
Warming the Earth and the Atmosphere-I
GEOL 1350: Introduction To Meteorology

Overview

- Some basic thermodynamic concepts
- Temperature
- Heat transfer in the atmosphere

Energy - the capacity to do work

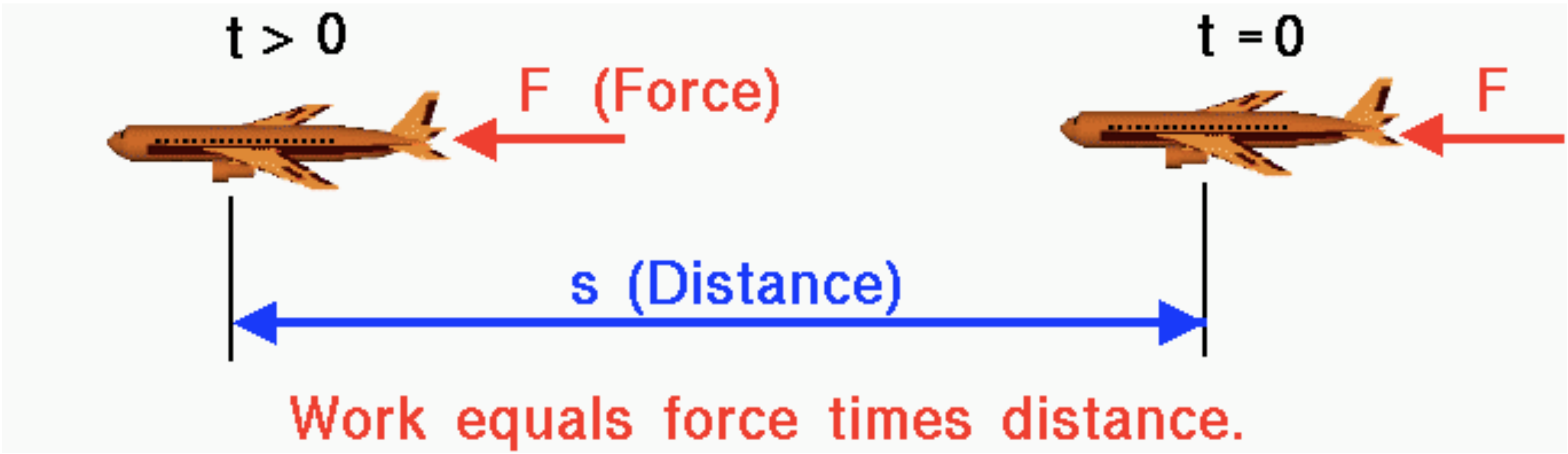
Work **is done on an object when a force moves it.**

How do we decided how much work is done?

The amount of work done is the *distance* traveled times the *force* in the direction of displacement

Work = Force • Distance

Energy - the capacity to do work



Work = Force • Distance

Forms of energy

kinetic energy **is the work that a body can do by virtue of its motion** $KE = \frac{1}{2} m v^2$

Potential energy **is the work an object can do as a result of relative position, or the *potential* to do work, or stored energy that can be converted to other forms of energy.**

$PE = m \times g \times h$ **m - mass, g - acceleration of gravity, h – object's height above ground**

