Thermal & Statistical Physics

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PHYS 343

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Heat

Thermal Energy

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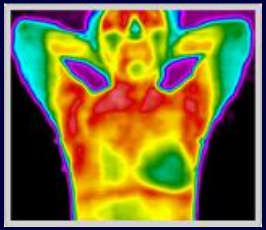
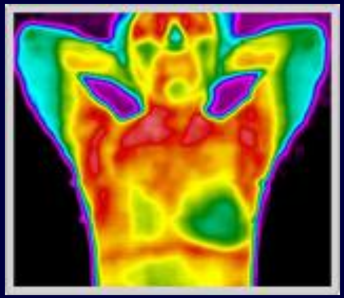


Heat and work

- *Heat always flows from a higher temperature to a lower one.*
  - Temperature as the driving force for the transfer of energy as heat.
  - Heat is never regarded as being stored within a body.
  - Like work, it exists only as energy in transit from one body to another.
  - Unit: calorie is defined as the quantity of heat which when transferred to one gram of water raised its temperature one degree Celsius, or, British thermal unit (BTU) is defined as the quantity of heat which when transferred to one pound mass of water raised its temperature one degree Fahrenheit.

What happens when you vigorously rub your hands together?



- *Your hands get warm.*
- *They get sweaty.*
- *They could even blister.*

You Are Doing Work!

- Force times distance.
- Increases kinetic energy.
- Particles in your hand move faster.
- Water tries to cool your hand.

Heat

The transfer of energy by means of a change in temperature

- ***Heat is energy just like motion, light and sound. It is generated by doing work.***
- ***Consider heat to be an entity that moves and reacts to its environment.***

What Causes Heat?

- *Heat change is caused by a change in the motion (speed) of the molecules in an object.*
- *The molecules in a hot body move faster than those in a cold body.*

The Molecules in an Object Undergo Three Types of Motion.

- *Translational : moving.*
- *Rotational : spinning.*
- *Vibrational : shaking.*

Temperature

The measure of the average kinetic energy of the particle in an object in a particular place.

Thermal Energy

- *The total kinetic and potential energy of all the particles in an object.*
- *This is also known as internal energy.*

Thermal Equilibrium

When two bodies of different temperatures are in contact, heat will move from the hot body to the cold body.

- ***Remember that Thermal equilibrium is that state between two objects when temperature does not change…when the transfer of energy is equal and the kinetic energy of each object is equal.***

Units

- Heat is measured in joules like all energy.
- Dieticians and biologists have unit the calorie as a unit of heat.
- 1 cal. = 4.19 joules

Heat Capacity

- The quantity of heat needed to raise one unit of mass of a substance by one degree of temperature.
- It is designated by *c*.
- Units are J/kg ºC

$$c = \frac{Q}{m\Delta t}$$

- **Q** = *heat exchanged*
- **M** = *mass of substance*
- ***ΔT*** = *change in temperature*

$$Q = mc\Delta t$$

Law of Heat Exchange

Law of Heat Exchange

In any heat transfer system, the heat lost by the hot substances equals the heat gained by the cold substances.

$$Q_{lost} = Q_{gained}$$

Heat Exchange

- *A process that absorbs heat as it progresses is called endothermic.*
- *A process that emits heat as it progresses is called exothermic.*

Heat Exchange

What happens when an ice cube melts in a glass of water?

It changes state from solid to liquid. During that change of state, the temperature does not change.

A new definition of heat….

Heat is the transfer of energy by means of a change in temperature and/or.

a change in phase

Latent Heat of Fusion

- Heat required to completely melt one kg of solid substance at constant temperature.
- This also applies to the freezing of one kg of liquid substance at constant temperature .
- $L_f = 3.34 \times 10^5$ J/kg for water.

The Equation

$$Q = mL_f$$

Latent Heat of Vaporization

- This also applies to the heat required to condense one kg of vapor at constant temperature.
- The heat required to vaporize one kg of liquid at constant temperature
- For water, $L_v = 2.26 \times 10^6$ J/kg

The Equation

$$Q = mL_v$$

Thermal Expansion of Materials

Thermal Expansion of Materials

- *All materials expand when heated and contract when heat is taken away.*
- *As KE increases, the distance between the particles increases and vise versa.*

Thermal Expansion …

- *Thermal expansion is a consequence of the change in the average separation between the atoms in an object*
- *If the expansion is small relative to the original dimensions of the object, the change in any dimension is, to a good approximation, proportional to the first power of the change in temperature*

