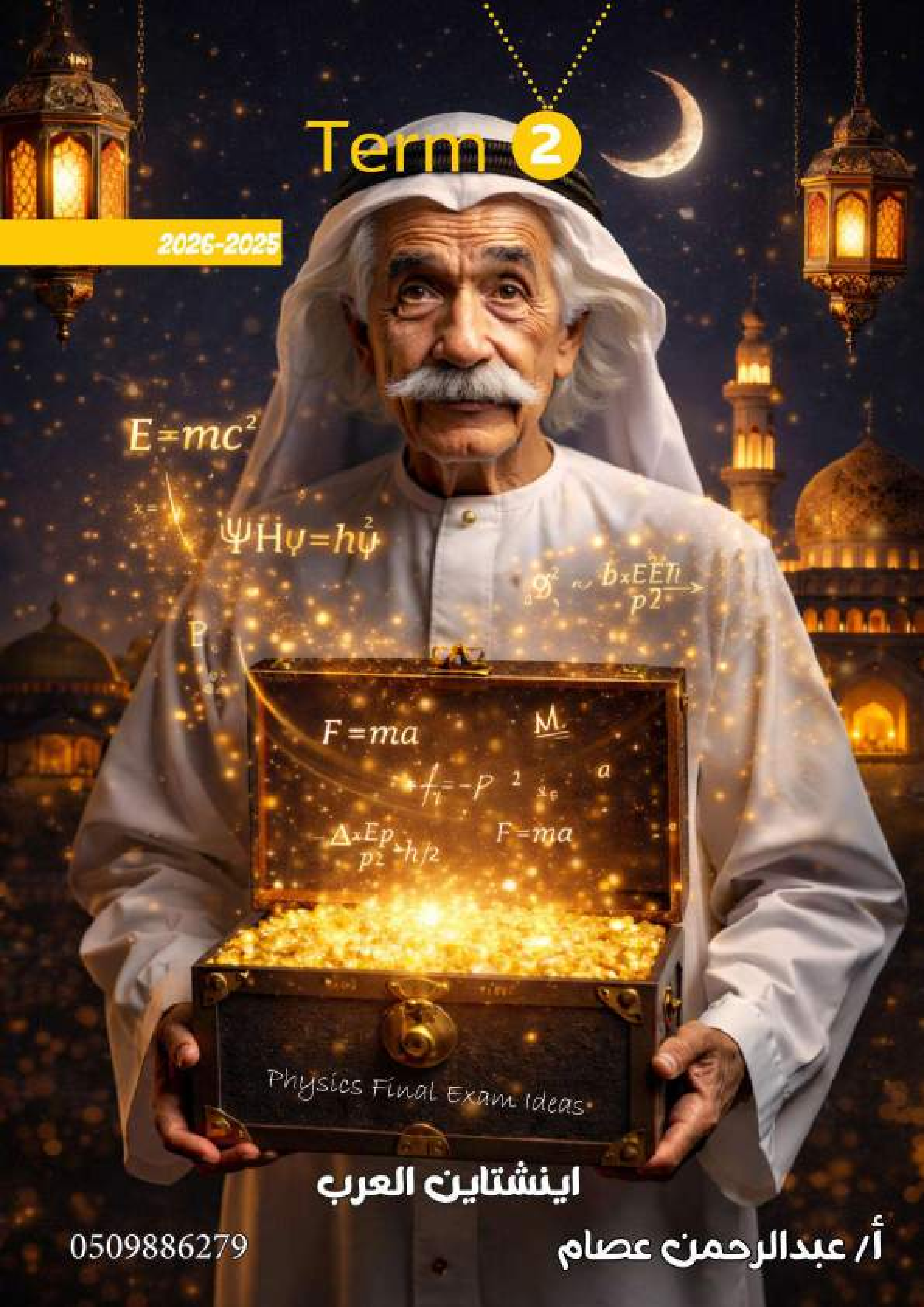
ملف مراجعة نهائية وحدة Thermal Energy ووحدة Matter of States وفق الهيكل منهج انسباير Inspire

Term 2

2026-2025



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Physics Final Exam Ideas

Grade 12-11, Advanced Stream Term Two

Module 11: Thermal Energy

- **Lesson 1:** Temperature, Heat, and Thermal Energy
- **Lesson 2:** Changes of State and Thermodynamics

Module 12: States of Matter

- **Lesson 1:** Properties of Fluids
- **Lesson 2:** Forces Within Liquids
- **Lesson 3:** *Fluids at Rest and in Motion (For Enrichment)*
- **Lesson 4:** Solids

Module 11: Thermal Energy

Lesson 1: Temperature, Heat, and Thermal Energy

Idea 1. The difference between **thermal energy** and **temperature**

1. Thermal Energy

Thermal energy is **the total kinetic and potential energy** of all particles in an object.
It depends on:

- The **number of particles** (mass).
- The **type of particles**.
- The **movement and interactions** among particles.

So, an object with more particles has **more thermal energy**, even if the temperature is the same.

2. Temperature

Temperature measures the **average kinetic energy** of the particles in a substance.
It depends only on:

- How fast the particles are moving (their kinetic energy).
  It does **not** depend on:
- The amount of matter (number of particles).
- The size or mass of the object.

Q. What happens to the thermal energy of an object when it is cut in half?

A. It becomes half. **B.** It stays the same. **C.** It becomes double. **D.** It becomes zero.

Correct answer: A

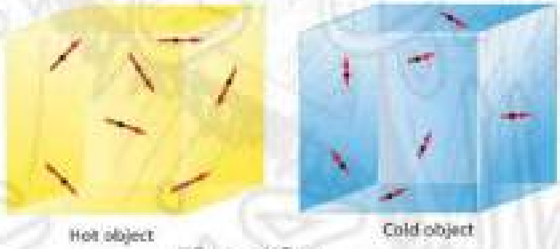
Q. What happens to the temperature of an object when it is cut in half?

A. It becomes half. **B.** It stays the same. **C.** It becomes double. **D.** It becomes zero.

Correct answer: B

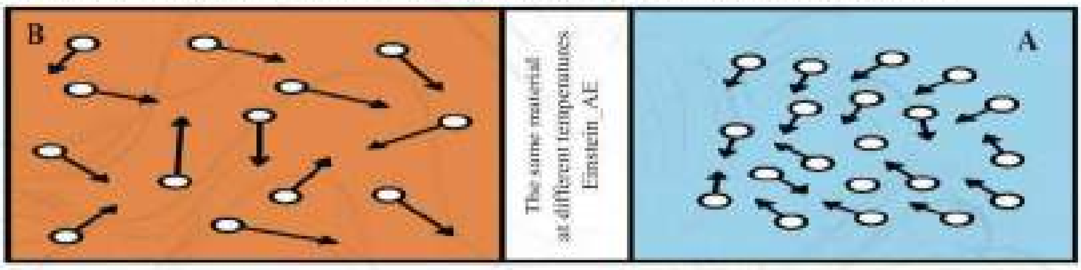
Idea 2. the difference between a hot object and a cold object

A **hot object** has a **higher temperature**, which means its particles have **greater kinetic energy** and move faster.
In contrast, a **cold object** has a **lower temperature**, so its particles have **less kinetic energy** and move more slowly.



$KE_{hot} > KE_{cold}$

Q. The figure shows two samples **A** and **B** from the same material at different temperatures.
Which of the following statements is true for the temperature of the samples?



ⓐ $T_A > T_B$ ⓑ $T_A < T_B$
ⓒ $T_A = T_B$ ⓓ We can't predict which one has greater temperature

Q. A plastic bottle initially containing hot air is placed into a bowl of ice as shown in the figure.
Which of the following statements is true?