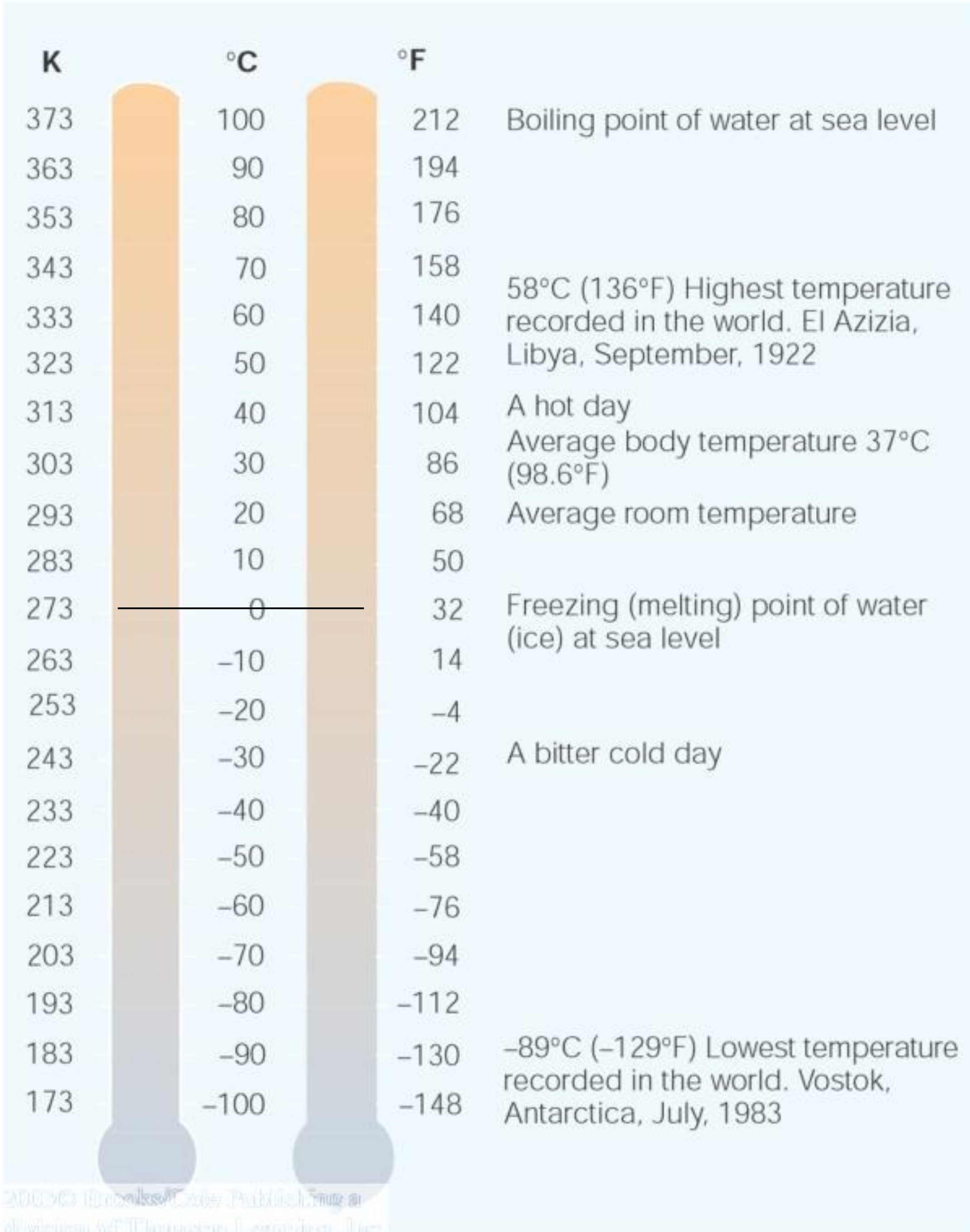
Internal Energy **– total energy stored in an object (potential + kinetic)**

Temperature **is a measure of average kinetic energy of a substance; simply, is a measure of average speed of air molecules**

High **temperatures corresponds to** ***faster*** **average molecule speeds**

Temperature scales - three commonly used scales:

- **Fahrenheit (°F)**
- **Celsius (°C)**
- **Kelvin (K)**



Fahrenheit (°F) and Celsius (°C) scales are calibrated to freezing and boiling water, but the Celsius range is 1.8 times more compact

The Celsius and Kelvin scales are the same except that K is 273.16 degree higher than °C

