Specific Heat

IB PHYSICS | THERMAL PHYSICS

Conductors and Insulators

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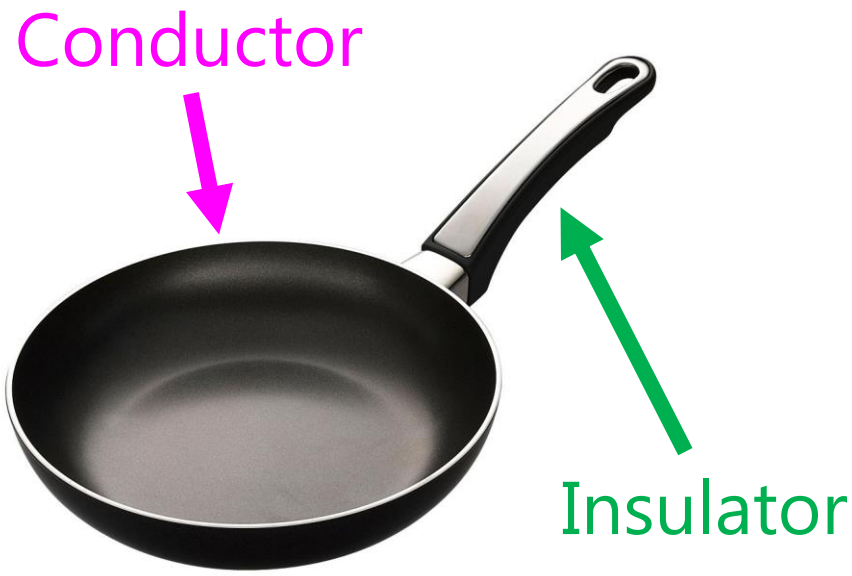


Conductor

A material through which energy can be easily transferred as heat

Insulator

A material that transfers energy poorly

Specific Heat

Specific Heat is the amount of **Energy** required to raise the temperature of 1 kg of a substance by 1 K

Specific Heat of Copper:

$$390\ J\ kg^{-1}\ K^{-1}$$

Specific Heat

The Lower the number, the less energy it takes to heat up

1) Which substance take the most energy to heat up?

Water

2) Which substance take the least energy to heat up?

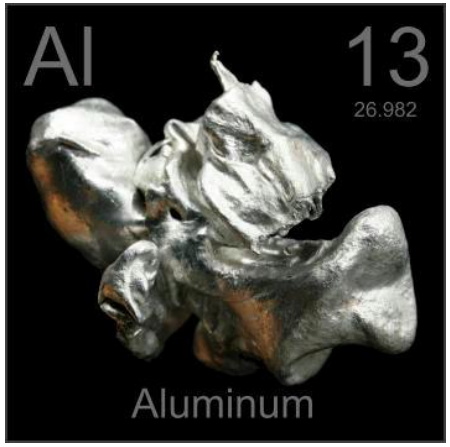
Lead

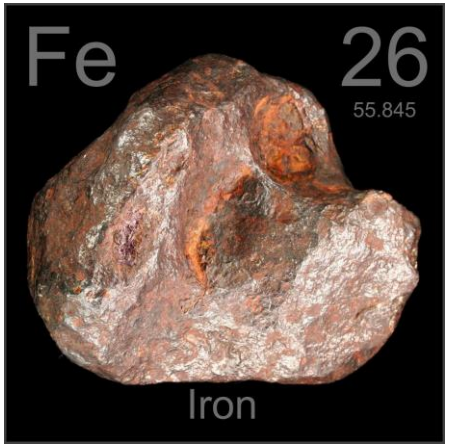
Material	Specific Heat ($J\ kg^{-1}\ K^{-1}$)
Aluminum	910
Copper	390
Iron	448
→ Lead	130
→ Water	4180
Air	1000
Dry Earth	1250

Specific Heat

Which metal will heat up faster, Aluminum or Iron?

Material	Specific Heat ($J\ kg^{-1}\ K^{-1}$)
Aluminum	910
Copper	390
Iron	448
Lead	130
Water	4180
Air	1000
Dry Earth	1250





Specific Heat

If Iron heats up faster based on its specific heat, then why do aluminum fry pans heat up faster?

more mass

Aluminum Skillet

$C = 910\ J\ kg^{-1}\ K^{-1}$

Iron Skillet

$C = 448\ J\ kg^{-1}\ K^{-1}$

Specific Heat Equations

Quantity	Symbol	Unit
Heat Energy	Q	$[J]$
Mass	m	$[kg]$
Specific Heat	c	$[J\ kg^{-1}K^{-1}]$
Change in Temp	ΔT	$[K]\ or\ [°C]$

$$Q = mc\Delta T$$

Specific Heat Calculations

How much energy is needed to increase the temperature of 0.755 kg of iron 20 K?

$$Q = mc\Delta T = (0.755)(448)(20)$$

$$\boxed{Q = 6{,}765 \text{ J}}$$

How much energy must a refrigerator absorb from 0.225 kg of water to decrease the temperature of the water from 35 °C to 5 °C?

$$Q = mc\Delta T = (0.225)(4180)(5 - 35)$$

$$\boxed{Q = -28{,}215 \text{ J}}$$

Material	Specific Heat ($J\ kg^{-1}\ K^{-1}$)
Aluminum	910
Copper	390
Iron	448
Lead	130
Water	4180
Air	1000
Dry Earth	1250

More Specific Heat Calculations

Air has a density of 1.3 kg m^{-3} and a specific heat capacity of 1000 J kg^{-1} K^{-1}. If 500 kJ was transferred to a room of volume 80 m^3, what was the temperature rise?