ⓐ The average kinetic energy of air particles decreases
ⓒ The average kinetic energy of air particles increases
ⓑ The average kinetic energy of ice particles decreases
ⓓ The average kinetic energy of ice particles and air particles in the bottle remain the same

Answer: A

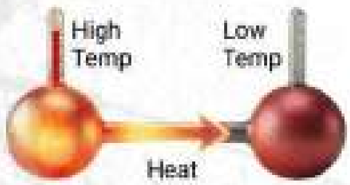
The bottle starts with **hot air** inside. When placed in **ice**, heat flows **from the hot air to the cold ice** (from higher temperature to lower temperature).

As the air **loses energy**, the **average kinetic energy** of its particles **decreases.**

Idea 3. Thermal Equilibrium

Thermal equilibrium is the state in which **two objects in contact have the same temperature**, so **no net heat transfer** occurs between them.

When two objects at different temperatures touch:



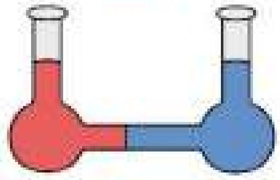
- Heat flows from the **hot object** (higher average kinetic energy) to the **cold object** (lower average kinetic energy).
- The hot object **loses energy**, and the cold object **gains energy**.
- This energy transfer continues until **both objects reach the same temperature**.

Q. A clinical thermometer is placed under the tongue of a patient to measure his temperature.
What is the principle **that thermometer uses in measuring the temperature**?

ⓐ Thermal Equilibrium ⓑ Change of State
ⓒ The First Law of Thermodynamics ⓓ The Second Law of Thermodynamics

Answer: A

Q. In the figure, two liquids are poured into two connected flasks.
If the red liquid is hotter than the blue liquid, **which one of the following statements is true?**



- ⓐ Heat continues to transfer between the liquids until they are separated
- ⓒ Heat transfers between the liquids until they have equal thermal energy
- ⓑ Heat transfers between the liquids until they reach the same temperature
- ⓓ Heat does not transfer between the liquids

Correct Answer: C

Q. In which case two bodies are described to be in **thermal equilibrium**?

- ⓐ When they are in thermal contact and are at the same temperature
- ⓒ When they are in thermal contact and are at different pressures
- ⓑ When they are not in thermal contact but are at the same pressure
- ⓓ When they are in thermal contact but are at different temperatures

Correct Answer: A

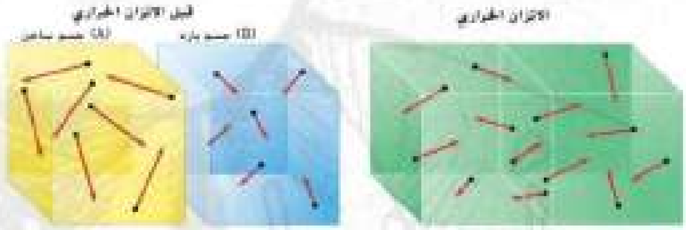
Q. When two bodies at different temperatures are placed in thermal contact with each other, heat flows from the hotter body to the cooler body until they both reach the same temperature. Assuming that no heat is lost to the surroundings:

Which of the following expressions is correct?

- ⓐ The heat gained by the hot body will be equal to the heat lost by the cold body
- ⓑ The heat gained by the hot body will be less than the heat lost by the cold body
- ⓒ The heat lost by the hot body will be greater than the heat gained by the cold body
- ⓓ The heat lost by the hot body will be equal to the heat gained by the cold body

Correct Answer: D

Q. The figure below shows two bodies, one **cold** and the other **hot**, before and at the **thermal equilibrium**. Which table describes the **average thermal energy** of the particles before and at equilibrium?



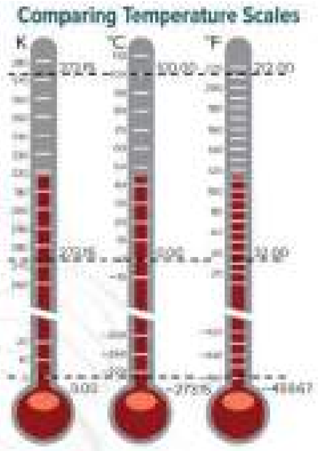
Before thermal equilibrium	In thermal equilibrium
QA > QB	QA = QB

Before thermal equilibrium	In thermal equilibrium
QA = QB	QA > QB

Before thermal equilibrium	In thermal equilibrium
QA = QB	QA < QB

Before thermal equilibrium	In thermal equilibrium
QA < QB	QA = QB

Idea 4. Temperature



Temperature Reference Points in Different Scales

Description	Celsius (°C)	Kelvin (K)	Fahrenheit (°F)
Boiling point of water	100	373	212
Freezing point of water	0	273	32
Absolute zero	–273.15	0	–459.67

Important Conversion Formulas

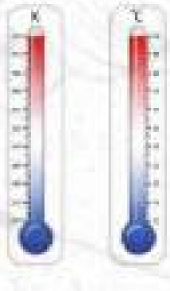
1. **From Fahrenheit to Celsius:** $T_C = \frac{5}{9} \times (T_f - 32)$
2. **From Celsius to Kelvin:** $T_K = T_C + 273$
   In case of reverse request, solution via Solve for X.

Q. Which of the following **temperatures** equals **the absolute zero**?

ⓐ 0.00° C ⓑ -459.67° F ⓒ 273.15° C ⓓ 0.00° F

Correct Answer: B

Q. The Celsius scale is used for everyday temperature measurements, but for scientific purposes it makes more sense to use the Kelvin scale.



Which of the following does *not* fit the Kelvin scale?

A. Temperature on the Kelvin scale can be positive or negative values.
B. Absolute zero on the Kelvin scale is −273 °C.
C. There is no kinetic energy of particles on the Kelvin scale at 0 K.
D. The conversion equation to the Kelvin scale is TK = 273 + TC.

Correct Answer: A

The table below shows the freezing point of water in different temperature scales.

Which row represents the correct degrees?

Row	Celsius	Fahrenheit	Kelvin
1	0	32	273
2	0	32	−273
3	0	–459	−273
4	100	212	373

Idea 5. Methods of Heat Transfer

Heat can be transferred in **three different ways**, depending on how energy moves from one place to another.

1. Conduction

Definition:
Heat transfer through **direct contact between particles** in solids, liquids, or gases.

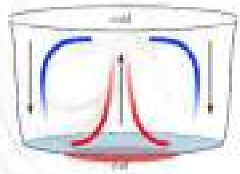
How it works:
Particles with higher kinetic energy collide with neighboring particles and pass energy along.

Example:
A metal rod heated at one end becomes warm throughout because energy travels through particle collisions.

2. Convection

Definition:
Heat transfer through the **movement of fluids** (liquids or gases).

How it works:
Hot fluid rises because it becomes less dense, while cold fluid sinks because it is denser.
This creates a **convection current**.



Example:
Boiling water — hot water rises to the top, and cold water sinks to the bottom.

examples:

- Atmospheric convection and turbulence, Thunderstorms, Ocean currents

Summary quote:
"The water at the bottom of the pot is heated by conduction and rises to the top, while the colder water at the top sinks to the bottom. This movement caused by temperature differences is called convection."

3. Radiation

Definition:
Heat transfer through **electromagnetic waves,** without needing any matter.

How it works:
Energy travels through space in the form of infrared radiation.

Example:
The Sun heating Earth across the vacuum of space.