$$K = {}^{o}C + 273.16$$

Conversation between

^oF and ^oC

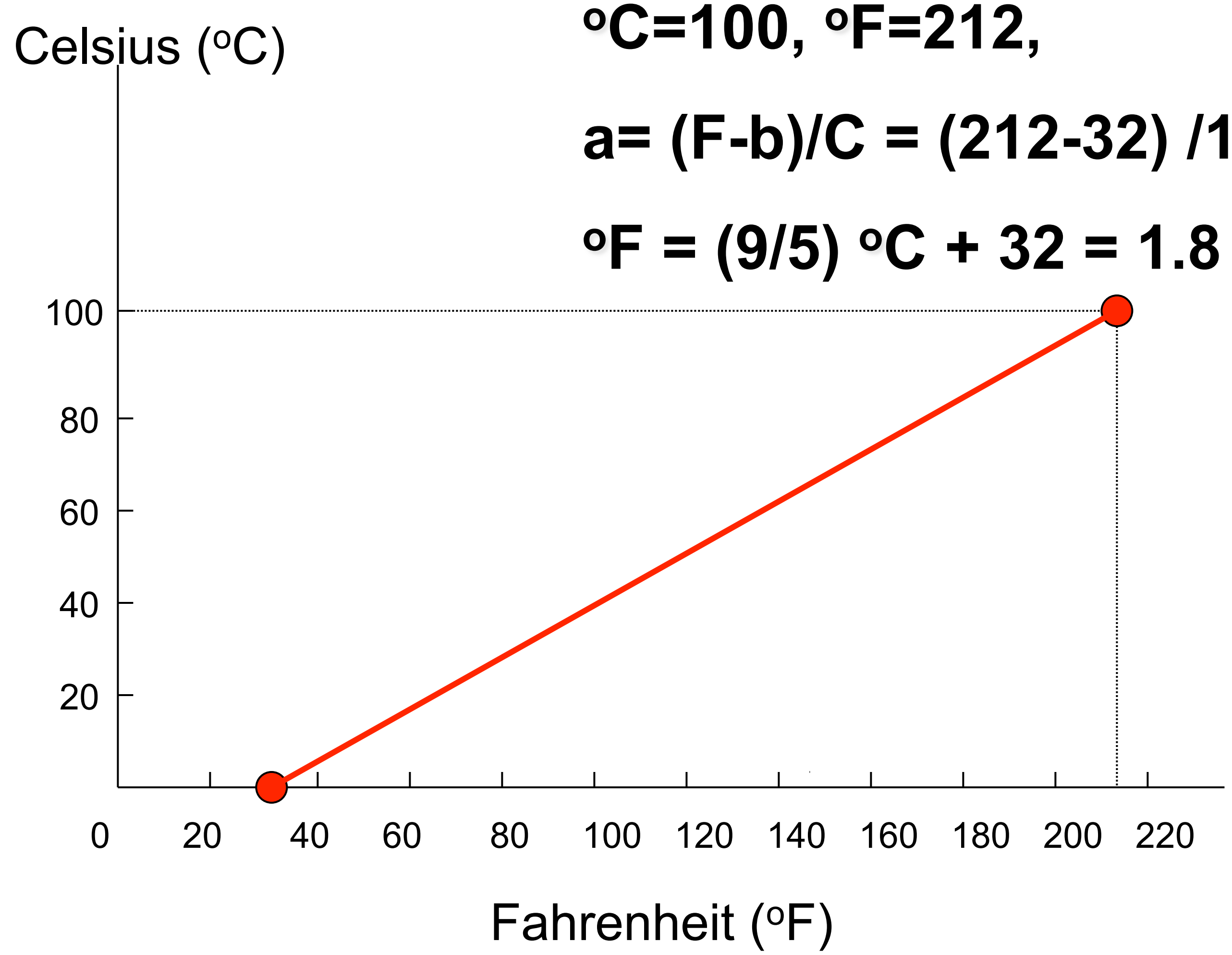
$F = a \cdot C + b$

$^oC=0$, $^oF=32$, $\rightarrow b=32$

$^oC=100$, $^oF=212$,

$a = (F-b)/C = (212-32)/100 = 9/5 = 1.8$

$^oF = (9/5)\ ^oC + 32 = 1.8\ ^oC + 32$



1) Convert temperature from 10°C to Kevin (K) and Fahrenheit (°F)

$10+273.16 = 283.16$ K

$1.8x10 + 32 = 50$ F

2) Convert temperature from 20°C to Kevin (K) and Fahrenheit (°F)

$20+273.16 = 293.16$ K

$1.8x20 + 32 = 68$ F

What is Heat ?

