Thermal Physics

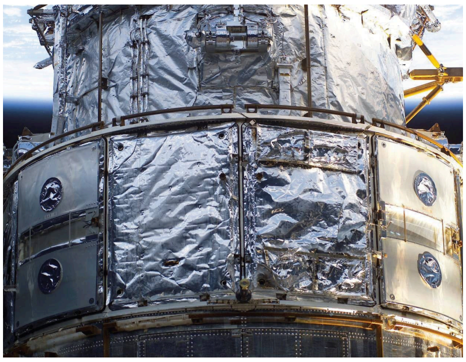
Understanding Heat, Energy, and Matter

Big Idea:

What makes hot things hot and cold things cold? Thermal physics reveals how invisible particles dancing at microscopic scales create the warmth of a campfire, the chill of space, and even the weather on Earth.

Real-Life Connection:

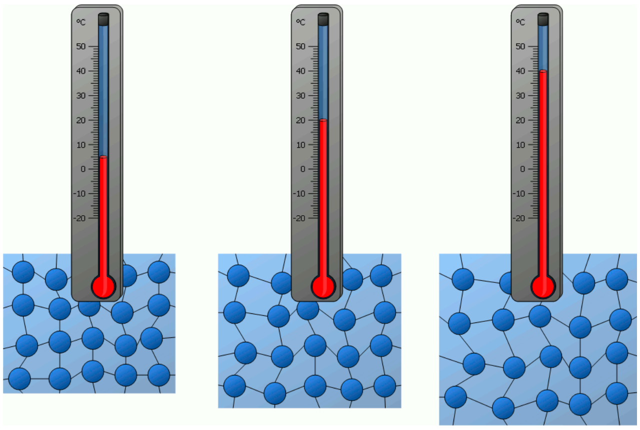
From your morning coffee cooling down to the insulation in spacecraft, thermal physics explains every process involving heat transfer. The same principles govern boiling water, melting glaciers, and even the thermal control systems that keep astronauts alive in orbit.



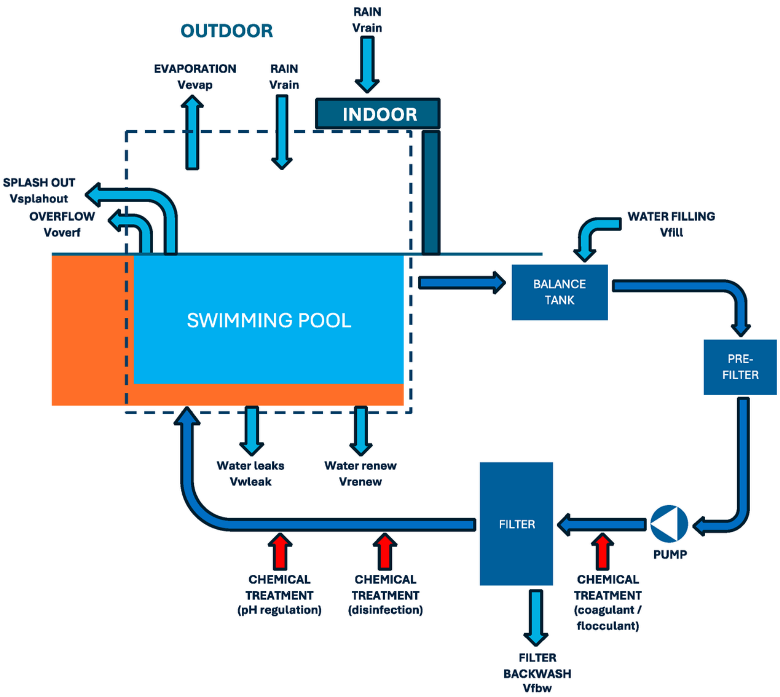
Core Understanding:

1. Temperature and Internal Energy

Temperature measures how energetic the particles in a substance are, not how much total energy it has. Internal energy is the sum of the kinetic energy (due to motion) and potential energy (due to intermolecular forces) of all particles.