Q. The transfer of thermal energy between air molecules in a closed room is an **example** of:

ⓐ Specific heat ⓑ Convection ⓒ Radiation ⓓ Conduction

Correct Answer: D

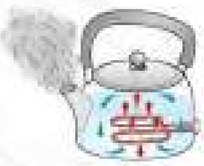
In a closed room, air molecules collide with each other and transfer thermal energy by **direct particle-to-particle contact**, which is **conduction**.

Q. The ray in this picture is an example of:

ⓐ Conduction ⓑ Convection ⓒ Radiation ⓓ Evaporation

Correct Answer: C

Q. Which of the following statements **NOT** correctly describes **convection currents**?



A. Convection occurs only in liquids and gases.
B. Convection occurs when warmer, less-dense air rises and cooler, denser air sinks.
C. Convection occurs in solids, liquids, and gases.
D. Convection currents occur when the colder, denser fluid sinks downward.

Correct Answer: C

Q. What do we call the **heating caused by the motion of particles** in a **liquid or gas** due to **temperature differences**?

ⓐ Conduction ⓑ Convection ⓒ Radiation ⓓ Evaporation

Correct Answer: B

How does heat transfer between the iron rod and the hand according to the figure?

a. Heat transfers from the rod to the hand by **conduction**.
b. Heat transfers from the rod to the hand by **convection**.
c. Heat transfers from the hand to the rod by **conduction**.
d. Heat transfers from the rod to the hand by **radiation**.

Correct Answer: A

Which of the following is **correct** about thermal energy transfer when a water beaker is heated on a stove?

a. The water in contact with the bottom of the beaker is heated by conduction.

b. The water in contact with the bottom of the beaker is heated by convection.

c. The waves carry the thermal energy through the water beaker to the stove.

d. The water at the surface is heated before the water at the bottom of the beaker.

Correct Answer: a.

Idea 6. Specific Heat

Specific heat is the amount of thermal energy needed to raise the temperature of **1 kg** of a substance by **1 K (or 1°C)**.

Property	High Specific Heat	Low Specific Heat
Energy needed to heat	Large	Small
Heating rate	Heats up slowly	Heats up quickly
Cooling rate	Cools slowly	Cools quickly
Examples	Water, ice, steam	Metals

Q. Heat energy is supplied at the same rate to the same amount of oil and water in similar containers.
Which of the following explains why the temperature of the oil rises more quickly than water?

ⓐ Oil has a greater heat of vaporization than water
ⓑ Oil has a smaller specific heat than water
ⓒ Oil has a smaller heat of vaporization than water
ⓓ Oil has a greater specific heat than water

Correct Answer: B

Oil heats up faster because it has a **lower specific heat**, meaning it requires **less energy** to raise its temperature compared to water.

Q. "The amount of heat required to raise the temperature of 1 kg of a substance by 1 K."
Which physical quantity is expressed in this definition?

ⓐ Specific heat ⓑ Heat of fusion ⓒ Heat of vaporisation ⓓ Heat of freezing

Idea 7. Measuring Heat

When heat is added to a substance, its temperature changes depending on three factors:

1. **Mass (m)** — larger mass requires more energy to change temperature.
2. **Specific Heat (C)** — a property of the material that tells how much energy is needed to raise the temperature of 1 kg by 1°C (or 1 K).
3. **Temperature Change (ΔT)** — the difference between the final and initial temperatures.

The relationship between these quantities is given by the heat equation:

$$Q = mC\Delta T = mC(T_f - T_i)$$

A 5290 J amount of heat is given to (0.500 kg) of water until its temperature becomes (17.53 °C).
What is **the initial temperature** of the water?

Given: C_w = 4180 J/(kg. K)

ⓐ 40.3 °C ⓑ 12.5 C ⓒ 18.7 °C ⓓ 15.0 °C

A (5 kg) cast iron pan is heated on a cooker from (170 K) to (296 K).
How **much thermal energy** had to be transferred to the pan?

Given: Specific heat of iron: $C = 450$ J/(kg .K)

ⓐ 29.0 kJ ⓑ 37.0 kJ ⓒ 29.3×10^3 J ⓓ 5.78×10^3 J

The same amount of thermal energy was added to two blocks of Aluminium and Iron with equal masses. If the temperature of the Aluminium block changed by **ΔT** and the specific heat of Aluminium is double the specific heat of Iron,
what is the change in the Iron's block temperature?

ⓐ ΔT ⓑ 2ΔT ⓒ 4ΔT ⓓ ΔT / 2

An iron pot is heated on a cooker from **170 K** to **300 K**.
What is the **mass of the pot** if **29.3×10^4 J** of thermal energy was added to it?

The specific heat of iron is **450 J/(kg·K)**.

ⓐ 5.0×10^2kg ⓑ 5.0 kg ⓒ 0.5 kg ⓓ 6.0 kg

A **5290 J** amount of heat is given to **0.50 kg** of water at **15.0°C**.
What is the **final temperature** of the water?

The specific heat of water is: $C_w = 4180$ J/(kg.K)

ⓐ 17.5 °C ⓑ 12.5 °C ⓒ 20.3 °C ⓓ 40.3 °C

Idea 8. Calorimeter and Measuring Specific Heat

A **calorimeter** is a device used to measure **thermal energy changes** in a substance.
It is designed to be **thermally insulated**, so little to no heat escapes to the surroundings.
This allows accurate measurement of how heat is transferred between a **hot substance** and **cold water** inside the calorimeter.

How the Calorimeter Works

When a hot substance is placed into cold water inside the calorimeter:

- The **hot substance loses heat.**
- The **cold water gains heat.**
- Heat flows until **both reach the same final temperature → thermal equilibrium.**

Because the system is insulated: $\Delta E_{cold} = -\Delta E_{hot}$

$$m_a C_a (T_f - T_a) = -m_b C_b (T_f - T_b)$$

Any unknown in a heat problem Solve for X

To find the specific heat of the unknown material, solve for C_h:

$$C_h = \frac{-m_c C_c (T_f - T_c)}{m_h (T_h - T_f)}$$

If the final temperature is unknown:

$$T_f = \frac{m_h C_h T_h + m_c C_c T_c}{m_h C_h + m_c C_c}$$

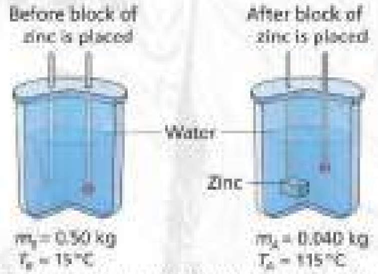
In the calorimeter shown in the figure below, the change in the thermal energy of a test substance (ΔE_a) equals the change in the thermal energy of the water ($-\Delta E_B$). Depending on this principle, which of the following equations solves the specific heat of the test substance (C_a)?

ⓐ $C_A = \frac{-m_B C_B \Delta T_B}{m_A \Delta T_A}$ ⓑ $C_A = \frac{-m_A C_A \Delta T_A}{m_B \Delta T_B}$ ⓒ $C_A = \frac{-m_B C_A \Delta T_A}{m_A \Delta T_B}$ ⓓ $C_A = -m_B C_B \Delta T_B$

FRQ Questions

A calorimeter contains **0.50 kg of water at 15°C**. A **0.040 kg block of zinc at 115°C** is placed in the water.

What is the final temperature of the system?



Hint:

Specific heat of zinc: $C_A = 388$ J/ (kg. °C)
Specific heat of water: $C_B = 4180$ J/ (kg. °C)

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A 100.0 g block of an **unknown material** at 100.0°C is placed in 100.0-g of water at 10.0°C. The final temperature of the mixture is 26.0°C.

