

# PHYS11 CH:11 The Hidden Energy

## Temperature, Heat, and Phase Change

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# Outline

# The Mystery of the Welder



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How does thermal energy travel from the arc to your skin meters away?

# Learning Objectives

By the end of this section, you will be able to:

- **11.1:** Explain that temperature is a measure of internal kinetic energy

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- **11.1:** Interconvert temperatures between Celsius, Kelvin, and Fahrenheit scales

# 11.1 What Is Temperature?

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**Reality:** Temperature measures average kinetic energy of molecules

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Temperature = what we measure on a thermometer

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Temperature = what we measure on a thermometer

Heat = transfer of energy due to temperature difference

Heat and temperature are NOT the same thing.

# 11.1 Thermal Energy: The Invisible Motion

## The Mental Model

Atoms and molecules are constantly bouncing around in random directions.  
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$$KE = \frac{1}{2}mv^2$$

Higher speed → greater kinetic energy → higher temperature

# 11.1 Temperature Scales

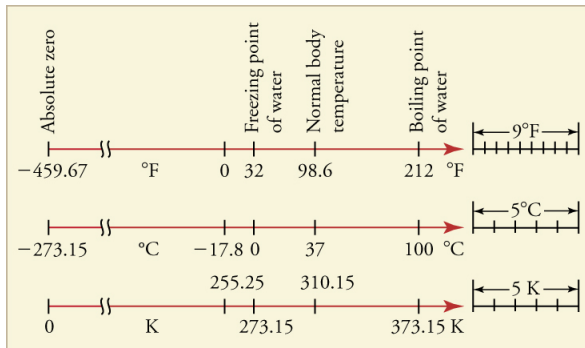


Figure: Fahrenheit, Celsius, and Kelvin scales compared

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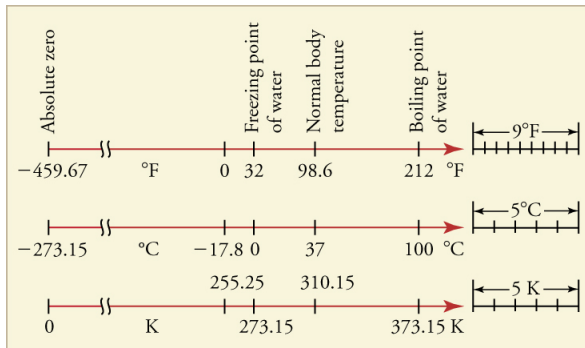


Figure: Fahrenheit, Celsius, and Kelvin scales compared

## Three scales, same physics:

- Celsius: water freezes at 0, boils at 100
- Fahrenheit: water freezes at 32, boils at 212
- Kelvin: absolute zero at 0, water freezes at 273.15

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## The Ultimate Limit

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At absolute zero, particles have minimum possible energy (quantum zero-point energy).

# 11.1 Converting Temperature Scales

## Key Conversion Equations

$$T_{\text{o}F} = \frac{9}{5} T_{\text{o}C} + 32$$

$$T_{\text{o}C} = \frac{5}{9} (T_{\text{o}F} - 32)$$

$$T_K = T_{\text{o}C} + 273.15$$

$$T_{\text{o}C} = T_K - 273.15$$

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## Quick Check

Room temperature: 25 C = ? F = ? K

# Attempt: Temperature Conversion

## The Challenge (3 min, silent)

Your body temperature is normally 98.6 F.

### Given:

- $T_{oF} = 98.6 \text{ F}$

**Find:** Body temperature in Celsius and Kelvin

*Can you decode your body's thermal state? Work silently.*

# Compare: Temperature Conversion

**Turn and talk (2 min):**

- 1 Which equation did you use to convert F to C?
- 2 Did you subtract 32 before or after multiplying by  $5/9$ ?
- 3 How did you convert C to K?