The energy *transferred* between objects as a result of the *temperature difference* between them

Unit for heat

calorie (cal) **is the energy needed to raise temperature of 1 gram of water 1 degree Celsius**

1 cal = 4.18 6 Joule or

1 Joule = 0.2389 cal

The temperature change of an object depends on -

How much heat is being added

The amount of matter

The **heat capacity** of the substance

Heat capacity of a substance is the ratio of the amount of heat energy absorbed by the substance to its corresponding temperature rise

C_p= heat input / temperature rise

Specific heat of a substance is heat capacity of the substance per unit mass

$c_p = C_p / m$

or, is the amount of heat required to increase the temperature of 1 gram of that substance 1 degree Celsius (cal/g/°C, or j/kg/°C)

Specific Heat of common substances

	Specific heat	
Substance	cal / g /° C	J/kg/ °C
Water	1.0	4186
Ice	0.50	2093
Air	0.24	1005
Sand	0.19	798

Sensible heat can be sensed by human. It's heat associated with temperature change.

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

How much sensible heat is needed to warm 1 kg of dry air by 10°C?

$$\Delta Q = 1\ \text{kg} \bullet 1005\ \text{J/kg/°C} \bullet 10\text{°C} = 10050\ \text{J}$$

Latent heat:

Heat required to change a substance from one state to another. It is a *hidden* heat until phase changes occur.