Specific heat of water: $C_W = 4180$ J/ (kg. °C)

What is the specific heat of the **unknown material**?

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Lesson 2: Changes of State and Thermodynamics

Idea 1. Change of State

Matter exists mainly in three states: **solid, liquid, and gas**.
When thermal energy is added to a substance, the movement of its particles increases, and the substance may change its state.

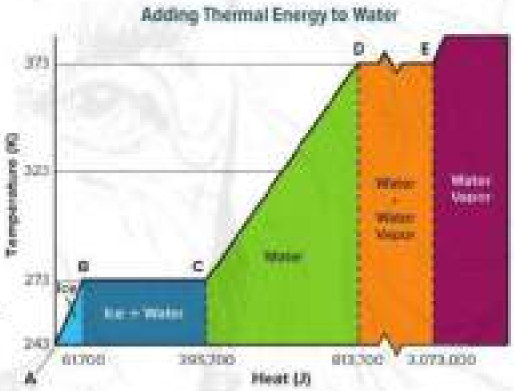
- **Heating a solid** increases particle motion until it melts into a **liquid**.
- **Heating a liquid** further increases particle energy until it becomes a **gas**.
- If the energy is removed (cooling), the reverse changes occur.

A substance changes state because the added thermal energy allows particles to **move faster, break some of their bonds,** and **gain more freedom of motion**.

Idea 2. The Heating Curve

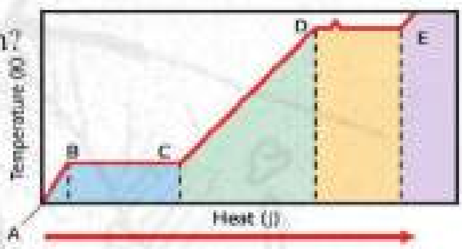
As heat is added to water:

- **Segment A–B:** Ice warms (temperature increases).
- **Segment B–C:** Ice melts (temperature stays constant).
- **Segment C–D:** Liquid water warms.
- **Segment D–E:** Water boils (temperature stays constant).
- **Segment E–F:** Steam warms.



During melting and boiling, **temperature does not increase** even though heat is added, because energy is used to **change the state**, not to raise temperature.

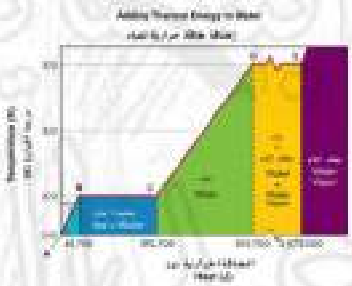
What is the **phase** of water between points **D** and **E** on the diagram?



ⓐ Solid and liquid ⓑ Liquid

ⓒ Liquid and gas ⓓ Solid

The diagram below shows the changes of state when thermal energy is added to **(1.0 kg)** of ice starting at **(243 K)** and continuing until it becomes water vapor.
What is the specific heat of water? *(Use data on the diagram)*



ⓐ 2.26×10^6 J/kg·K ⓑ 3.34×10^5 J/kg·K
ⓒ 2060 J/kg·K ⓓ 4180 J/kg·K

Idea 3. Melting Point

The **melting point** is the temperature at which a solid changes into a liquid.
At this point, added thermal energy does **not** increase temperature; instead, it is used to weaken the bonds between particles so they can move more freely.
This process appears on a heating curve as a **horizontal line**, where temperature remains constant while the phase changes.

Idea 4. Boiling Point

The **boiling point** is the temperature at which a liquid changes into a gas.
Once the entire liquid reaches this temperature, further heating does not raise temperature.
All added thermal energy goes into breaking intermolecular forces to turn liquid into vapor.
This also appears as a **horizontal plateau** on the heating curve.

Idea 5. Heat of Fusion

The **heat of fusion (Hf)** is the amount of thermal energy needed to melt **1 kg of a solid** at its melting point without changing its temperature.
Energy during melting is used to **break bonds**, not to increase the motion of particles.

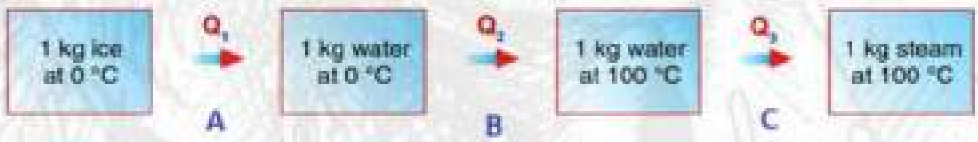
Idea 6. Heat of Vaporization

The **heat of vaporization (Hv)** is the energy required to convert **1 kg of a liquid** into gas at its boiling point.
This energy is absorbed to **separate particles completely**, allowing them to move freely as vapor.

While a substance is heated, it reaches its boiling point.
What happens if heating continues while it is boiling?

ⓐ The temperature of the substance decreases
ⓑ The temperature of the substance does not change
ⓒ The thermal energy of the substance decreases
ⓓ The temperature of the substance increases

A (1.0 kg) block of ice at (0.0 °C) is heated until it changes into steam at (100.0 °C).



Why does the **temperature** at **processes A** and **C not change** even though heat is absorbed?

ⓐ The heat is used to overcome the forces of attraction between the molecules
ⓒ The heat is used to increase the forces of attraction between the molecules
ⓑ The heat is lost in the external environment
ⓓ The heat is not used to increase temperature unless the mass of the material is very large

What is **the amount of thermal energy** needed to change the state of **1 kg** of a substance from **liquid to gas**?

ⓐ Heat of Fusion ⓑ Heat of Vaporization ⓒ Specific Heat ⓓ Melting Point

Idea 7. Heat Required for Phase Change

When a substance changes state, the temperature **does not change** even though heat is being added or removed.
Instead, the thermal energy goes into **breaking or forming bonds** between particles.

1. Heat Required to Melt a Solid

To melt a solid at its melting point: $Q = mH_f$

- Energy is used to **break bonds** so particles can move from solid to liquid.

2. Heat Required to Vaporize a Liquid

To vaporize a liquid at its boiling point: $Q = mH_v$

- Energy is used to **separate particles completely** and turn liquid into gas.

3. Freezing and Condensation

When a liquid freezes or vapor condenses:

$$Q = -mH$$

- Heat is **released** to the surroundings.
- The negative sign shows that the substance **loses** thermal energy.

A block of metal of mass **(5 kg)** requires **(3.15×10^5 J)** of thermal energy to change its state from a solid to a liquid at its melting point.
Which of the metals listed in the table below is this metal?

Table: Heats of Fusion and Vaporization of Common Substances

Material	Heat of Fusion (J/kg)	Heat of Vaporization (J/kg)
Gold	6.30×10^4	1.64×10^6
Silver	1.04×10^5	2.36×10^6
Lead	2.04×10^4	8.64×10^5
Mercury	1.15×10^4	2.72×10^5

ⓐ Silver ⓑ Mercury ⓒ Lead ⓓ Gold

The heat required to melt a block of copper is (82×10^5 J).
The heat of fusion of copper is (2.05×10^5 J/kg).
What is the mass of the block?

ⓐ 2.5×10^{-2} kg ⓑ 40.0 kg ⓒ 168.0 kg ⓓ 840.0 kg

Idea 8. When Temperature Changes vs. Stays Constant

1. When the Temperature Changes

If the substance is **heating up or cooling down**, the temperature changes and we use the **specific-heat equation**: $Q = mC\Delta T$

This equation is used during:

- Heating a solid
- Heating a liquid
- Heating a gas
- Cooling processes

Here, heat changes the **average kinetic energy** of particles → so **temperature changes**.