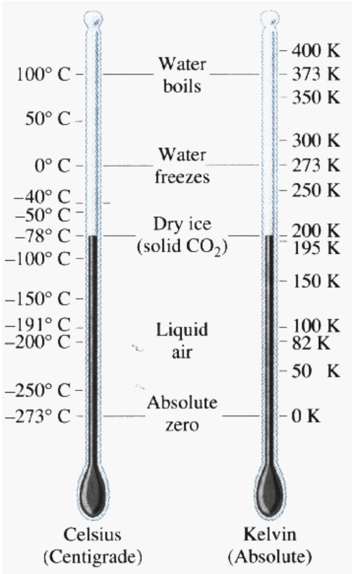
A hot cup of tea at 90 °C might have less total internal energy than a swimming pool at 25 °C, because the pool has far more particles!



2. Absolute Temperature (Kelvin Scale)

The Kelvin scale (K) starts at absolute zero (0 K), where particles have minimum possible energy. Conversion: T(K) = T(°C) + 273.15

At 0 K, motion doesn't stop completely but reaches its lowest quantum limit, a reminder of nature's "speed limit" for coldness.

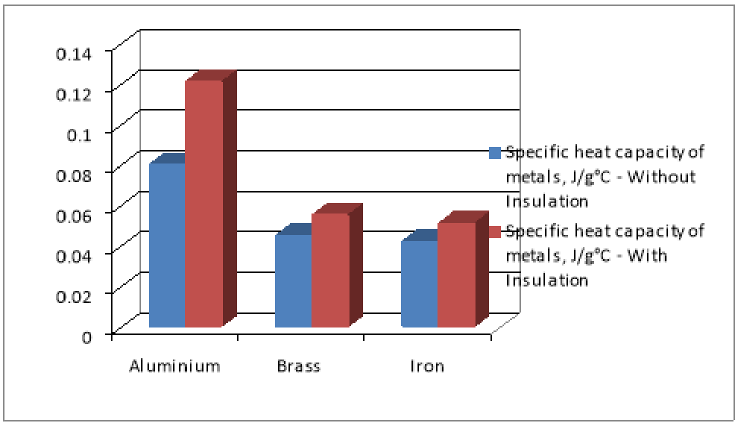


3. Specific Heat Capacity & Latent Heat

Different materials store and release heat differently.

Specific heat capacity (c): the energy needed to raise 1 kg of a substance by 1 K.

Formula: $Q = mc\Delta T$



Specific latent heat (L): the energy needed to change the state of 1 kg of a substance without changing its temperature.

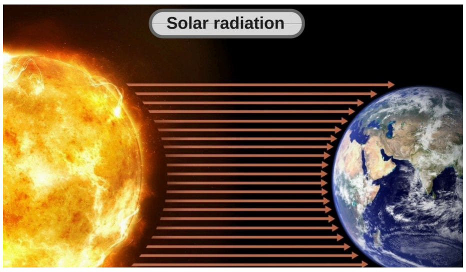
Formula: $Q = mL$

Example: When ice melts at 0 °C, energy goes into breaking molecular bonds, not raising temperature.

4. Energy Transfer & Heat Flow

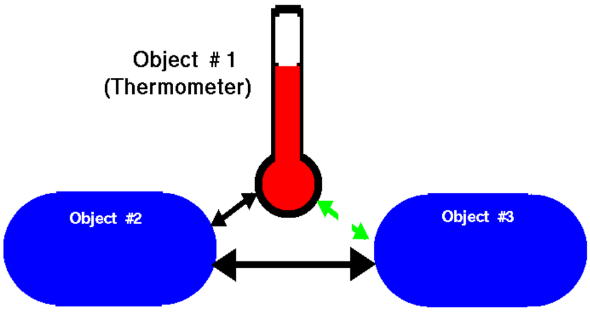
Energy always flows from hotter to cooler regions, nature’s quest for balance.

Conduction: heat transfer through direct contact (like a metal spoon heating up in soup).
Convection: heat transfer through moving fluids (boiling water circulates heat).
Radiation: energy transfer by electromagnetic waves (the Sun warming Earth through space).



