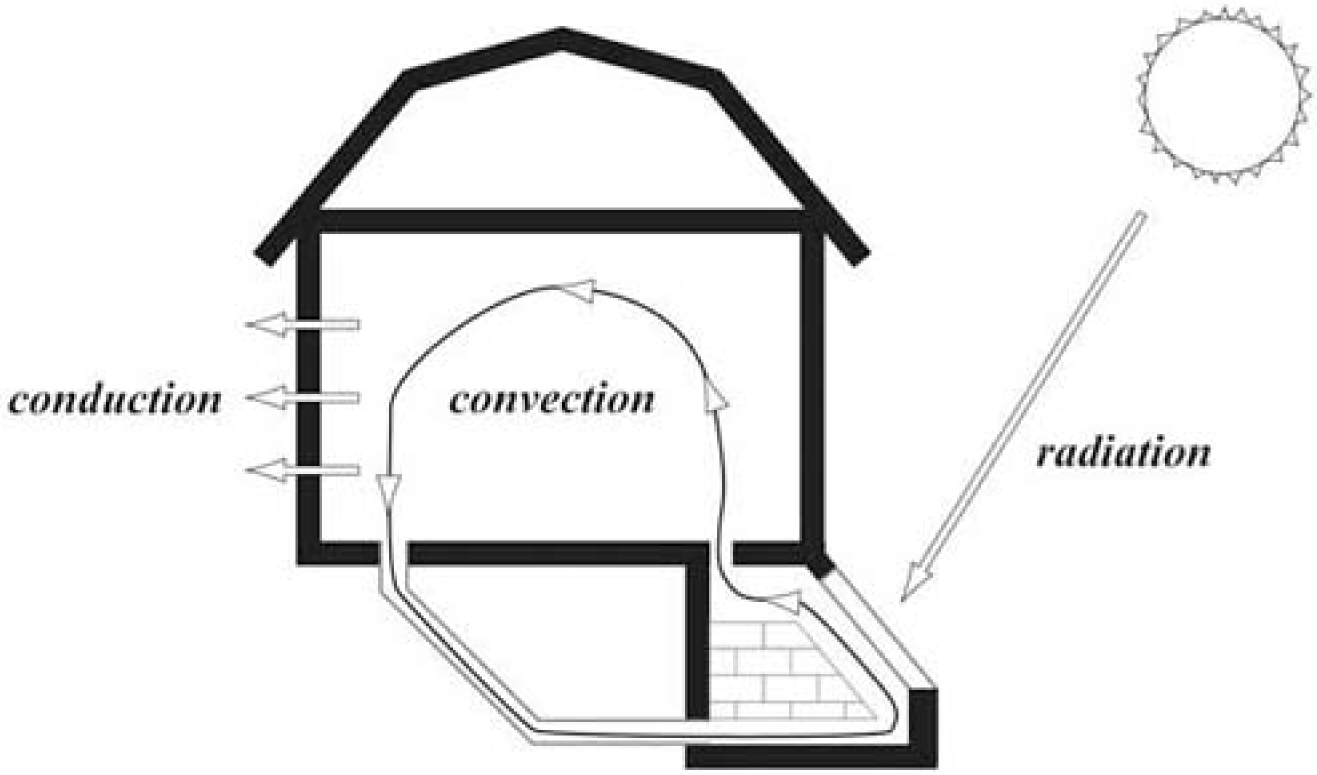
a. 10 seconds

b. 32 seconds

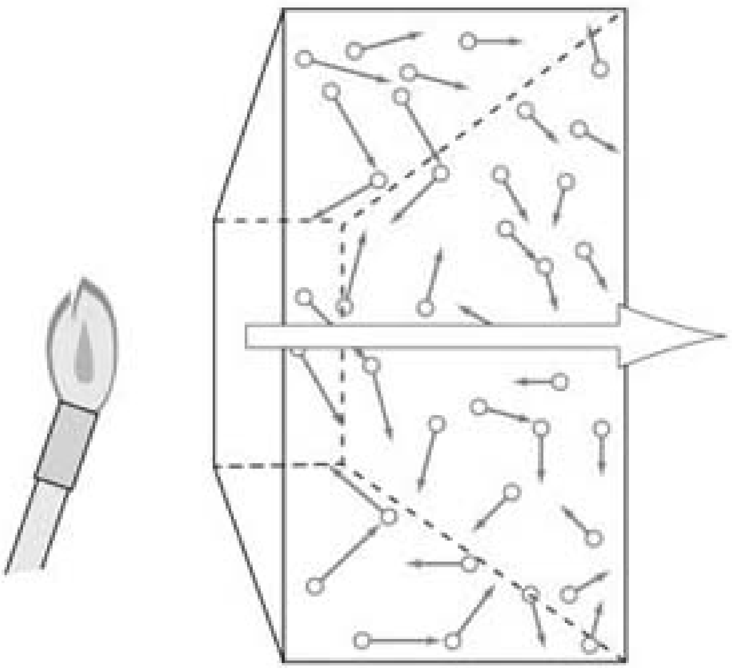
c. 1000 seconds

d. 4200 seconds

Three Modes of Heat Transmission



Transmission of Heat by Conduction

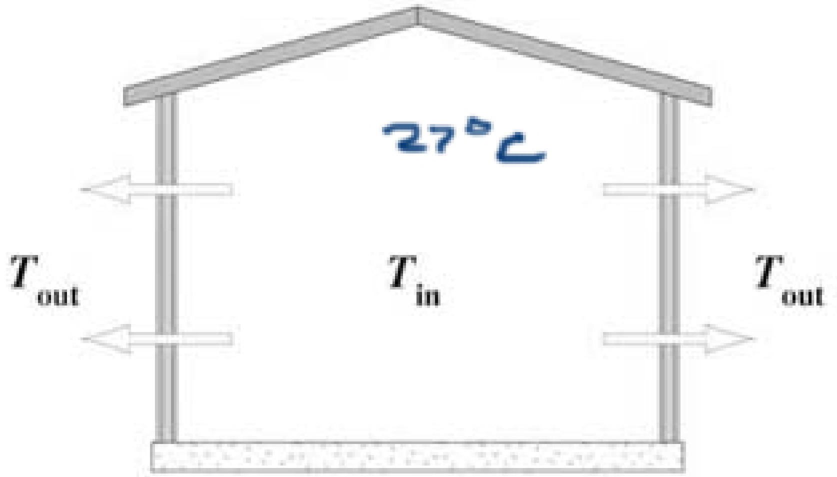


$$\frac{Q}{t} = K\,A\,\frac{\Delta T}{\Delta x}$$

Q	=	heat flow
t	=	time
K	=	thermal conductivity of material
A	=	cross-sectional area
ΔT	=	temperature difference across the conductor $(T_2 - T_1)$
Δx	=	conductor thickness

When warmer (faster) molecules collide with cooler (slower) molecules, the warmer molecules transfer part of their energy to the cooler molecules. Conduction of heat is occuring.

Night or day, the interior of a house is maintained at a constant temperature of 27°C. During the day, the outside temperature is 17°C. At night, the outside temperature is 7°C. What is the approximate percentage increase in the rate of heat lost by conduction through the walls of a house at night versus the day?

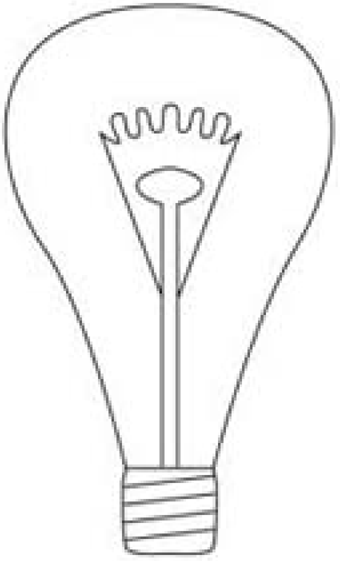


17°C day
7°C night

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

a. 3%   b. 9%   c. 50%   d. 100%

Transmission of Heat by Radiation - Stefan's Law



The tungsten filament (ε = 0.4) of a typical 100W bulb has a surface area of 40mm² and an operating temperature of about 3200K.

$$\frac{Q}{t} = A\varepsilon\sigma T^4$$

4th power! in Kelvin!

emissivity

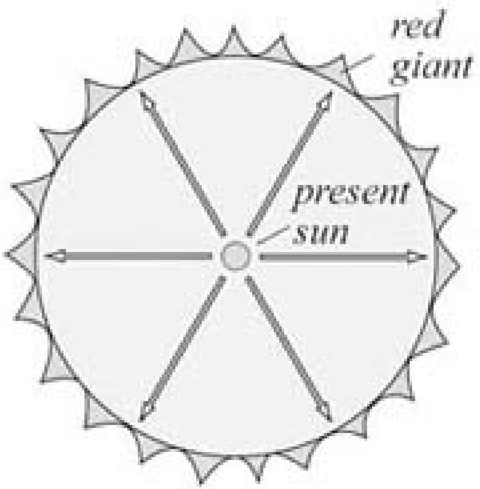
Q	=	heat (light) emitted
t	=	time
A	=	surface area of emitter
ε	=	emissivity