2. When the Temperature Stays Constant

If the substance is **changing state** (melting, freezing, boiling, condensing), the temperature stays **constant**, and we use:

Melting or Freezing

$$Q = mH_f$$

Boiling or Condensation

$$Q = mH_v$$

Hf = heat of fusion **Hv** = heat of vaporization

In phase changes, heat is used to **break or form bonds** between particles, not to change kinetic energy → so **temperature stays constant** even though energy is absorbed or released.

How much **energy** is required to change a **35.0 g** ice cube at **–5.00 °C** into steam at **115 °C**?

Hint:

Specific heat of ice: $C_{ice} = 2060$ J/(kg °C) Specific heat of water: $C_{water} = 4180$ J/(kg °C)
Specific heat of steam: $C_{steam} = 2020$ J/(kg °C) Heat of fusion: $H_f = 3.34 \times 10^5$ J/kg
Heat of vaporization: $H_v = 2.26 \times 10^6$ J/kg

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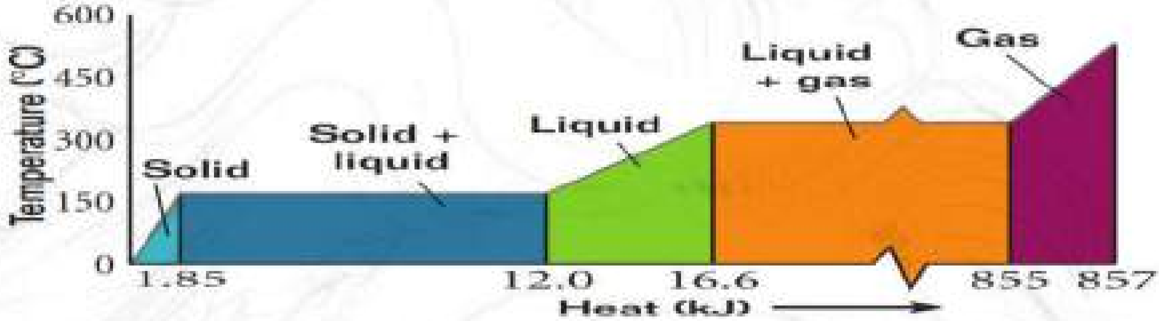
The heating curve shows how the temperature of a **23 g** sample of a substance change as heat energy is added. The curve includes several regions: solid, solid–liquid mixture, liquid, and finally liquid–gas mixture leading to the gas phase.



Students must extract data from the graph, apply the correct formulas, and present the solution in a clear and organized manner.

يجب على الطالب استخدام البيانات من المنحنى، وكتابة القوانين، وتنظيم خطوات الحل بالتفصيل.

Calculate the **specific heat capacity of the liquid**

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Determine the **latent heat of fusion**.

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Calculate the **specific heat capacity of the solid**

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Calculate the **specific heat capacity of the Gas**

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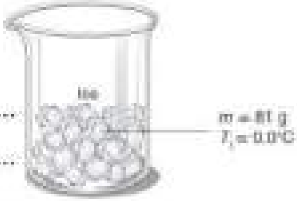
In the figure below, **81 g of ice melts and then warms to 10°C.**
How much thermal energy is absorbed from the surroundings during this process?



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A quantity of water vapor at a temperature of 100°C was used to convert **1.0 kg of ice** at 0.0°C into water at 100°C (the final temperature of the mixture is 100°C).

Important Final Note (your request):

Heating stops completely when the mixture reaches 100°C.

You don't need to do any calculations after this point.

Specific heat capacity of water: $\boldsymbol{c = 4180}$ J/kg.°C
heat of fusion of ice: $\boldsymbol{H_f = 3.34 \times 10^5}$ J/kg
heat of vaporization of water: $\boldsymbol{H_v = 2.26 \times 10^6}$ J/kg
What is **the mass of steam** used for heating?

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How much energy is required to change a 35.0 g ice cube at −5.00 °C into steam at 115 °C?

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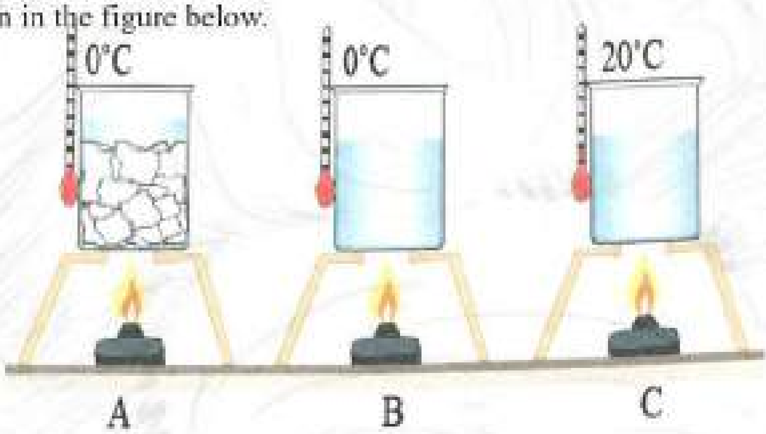
A constant thermal heating flame was placed under a beaker containing ice cubes with a mass of **2 kg**. The temperature measurement was taken when heating began, and it was **0°C** in stage **A**. The ice cubes began to gradually melt and turn into liquid water at a temperature of **0°C** in stage **B**. After a period of time, the temperature of the liquid water rose to **20°C** in stage **C**, as shown in the figure below.



If you know that the specific heat of water is $c = 4180$ J/kg. °C

and the heat of fusion of ice is $H_f = 3.34 \times 10^5$ J/kg,

answer the following:

A. Why did the temperature not increase during the melting of ice and turning into liquid water in stages A to B?

(Write your answer on the lines provided.)

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B. Calculate each of the following:

The amount of thermal energy required to melt ice in stage A to B.

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The amount of thermal energy needed to raise the temperature of the water in stage B to C.

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The total amount of thermal energy needed to raise the temperature of ice from (0°C) to water at (20°C).

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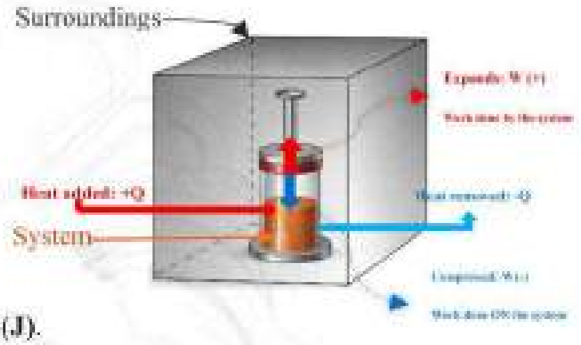
Idea 9. The First Law of Thermodynamics

The First Law of Thermodynamics states that the change in the **internal energy** of a system depends on two things:

1. **Heat added to the system (Q)**
2. **Work done by the system (W)**



$$\Delta U = Q - W$$

Where:

- **ΔU** = change in the internal thermal energy of an object
- **Q** = heat added to the object
- **W** = work done *by* the object
- All the terms represent **energy** and are measured in **joules (J)**.

Table: Signs in the First Law of Thermodynamics

Symbol	Meaning	Positive (+)	Negative (−)
Q	Heat added or removed	Heat **added to** the system Energy is added to the system	Heat **lost by** the system Energy is **removed** from the system
W	Work done by or on the system	Work **done by** the system (gas expands)	Work **done on** the system (gas is compressed)
ΔU	Change in internal energy	Internal energy **increases**	Internal energy **decreases**

Note (Important):

When the **temperature stays the same**, the **change in internal energy is zero**: $\Delta U = 0$

$$W = Q$$

This means **all the absorbed heat becomes work** in an isothermal expansion.