Solids

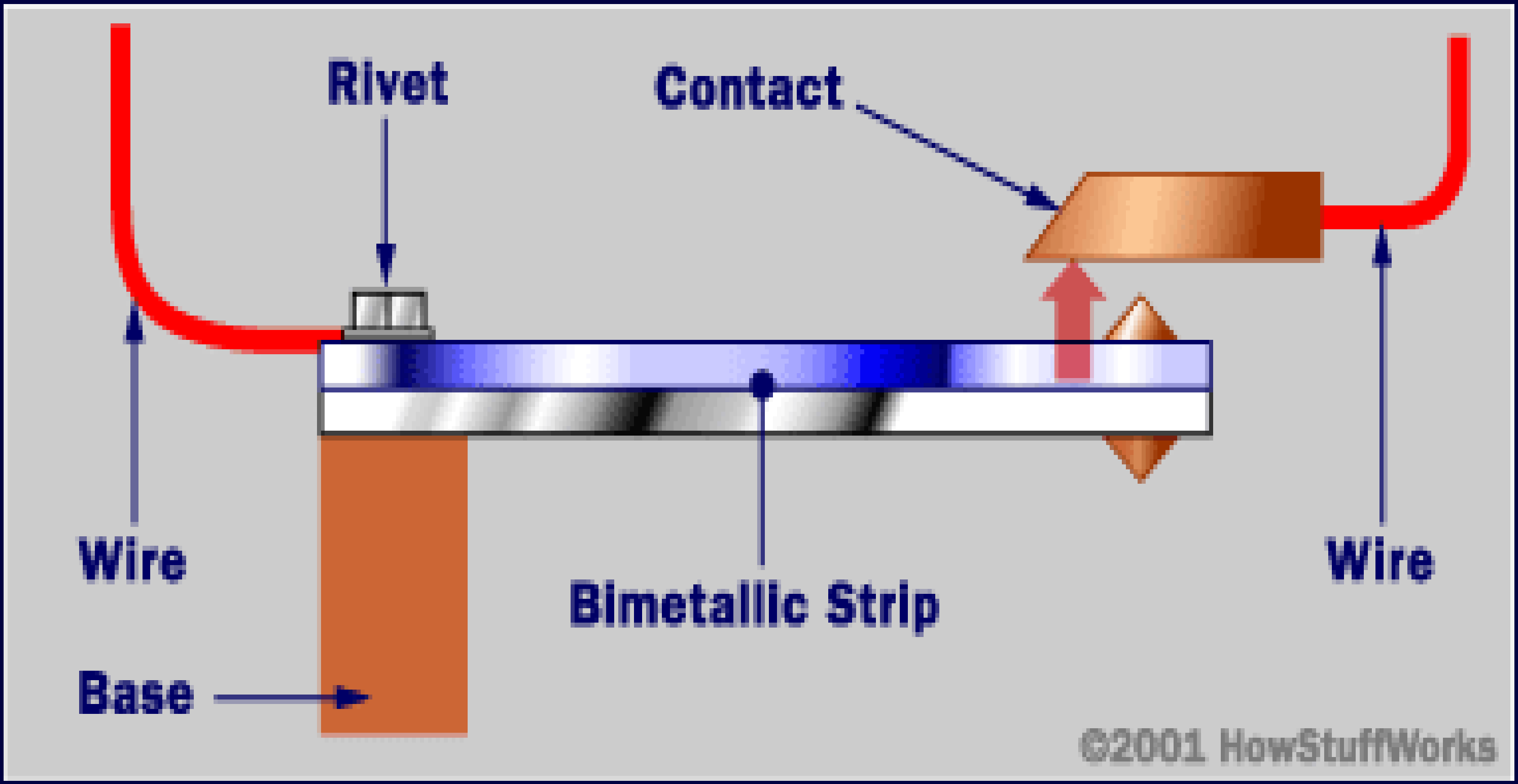
linear expension

- Solids can undergo linear expansion when heated.
- This expansion varies directly with the change in temperature.
- Each material has its own coefficient of linear expansion, α.

The Equation

$$\Delta l = \alpha l \Delta T$$

- Δl = change in length
- a = coefficient of linear expansion
- DT = change in temperature
- l = original length


Rivet
Contact
Wire
Wire
Bimetallic Strip
Base
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Higher coefficient of thermal expansion

volume expension

- The change in volume is proportional to the original volume and to the change in temperature
- $$\Delta V = \beta V_i \,\Delta T$$

Liquids

- *Liquids and solids can expand volumetrically.*
- *All materials have their own* ***coefficient of volumetric expansion, β.***