σ	=	Stefan-Boltzmann constant (5.7×10^{-8} $W/m^2 \cdot K^4$)
T	=	emitter absolute temperature

A good absorber is a good emitter

A good reflector is a poor emitter.

ε = 1 for a perfect blackbody only absorbs and emits

Scientists predict that in approximately five billion years the energy from a changing hydrogen fusion dynamic within our sun will push the outermost layers of the star outward. Expanding and cooling, the sun will become a red giant, perhaps even engulfing the earth. If its temperature decreases from 6000K to 3000K and its radius undergoes a 40 fold increase, what will be the resulting change in the luminosity of the Sun? (luminosity is the rate of total light emission)



Growth of the sun into a red giant will occur in approximately five billion years.

$$\frac{Q}{t} = A\varepsilon\sigma T^4$$

$\frac{1}{2}T \rightarrow \frac{1}{16}$ X change

$40r \rightarrow 1600$X change

a. 16 fold decrease

b. 80 fold decrease

c. 20 fold increase

(d.) 100 fold increase

$A = 4\pi r^2$

Engineers designed the Apollo capsule/command module to be constructed with a silvered exterior to control heat exchange with the environment during space travel. Which of the following were among the effects of this design feature on heat exchange?

a. Maximizing the absorption of energy from the surroundings

b. Minimizing the radiation of energy to the surroundings

c. Minimizing convection currents within the vehicle

d. Maximizing conductive diffusion of heat along the vehicle