What is the amount of net heat if the net work done by a system is (50 J), while the increase in its internal energy is (20 J)?

ⓐ −70 J ⓑ 20 J ⓒ 70 J ⓓ −20 J

A gas balloon absorbs **85 J** of thermal energy. The balloon expands but stays at the **same temperature**. How much **work** did the balloon do in expanding?

ⓐ **85 J** ⓑ **−85 J** ⓒ **0 J** ⓓ **170 J**

Which statement about the First Law of Thermodynamics is correct?

a. The First Law of Thermodynamics states that the change in the internal energy of an object is equal to the heat added to the object **minus** the work done **by** the object.

b. The First Law of Thermodynamics states that the change in the internal energy of an object is equal to the heat added to the object **plus** the work done **by** the object.

c. The First Law of Thermodynamics states that the change in the internal energy of an object is equal to the heat added to the object **minus** the work done **on** the object.

d. The First Law of Thermodynamics states that the change in the internal energy of an object is equal to the heat added to the object **plus** the work done **on** the object.

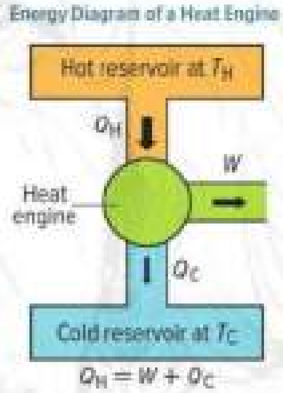
Idea 9. Difference Between a Heat Engine and a Refrigerator (in Terms of Work)

1. Heat Engine – Work Output

A **heat engine** takes heat from a **hot reservoir** and converts part of it into **useful work**.

- Heat in: Q_H
- Waste heat out: Q_C
- Work done *by* the engine:

$$W = Q_H - Q_C$$



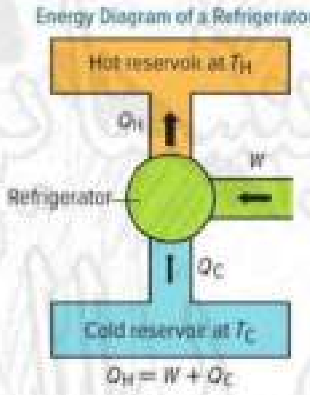
Key point:

A heat engine **produces work**.
Work flows **out of the device**.

2. Refrigerator – Work Input

A **refrigerator** transfers heat from a **cold reservoir** to a **hot reservoir**, which cannot happen on its own.
So the refrigerator **requires work input**.

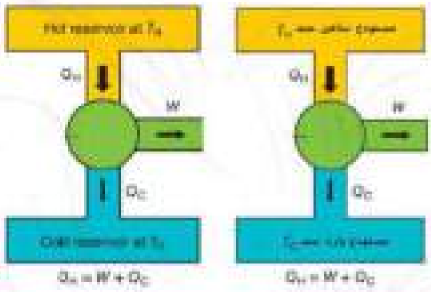
- Work done *on* the refrigerator: W
- It absorbs heat from cold space: Q_C
- It releases heat to the hot surroundings: $Q_H = Q_C + W$



Key point:

A refrigerator **consumes work**.
Work flows **into the device**.

Which device does this heat diagram represent?



ⓐ **Heat generator** ⓑ **Heat engine** ⓒ **Refrigerator** ⓓ **Electrical pump**

Idea 10. Engine Efficiency & Waste Heat

1. Engine Efficiency (Thermal Efficiency)

Engine efficiency tells us **how well an engine converts the heat input** Q_H into **useful work** W.

$$e = \frac{W}{Q_H} = 1 - \frac{Q_C}{Q_H}$$

- Net work is given by: $W_{net} = Q_H - Q_C$
- If **all** the heat input became work → efficiency would be **100%**.
- But this is **impossible** because some energy is always lost as **waste heat** Q_C.
- No real engine can reach 100% efficiency.

2. Waste Heat

Not all the heat entering an engine turns into useful mechanical work.

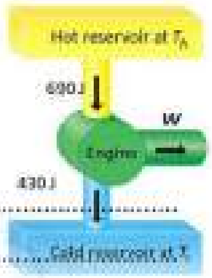
Sources of Waste Heat

- The **engine block** becomes hot.
- **Exhaust gases** carry heat away.
- The **radiator** removes heat to the air.
- **Friction** between moving parts converts energy into heat.

Key Idea

Waste heat is **unavoidable**, and every real engine must release some heat into the surroundings.

An engine receives 690 J of heat from a hot reservoir and gives off 430 J of heat to a cold reservoir.



a. What is the work done by the engine?

b. What is the efficiency of the engine?

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What is the efficiency of an engine that exhausts 870 J of heat in the process of doing 340 J of work?

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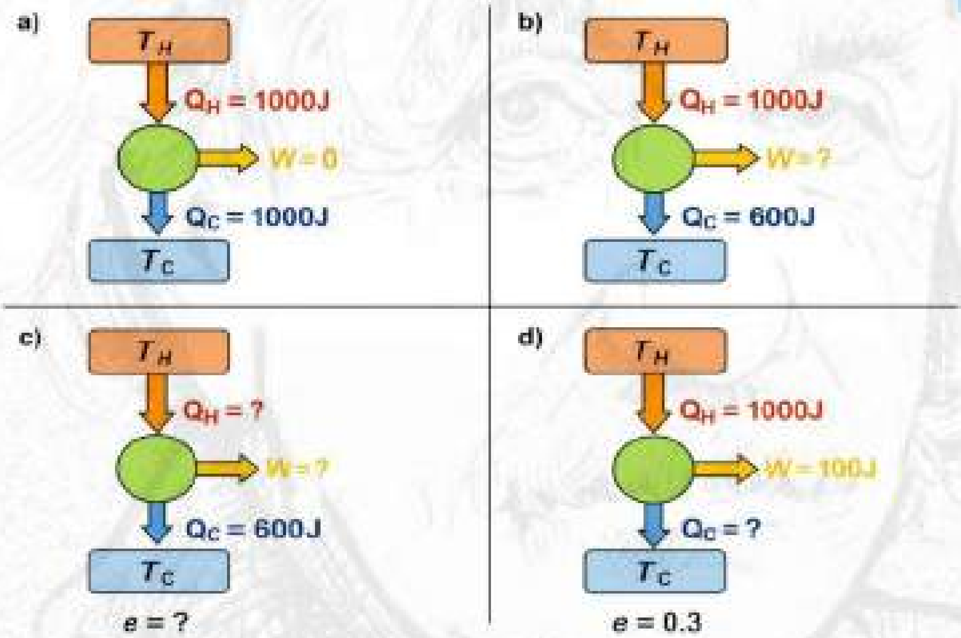
diagrams, calculate the missing variable(s).