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$$T_K = 37.0 + 273.15 = \boxed{310.2 \text{ K}}$$

**Check:** 37 C is normal body temp. Makes sense!

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- **11.2:** Explain heat, heat capacity, and specific heat
- **11.2:** Distinguish between conduction, convection, and radiation
- **11.2:** Solve problems involving specific heat and heat transfer

## 11.2 Heat: Energy on the Move

### The Universal Law

**Heat** = transfer of thermal energy from hot to cold

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**Heat** = transfer of thermal energy from hot to cold

### Key insights:

- Heat is NOT a substance - it's energy in transit
- Heat always flows from high to low temperature
- Heat stops flowing when temperatures equalize
- Heat is measured in joules (J), like all energy

## 11.2 The Heat Equation

### Nature's Rule for Temperature Change

$$Q = mc\Delta T$$

Heat transferred = mass  $\times$  specific heat  $\times$  temperature change



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### What each variable means:

- $Q$  = heat transferred (J)
- $m$  = mass (kg)
- $c$  = specific heat (J/kg·C)
- $\Delta T$  = temperature change (C or K)

## 11.2 Specific Heat: Material Stubbornness

### The Mental Model

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Water requires 5× more energy than iron to heat the same amount!

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Wood and metal at room temperature.

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**Why does metal feel colder when you touch it?**

**The answer:**

- Both are same temperature
- Metal conducts heat faster than wood
- Metal pulls heat from your hand rapidly
- You sense rate of heat loss, not temperature!

## 11.2 Three Modes of Heat Transfer

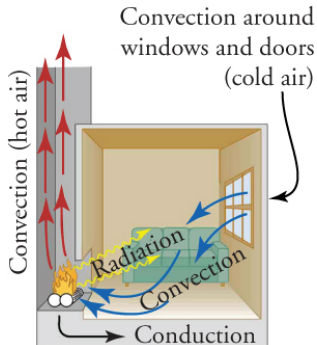


Figure: Fireplace: all three modes at once

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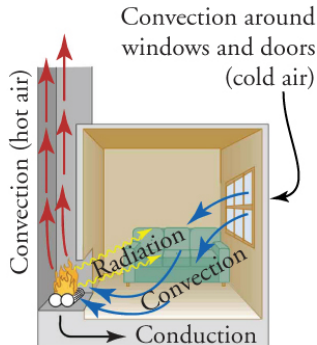


Figure: Fireplace: all three modes at once

- **Conduction:** through physical contact
- **Convection:** by fluid movement
- **Radiation:** by electromagnetic waves

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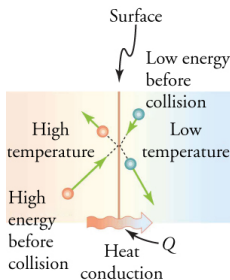


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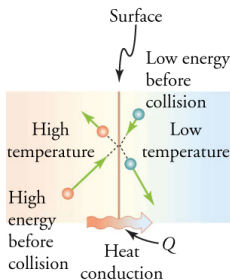
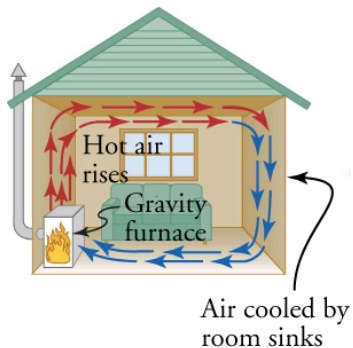


Figure: Energy transfers through collisions

**Good conductors:** metals (copper, aluminum, gold)

**Poor conductors:** wood, plastic, rubber (insulators)

## 11.2 Convection: Fluid Flow



**Figure:** Heated air rises, cool air sinks

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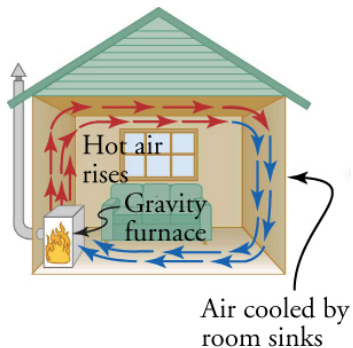