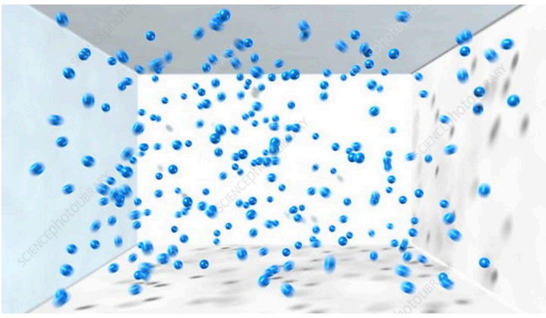
5. Thermal Equilibrium & Zeroth Law

When two systems reach the same temperature, they are in thermal equilibrium, no net energy flows.
The Zeroth Law says: If A is in thermal equilibrium with B, and B with C, then A is with C.This simple idea lets us measure temperature using thermometers!



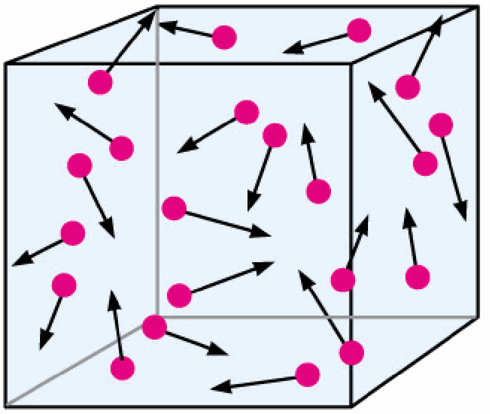
6. Ideal Gas Laws

For an ideal gas, particles move randomly and don't attract each other.
Formula: $pV = nRT$
p: pressure
V: volume
n: moles of gas
R: gas constant (8.31 J mol^{-1} K^{-1})
T: temperature (K)
As temperature rises, particle speed increases, collisions with container walls become more frequent and forceful and increasing pressure.



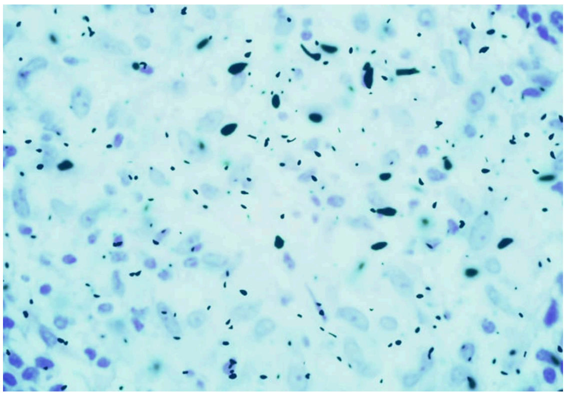
7. Kinetic Model of an Ideal Gas

The average kinetic energy of gas molecules is directly proportional to temperature: $E_k(avg) = (3/2)kT$, where k is the Boltzmann constant. This bridges microscopic motion with macroscopic temperature, a triumph of the Nature of Science in unifying scales of reality.



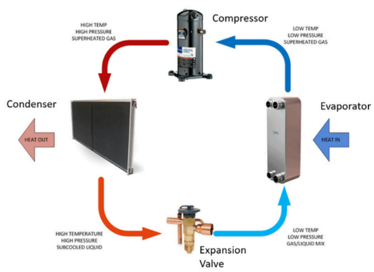
8. Brownian Motion & Molecular Behavior

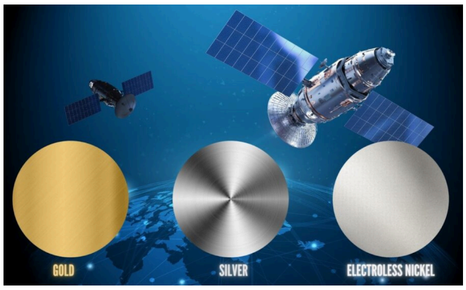
Tiny pollen grains dancing in water (first seen by Robert Brown) gave evidence that atoms exist, their random jiggling caused by collisions with unseen water molecules. It's a beautiful example of indirect evidence leading to a scientific breakthrough.