(a)$Q_H = 1000\text{ J}, Q_C = 1000\text{ J}, W = 0$ **Find:** $e = ?$

(b)$Q_H = 1000\text{ J}, Q_C = 600\text{ J},$ **Find:** $W = ?\ , e = ?$

(c)$Q_C = 600\text{ J}, e = 0.3$ **Find:** $Q_H = ?, W = ?$

(d)$Q_H = 1000\text{ J}, W = 1000\text{ J}$ **Find:** $Q_C = ?$

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Idea 11. Second Law of Thermodynamics

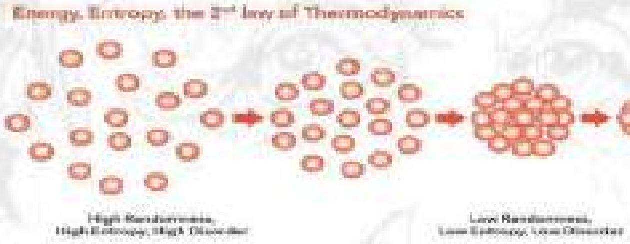
The **Second Law of Thermodynamics** explains that thermal energy naturally spreads out from regions of **higher temperature** to regions of **lower temperature**.
This spreading continues **until energy becomes more evenly distributed**.

Energy Spreads Out

When a hot object touches a cold one, thermal energy has a natural tendency to **disperse** or **spread out**.
Energy moves from the warmer object **to the cooler object**, increasing the disorder of energy distribution.

Example from the figure:

- A melting ice pop cools a pizza because energy flows **from the warm pizza to the cold ice pop**, not the opposite.



Why the Reverse Cannot Happen Spontaneously

Although the First Law allows energy to flow either way (as long as total energy is conserved), the **Second Law** says:

Energy will not spontaneously flow from a colder object to a hotter object.

Such a process would require **external work or intervention**.

Which statement about the Second Law of Thermodynamics is correct?

a. The Second Law of Thermodynamics states that heat naturally flows from a colder object to a hotter object without any external work.

b. The Second Law of Thermodynamics states that thermal energy spreads out and will naturally flow from a hotter object to a colder object.

c. The Second Law of Thermodynamics states that all of the heat added to a system can be completely converted into work.

d. The Second Law of Thermodynamics states that isolated systems become more ordered over time as energy concentrates in one region.

Idea 12. Entropy & the Second Law of Thermodynamics

Entropy is a measure of how much energy in a system becomes **spread out** or **dispersed**. A system where energy is distributed evenly has **high entropy**, while a system where energy is concentrated has **low entropy**.

The **Second Law of Thermodynamics** states that **natural processes move in the direction that increases the total entropy of the universe**.
This means energy naturally spreads out unless work is done to concentrate it again.

Why Energy Spreads Out

When a hot object touches a cold object, thermal energy moves from **higher energy concentration (hot)** to **lower concentration (cold)**, increasing entropy.
Reverse processes—such as heat flowing from cold to hot—do not occur spontaneously.

Entropy in Heat Engines

Heat engines cannot convert all heat into work because some energy always spreads out as **waste heat**, increasing entropy.
This is why **no engine is 100% efficient**.

Change in Entropy Formula

For a reversible process:

$$\Delta S = \frac{Q}{T}$$

- Q: heat added
- T: temperature in Kelvin
- Units: J/K

Entropy increases when heat is added to a system at a given temperature.

A 10 kg block of ice at 273 K melts. The heat of fusion for water is 3.34×10^5 J/kg.

What is the **change in entropy** during melting?

ⓐ 1.22×10^6 J/K ⓑ 3.34×10^5 J/K ⓒ 3.34×10^6 J/K ⓓ 1.22×10^3 J/K

Electrical cables are made of copper whose melting point is 1,085°C.

What is **the heat of fusion** of copper if a 6.2 kg block of copper experiences an entropy change of 940.5 J/K upon melting?

ⓐ 1.65×10^5 J/kg ⓑ 6.51×10^5 J/kg ⓒ 6.02×10^5 J/kg ⓓ 2.06×10^5 J/kg

A **1.0 kg** sample of water is heated from **273 K** to **274 K**.
The specific heat capacity of water is: $c = 4180$ J/kg.K **What is the change in entropy**?

ⓐ 1.0×10^{-2} J/K ⓑ 4180 J/K ⓒ 4.18 J/K ⓓ 15.3 J/K

A **1.0 kg** block of ice is completely melted at **273 K**.
The heat of fusion for water is: $H_f = 3.34 \times 10^5$ J/kg

What is the change in entropy during melting?

ⓐ 3.34×10^6 J/K ⓑ 3.34×10^5 J/K ⓒ 1.22×10^6 J/K ⓓ 1.22×10^3 J/K

Module 12: States of Matter

Lesson 1: Properties of Fluids

Fluids are materials that can **flow** and **do not have a definite shape**.
They include **liquids** and **gases**.
Unlike solids, which maintain a fixed shape, fluids **take the shape of the container** they occupy.
Examples: water, oil, air.

2. Liquids and Their Properties

• Definite Volume, No Definite Shape

Liquids have a **fixed volume**, but their shape changes depending on the container they are in.

• Behavior with Temperature Changes

Liquids can change state when temperature changes:

- **Cooling a liquid → solid** (water → ice)
- **Heating a liquid → gas** (water → vapor)

• Real-Life Example

An iceberg has a **fixed shape**, but the surrounding water **flows** and takes the shape of its environment.

Plasma – The Fourth State of Matter

Plasma is formed when a gas is heated to extremely high temperatures.
At these temperatures, collisions between particles become energetic enough to **strip electrons** from atoms, creating a mixture of:

- **Negatively charged electrons**
- **Positively charged ions**

This ionized, gas-like state is called **plasma**, and it behaves differently from ordinary gases.

Properties of Plasma

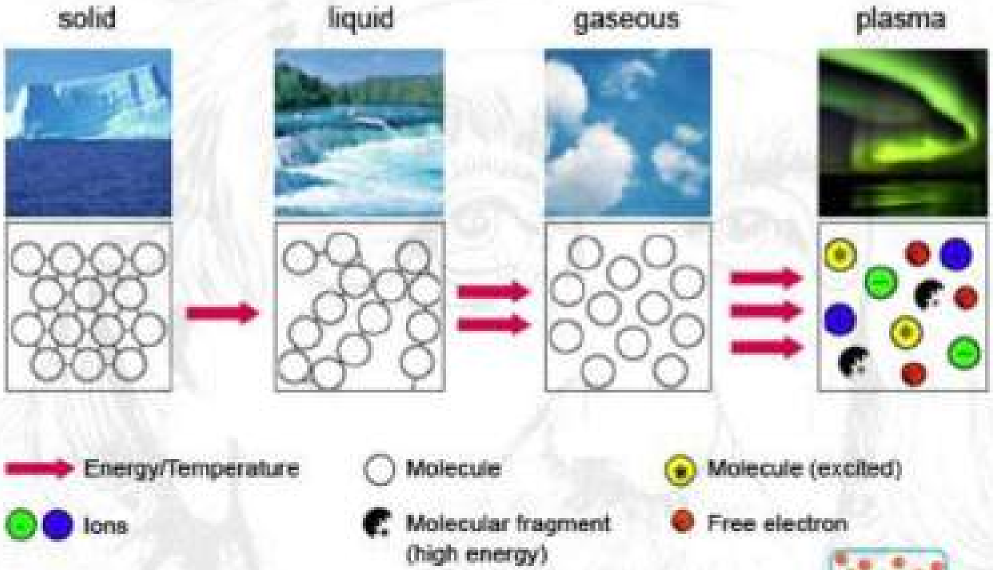
- Plasma **conducts electricity**, unlike normal gases.
- Plasma glows with bright colors when electrical energy excites its charged particles.
- Plasma is affected by electric and magnetic fields.

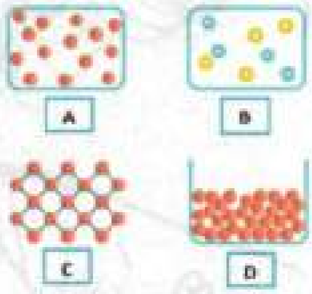
Where Do We Find Plasma?