Latent Heat is an Important source of atmospheric energy

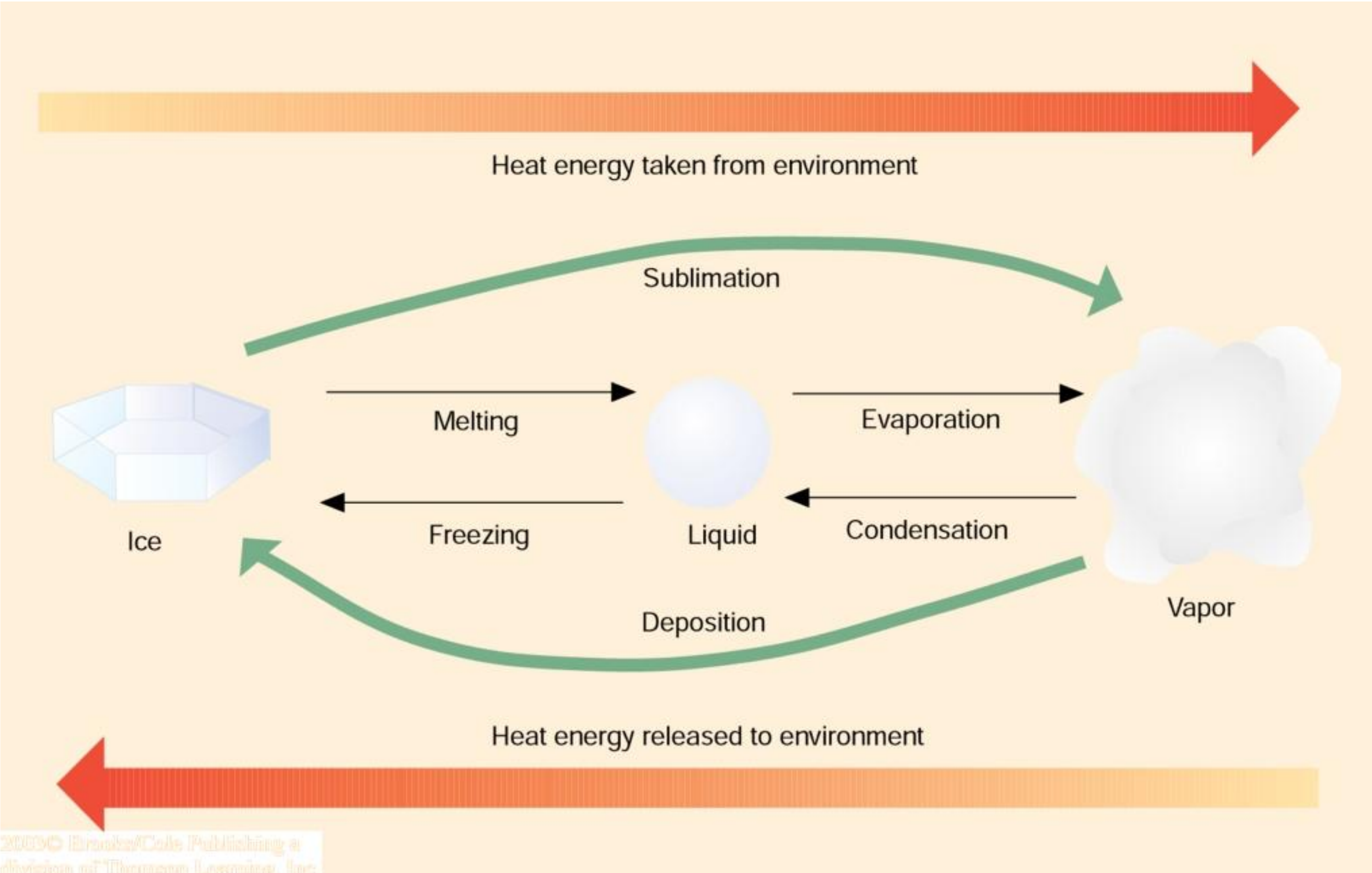
$\Delta Q_L / m_{air} = L$

$L_v = \pm 2.5 \times 10^6$ J kg^{-1} condensation/evaporation

$L_f = \pm 0.334 \times 10^6$ J kg^{-1} fusion or melting

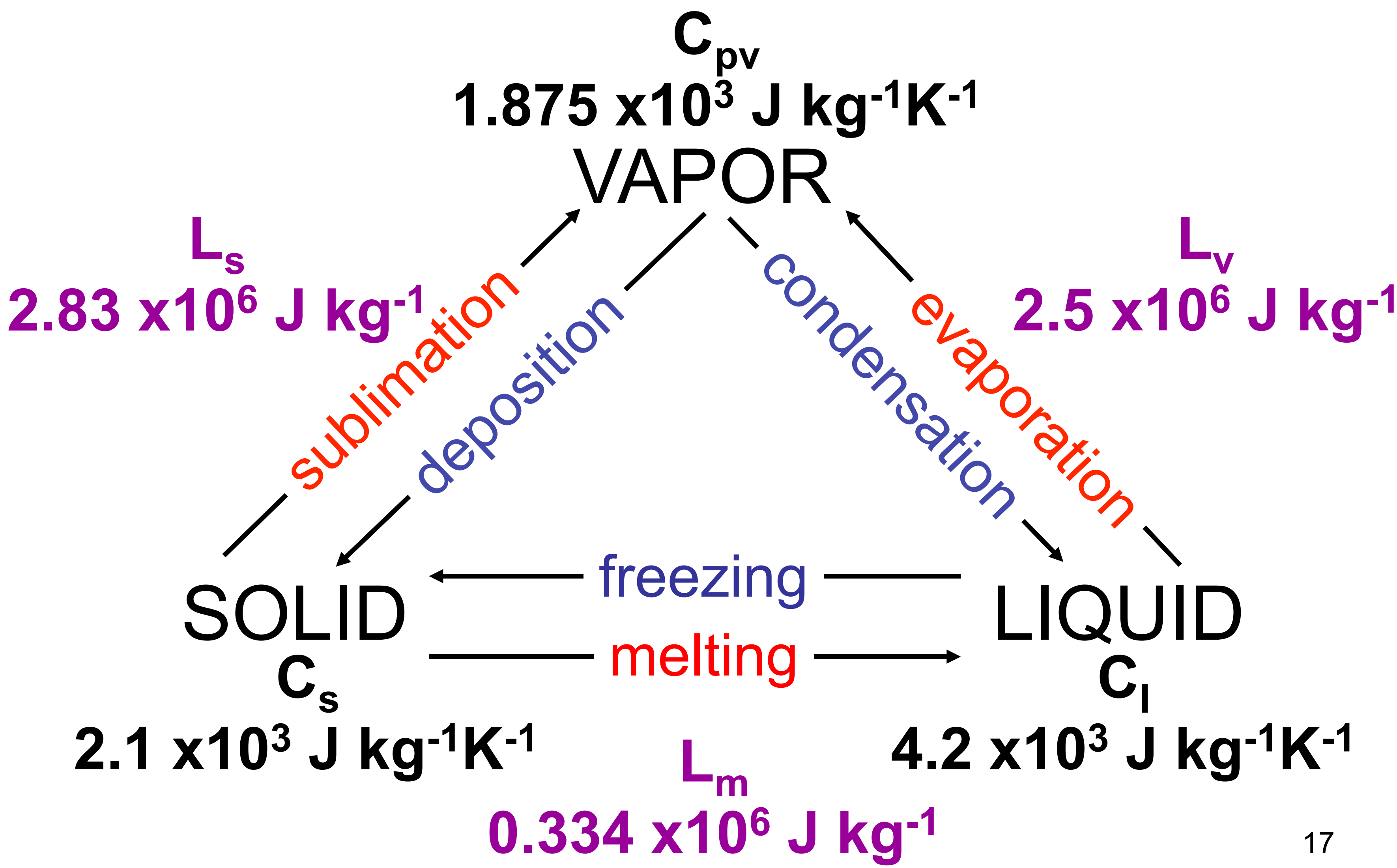
$L_d = \pm 2.83 \times 10^6$ J kg^{-1} deposition or sublimation