$Q = 500{,}000\ \text{J}$

$c = 1000\ \text{J kg}^{-1}\ \text{K}^{-1}$

$m = D \times V = (1.3)(80) = 104\ \text{kg}$

$$\Delta T = \frac{Q}{mc} = \frac{500{,}000}{(104)(1{,}000)}$$

$$\Delta T = 4.81\ \text{K}$$

How long will it take a 2.20 kW kettle to raise the temperature of 800 g of water from 16.0°C to its boiling point if the specific heat capacity of water is 4180 J kg^{-1} K^{-1}?

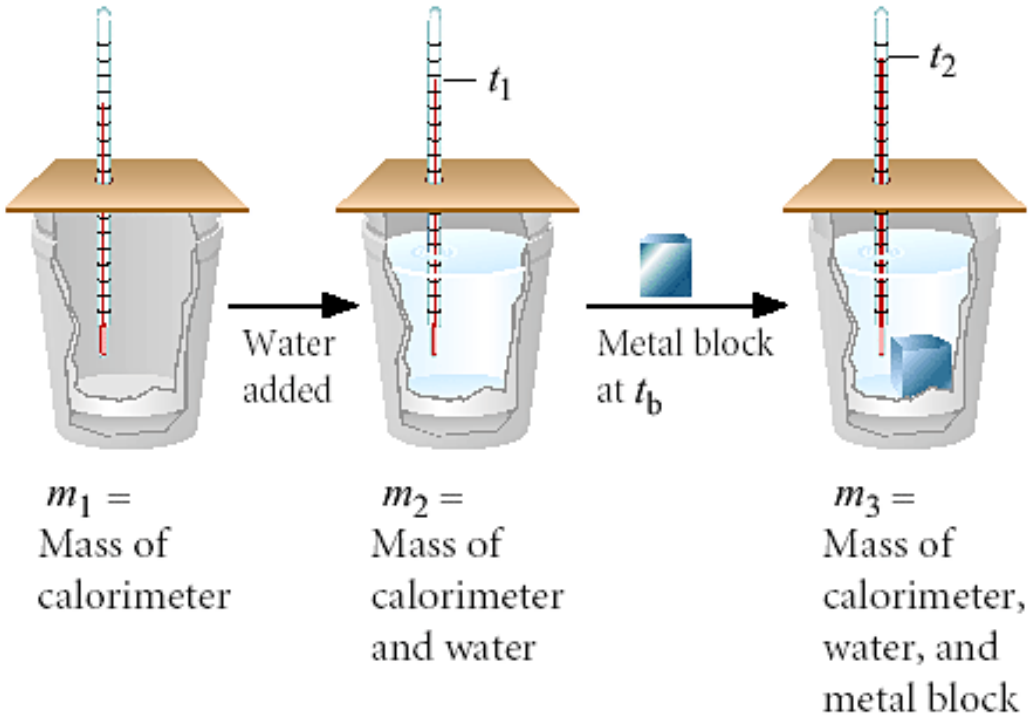
$$Q = mc\Delta T = (0.8)(4180)(100 - 16) = 280{,}896\ \text{J}$$

$2.2\ \text{kW} = 2{,}200\ \text{W} = 2{,}200\ \text{J s}^{-1}$

$$\frac{280{,}896\ \text{J}}{2{,}200\ \text{J s}^{-1}} = 128\ \text{s}$$

Conservation of Heat

If our system is closed to the surroundings, heat must be conserved



Heat energy lost by the metal

Heat energy gained by the water

Conservation of Heat

Heat energy gained by the water = heat energy lost by the metal

If you have 0.05 kg of water at 20°C and you put in 0.031 kg of an unknown substance that is originally 100°C, you measure that the final temp of everything is 25°C. What is the unknown metal?

Step 1: Find the Heat Energy of the Water

Specific Heat of Water
4180 J kg^{-1} K^{-1}

$$Q = mc\Delta T = (0.05)(4180)(25 - 20)$$

$$Q = 1{,}045 \text{ J}$$

Conservation of Heat

Heat energy gained by the water = heat energy lost by the metal

If you have 0.05 kg of water at 20°C and you put in 0.031 kg of an unknown substance that is originally 100°C, you measure that the final temp of everything is 25°C. What is the unknown metal?

Step 2: Using the heat energy step one. Find mystery specific heat

$$1{,}045\ \text{J} = mc\Delta T = (0.031)(c)(100 - 25)$$

$$c = 449\ \text{J kg}^{-1}\ \text{K}^{-1}$$

Specific Heat (J/kg*K)	
Water (liquid)	4190
Steam	1870
Ammonia (gas)	2060
Ethanol (liquid)	2440
Aluminum	897
Carbon (graphite)	709
Copper	390
Gold	129
Iron	448
Mercury	140
Lead	129
Silver	234

Lesson Takeaways

- ❑ I can define specific heat capacity with proper units
- ❑ I can describe the effect of larger or smaller specific heat values
- ❑ I can relate specific heat capacity to the heat energy and temperature change
- ❑ I can describe how a calorimeter uses the conservation of heat to study a material's specific heat