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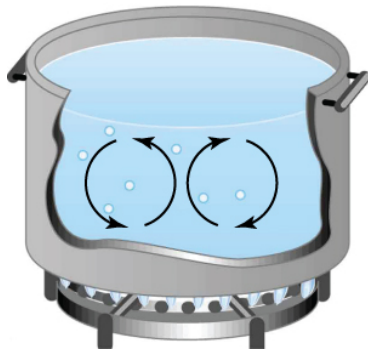
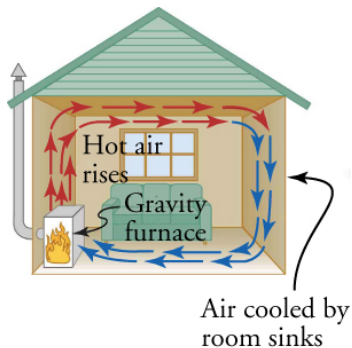
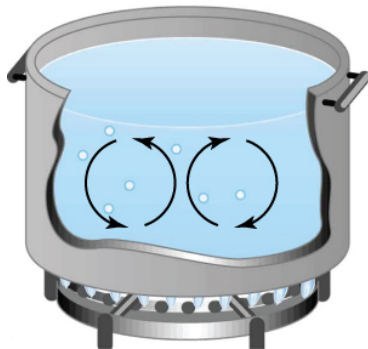


Figure: Water circulation in pot

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**Figure:** Water circulation in pot

**Key idea:** Hot fluid expands, becomes less dense, rises

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### Examples:

- Feel warmth from fire without touching
- Microwave oven heating food
- Infrared heat lamps
- Sun warming Earth

## 11.2 Color and Radiation

### Color affects absorption and emission:

- **Black:** best absorber AND radiator



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### Real-World Application

Hot climates: wear white to reflect heat

Cold nights: black asphalt radiates heat faster than grass

Space blankets: shiny surface reflects body heat back

# Attempt: Heating Water

## The Challenge (4 min, silent)

You heat 2.0 kg of water from 20 C to 80 C.

### Given:

- $m = 2.0 \text{ kg}$
- $c_{\text{water}} = 4186 \text{ J/kg}\cdot\text{C}$
- $T_i = 20 \text{ C}, T_f = 80 \text{ C}$

**Find:** Heat energy required (Q)

*Can you calculate energy needed? Work silently.*

# Compare: Heat Calculation

**Turn and talk (2 min):**

- 1 What equation did you use?
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$$\Delta T = T_f - T_i = 80 - 20 = 60 \text{ C}$$

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$$Q = 502,320 \text{ J} = \boxed{502 \text{ kJ}}$$

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**Check:** About 500 kJ to heat 2 L water by 60 degrees. Reasonable!

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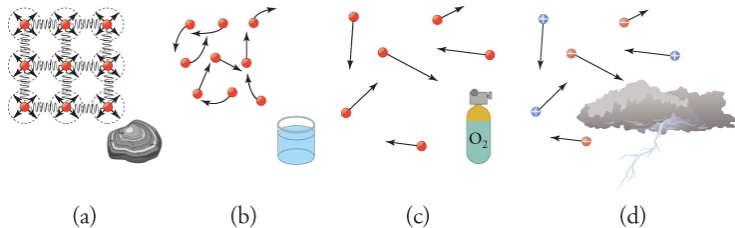
- **11.3:** Explain changes in heat during changes of state
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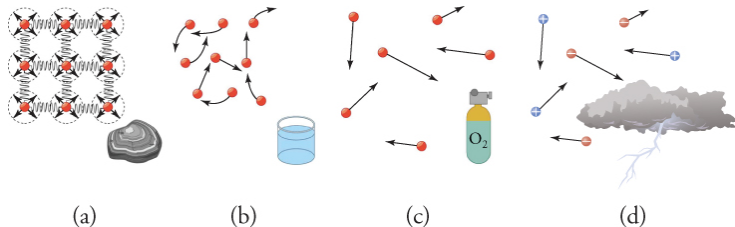
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- **11.3:** Describe latent heats of fusion and vaporization
- **11.3:** Solve problems involving phase changes

# 11.3 The Four Phases of Matter



**Figure:** Solid, liquid, gas, and plasma

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**Energy ranking:** Solid | Liquid | Gas | Plasma