Heat exchange with environment during phase change



As water moves toward vapor it absorbs latent heat to keep the molecules in rapid motion

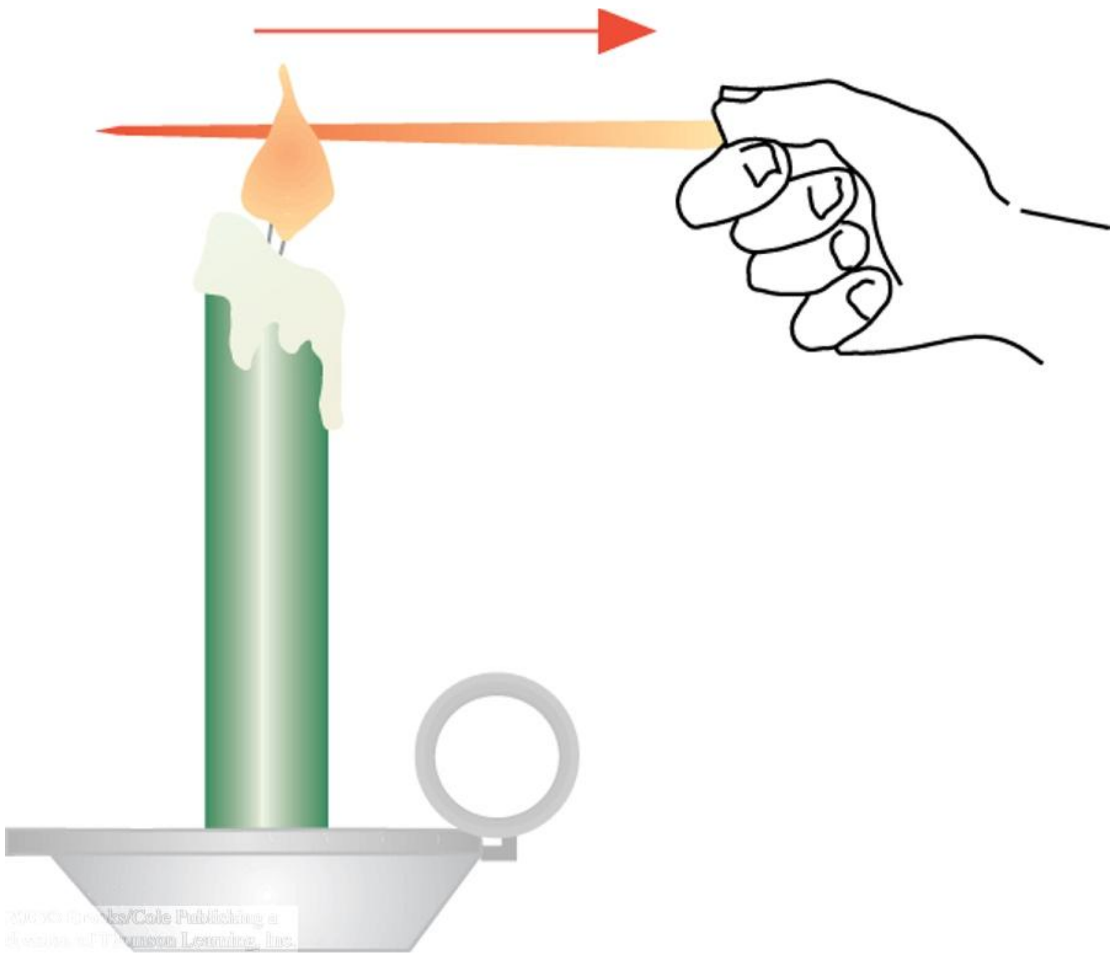
Phase Changes



Heat Transfer in the Atmosphere

- **Conduction**
- **Convection**
- **Advection**
- **Radiation**

Conduction



Conduction of heat energy occurs as warmer molecules transmit vibration, and hence heat, to adjacent cooler molecules.