$$\Delta V = \beta V \Delta T$$

The Equation

$$\Delta V = \beta V \Delta T$$

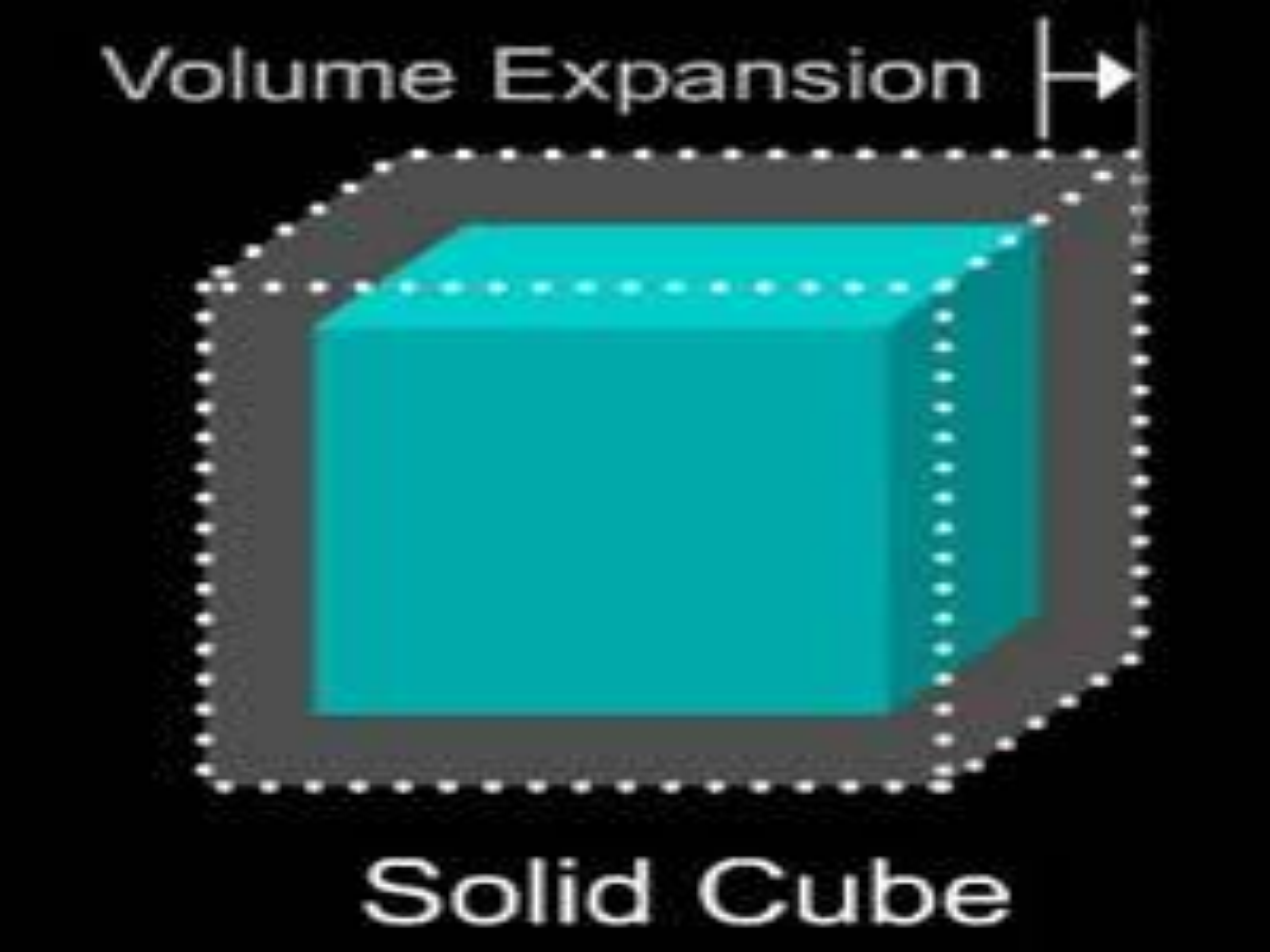
ΔV = change in volume

β = coefficient of volume expansion

ΔT = change in temperature

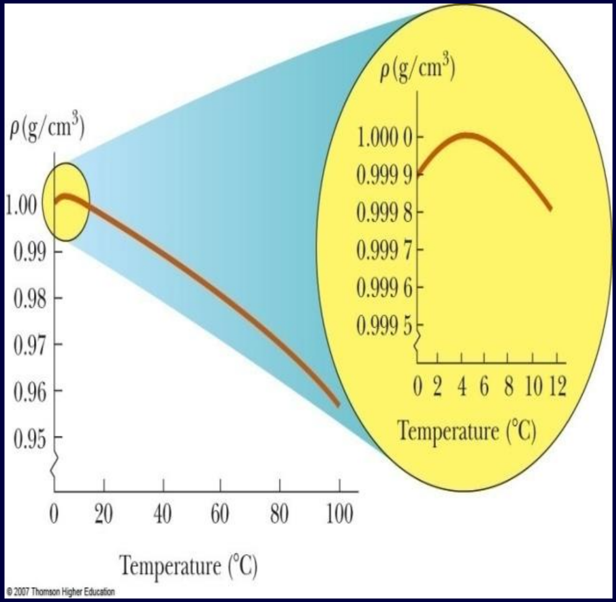
V = original volume

$\beta = 3\alpha$ for solids


Volume Expansion
Solid Cube

Water's Unusual Behavior

- As the temperature increases from 0^oC to 4^oC, water contracts
  - Its density increases
- Above 4^oC, water expands with increasing temperature
  - Its density decreases
- The maximum density of water (1.000 g/cm^3) occurs at 4^oC



Here Are Some Ideas…

- *All bodies contain heat.*
- *Heat is transferred by a change in temperature.*
- *All forms of energy can be turned into thermal energy.*

Here Are Some Ideas…cont

- *The rate at which your body exchanges heat with its environment is a critical factor to your wellness.*
- *Your body is always trying to attain thermal equilibrium with its surroundings.*

Absolute Zero

- O Kelvins
- The absence of heat