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- Condensation: gas  $\rightarrow$  liquid
- Deposition: gas  $\rightarrow$  solid

## 11.3 Latent Heat: The Hidden Energy

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**Latent heat** = hidden energy used to change phase without changing temperature

## 11.3 Phase Diagram: Ice to Steam

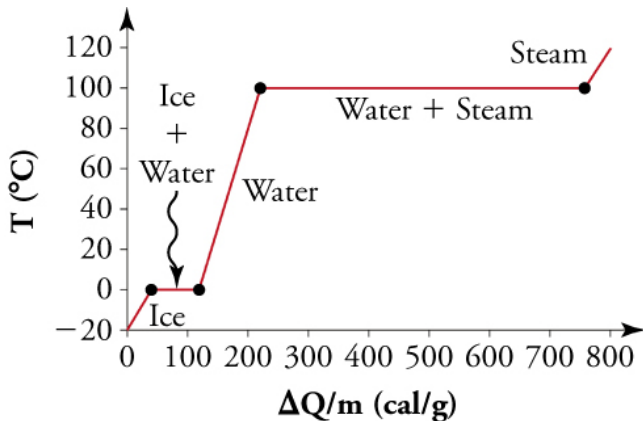


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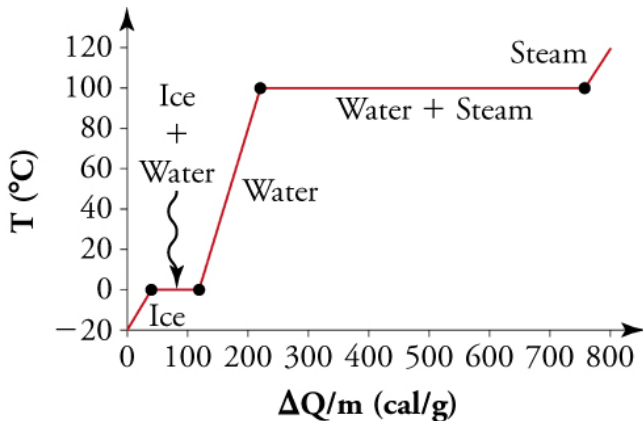


Figure: Temperature vs energy for water

**Flat regions** = phase changes (temp constant)

**Sloped regions** = temperature increasing

## 11.3 Latent Heat Equations

### Nature's Rules for Phase Change

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- $L_f = 334 \text{ kJ/kg}$  (latent **heat** of fusion)
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Note: No  $\Delta T$  in these equations - **temperature** doesn't change!

# Attempt: Melting Ice

## The Challenge (3 min, silent)

How much energy is needed to melt 0.50 kg of ice at 0 C?

### Given:

- $m = 0.50 \text{ kg}$
- $L_f = 334 \text{ kJ/kg}$
- Ice already at 0 C (melting point)

**Find:** Heat energy  $Q$  required

*Can you calculate the hidden energy? Work silently.*

# Compare: Latent Heat

**Turn and talk (2 min):**

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**Check:** That's enough energy to raise 1 kg of water by 40 C!

Phase changes require enormous energy.

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**On humid days:** Less evaporation  $\rightarrow$  less cooling  $\rightarrow$  you feel hotter

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Condensation releases same energy that vaporization absorbed.

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- Creates powerful updrafts and winds

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# Key Equations

## Temperature Conversions:

$$T_{oF} = \frac{9}{5} T_{oC} + 32 \quad (1)$$

$$T_{oC} = \frac{5}{9} (T_{oF} - 32) \quad (2)$$

$$T_K = T_{oC} + 273.15 \quad (3)$$

## Heat Transfer:

$$Q = mc\Delta T \quad (\text{temperature change}) \quad (4)$$

$$Q = mL_f \quad (\text{melting/freezing}) \quad (5)$$

$$Q = mL_v \quad (\text{vaporization/condensation}) \quad (6)$$

## Water Constants:

- $c_{\text{water}} = 4186 \text{ J/kg}\cdot\text{C}$
- $L_f = 334 \text{ kJ/kg}$
- $L_v = 2256 \text{ kJ/kg}$

Complete the assigned problems  
posted on the LMS



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