Warm ground surfaces heat overlying air by conduction.

Heat transfer in the atmosphere

Conduction –

- the process of heat transfer from molecule to molecule
- molecules transfer energy by coming into contact with one another
- conduction requires contact
- heat transferred by conduction *always* flows from warmer to colder regions

The amount of heat transferred by conduction depends on-

1. Temperature difference between the two objects

2. Their ***thermal (heat) conductivity*** – the ability of a substance to conduct heat by molecular motions

Heat conductivity of common substances

Substance	Heat conductivity (W/m/°C)
still air	0.023
wood	0.08
dry soil	0.25
water	0.60
snow	0.63
ice	2.1
iron	80

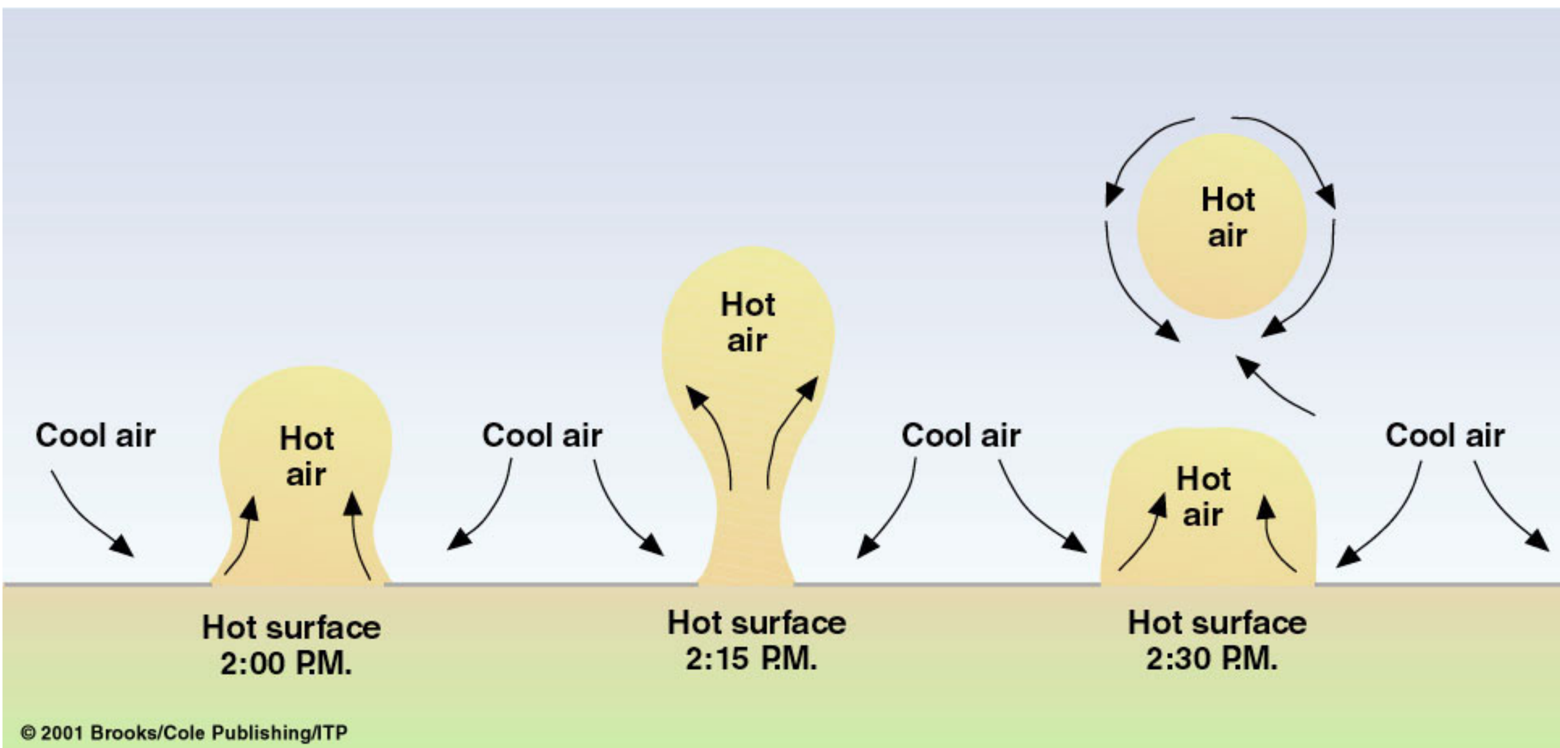
Air is a extremely poor conductor ! Inefficient for heat transfer in the atmosphere