Applications & Examples:

-Home insulation reduces conduction and convection, keeping houses warm.
-Refrigerators use phase change (latent heat) in coolant gases to absorb heat from inside.
-Satellites rely on reflective coatings to manage radiative heat transfer in space.



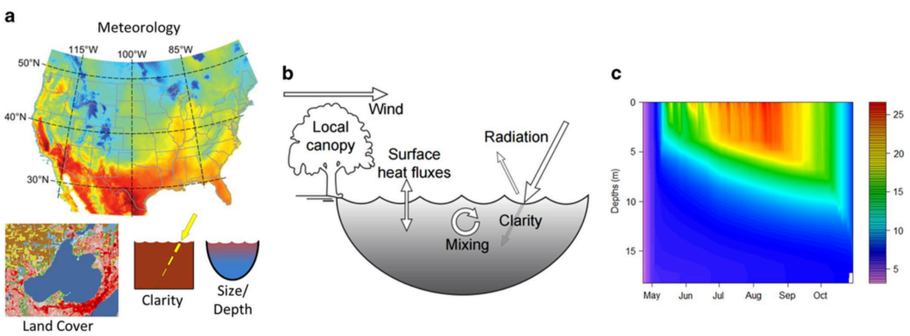


Quick Concept Table:

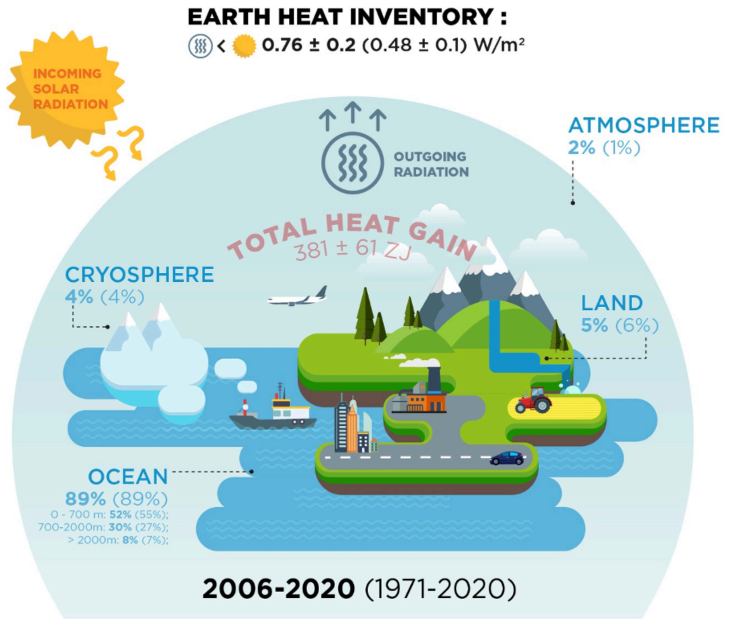
Quantity	Symbol	Unit	Meaning
Temperature	T	K	Measure of average kinetic energy
Specific heat capacity	c	$J\ kg^{-1}\ K^{-1}$	Energy to raise 1 kg by 1 K
Latent heat	L	$J\ kg^{-1}$	Energy for phase change
Pressure	p	Pa	Force per unit area
Volume	V	m^3	Space occupied by gas
Moles	n	mol	Amount of substance

Think & Reflect:

-Why does a large lake stay cool for months even after days of summer heat?



-How could understanding heat flow guide global solutions to energy efficiency and climate change?



Summary:

Thermal physics connects the dance of atoms to the warmth of life and technology. From the whisper of random molecular motion to the grand flow of energy across planets, it shows that temperature is motion, and heat is energy in transit.

Next Step:

For step-by-step derivations, IB-style questions, and examiner insights, explore LumiKnow Premium Physics Notes, your deeper dive into the physics of energy, matter, and motion.