Heat Transfer in the Atmosphere - Convection

where air moves from one place to another, carrying it's heat energy with it

Convection always requires motion !

in atmospheric science, *convection* is usually associated with vertical movement of the fluid (air or water) - hot air rises



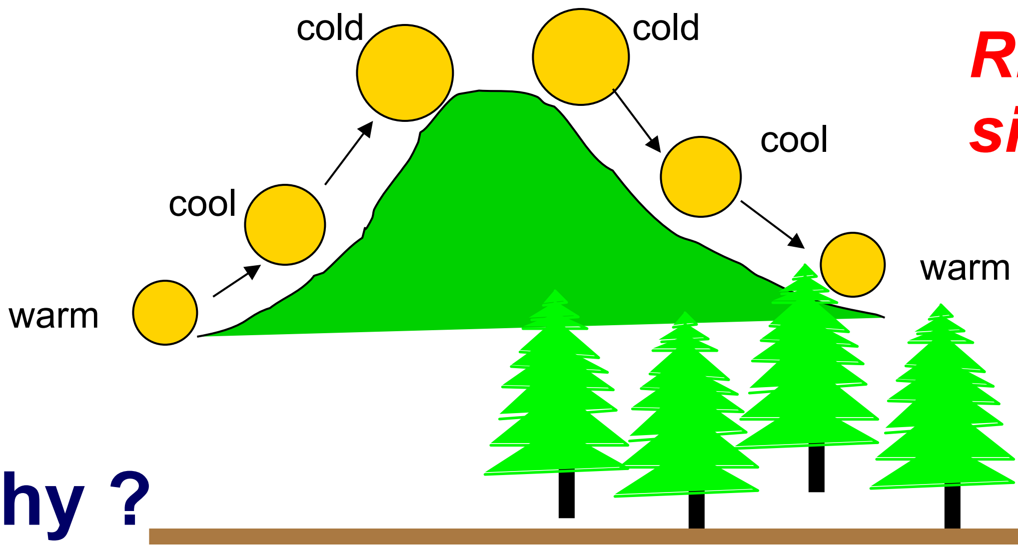
Convection

The rate of energy transferred by convection depends on the temperature of the rising air parcel compared to the temperature of its surrounding atmosphere

- strong in summer and weak in winter
- strong over tropics and weak in polar region

A efficient way to transfer heat in the atmosphere!

- Air parcel that rises will expand and cool
- Air that sinks is compressed and warmed



Ha... st rule in me... - Rising ... cools and sinkin... r warms

Why ?

Because atmospheric pressure always decrease with height

Advection

Horizontally moving part of the circulation (called wind) carries properties of the air in that particular area with it.

The transfer of these properties by horizontally moving air is called advection.

Summary

1. The temperature of a substance is a measure of the average speed of its atoms and molecules. Faster the air molecules move, the higher the temperature.
2. Evaporation (transformation of liquid to vapor) is a cooling process and condensation (transformation of vapor into liquid) is a warming process.
3. Heat is energy transferred from one object to another because of temperature difference between them.
4. The transfer of heat within our atmosphere can take place by conduction, convection and radiation.
5. Air is a poor conductor of heat.
6. Convection is an important mechanism of heat transfer, as it represents the vertical movement of warmer air upward and cooler air downward.