Although it may seem uncommon, plasma is actually the **most abundant state of matter in the universe**.

Examples include:

- **Stars**, including the Sun
- **Lightning bolts**
- **Neon signs** (as shown in the image)
- **Fluorescent lamps**
- Much of the matter between stars and galaxies





Which of the following substances are fluids?

a. A and D **b. B and C**

c. C and A **d. D and C**

Which of the following is NOT a fluid?

A) Water B) Sand C) Oil D) Air

A state of matter that is formed at high temperatures, where collisions between particles become energetic enough to remove electrons from atoms, producing ions and an electron cloud. Found in stars, lightning, and neon signs, it can conduct an electric current.

What state of matter is this?

ⓐ Solid ⓑ Gas ⓒ Plasma ⓓ Liquid

Idea – Pressure

Pressure is the force applied per unit area.

$$P = \frac{F}{A}$$

The SI unit of pressure is the **Pascal (Pa) equal** N/m²

Relationship

Pressure has a **direct relationship** with force.

$$P \propto F$$

Meaning:

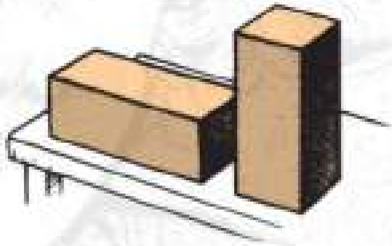
- When **force increases, pressure increases.**
- When **force decreases, pressure decreases.**

Pressure has an **inverse relationship** with area.

$$P \propto \frac{1}{A}$$

Meaning:

- When **area increases, pressure decreases.**
- When **area decreases, pressure increases.**



In solids, pressure is transmitted through the **contact area**.

- Small contact area → high pressure
- Large contact area → low pressure

The diagram shows four solid pieces of the same metal.
Each piece has the same thickness and stands on a bench as shown.

Which piece of metal produces **the greatest pressure** on the bench?

ⓐ A ⓑ B ⓒ C ⓓ D

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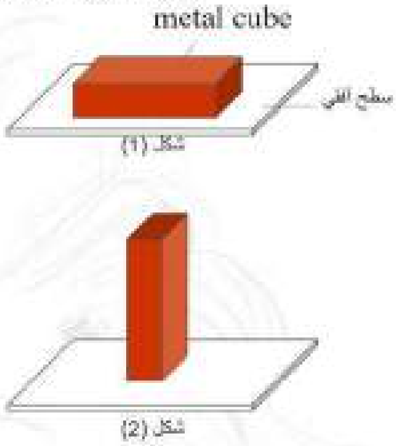
A **metal cube** is placed horizontally on a flat surface as shown in Figure (1).
Then its position is changed so that it stands vertically as shown in Figure (2).

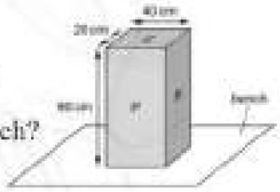
Which correctly describes the effect of this change on:

- the **contact area** between the cube and the surface
- the **pressure** exerted by the cube on the surface



Choice	Contact Area	Pressure
(a)	Decreases	Decreases
(b)	Decreases	Increases
(c)	Increases	Decreases
(d)	Increases	Increases

The diagram shows a solid block resting on a bench.
The dimensions of the block are shown, and the three labelled faces are **P**, **Q**, and **R**.



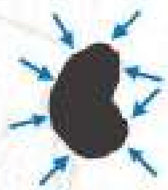
On which labelled surface should the block rest to produce the **smallest pressure** on the bench?

A **P** B **Q** C **R** D Any **of P, Q, or R**

If a person stands on one foot instead of two.

what happens to the force and the pressure on the ground?

A. Both the force and the pressure decrease
B. Both the force and the pressure increase
C. Pressure increases, but the force remains the same
D. The force increases, but the pressure remains the same



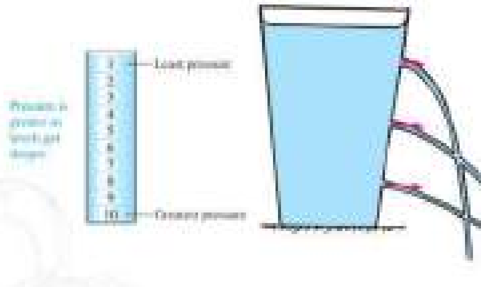
Idea – Pressure in Liquids

1. Liquids Exert Pressure in All Directions
Liquids are made of particles that move freely and can slide past each other.
Because of this movement, liquid particles **collide with the walls** and the bottom of their container. These collisions create **pressure**.
This pressure is **equal in all directions** at the same depth.

Idea: Pressure Increases with Depth

As depth increases, the amount of liquid above a point increases.
More liquid means **more weight pressing down**, which increases pressure.

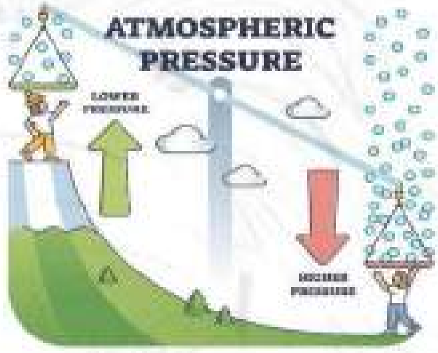
Deeper point → more liquid above → greater pressure



Idea: Inverse Relationship Between Height and Pressure

In fluids such as the atmosphere, there is an **inverse relationship** between **height** and **pressure**.

$$P \propto \frac{1}{h}$$



Meaning:

- As **height increases**, **pressure decreases**.
- As **height decreases**, **pressure increases**.

The Earth is surrounded by an envelope of gases called the atmosphere, and this atmosphere exerts pressure on objects on the Earth's surface, known as atmospheric pressure.

How does atmospheric pressure change with increasing altitude above sea level?

A. It depends on the temperature
B. It remains constant
C. It increases
D. It decreases

3. Pressure Does Not Depend on the Total Amount of Liquid

Only **depth**, **density**, and **gravity** affect liquid pressure.
It does **not** depend on:

- The total volume of the liquid
- The shape of the container

Pressure in Liquids

$$P = \rho g h$$

Where:

- ρ= density of the liquid
- g= gravitational acceleration
- h= depth

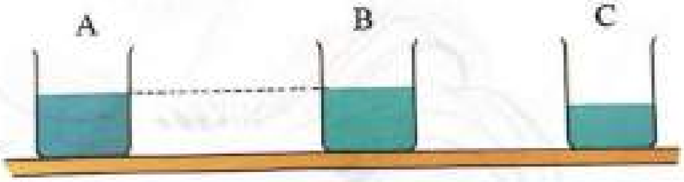
This formula shows that pressure increases when:

- The **depth** increases
- The **density** increases (seawater > freshwater)

The figure shows three containers (**A, B, C**).
Container **A** contains **salt water**, while containers **B** and **C** contain **pure water**.

Which of the following relationships correctly describes the **pressure at the base** of each of the three containers? **Hint:** Salt water has a **higher density** than pure water

Choice	Pressure Relationship
A	$P_A = P_B = P_C$
B	$P_A > P_B = P_C$
C	$P_A = P_B > P_C$
D	$P_A > P_B > P_C$



The figure shows a water tank that supplies water to a house.
What is the water pressure at point **X** at the bottom of the tank?
(Density of water = 10^3 kg/m^3)

A. 3.92×10^4 N/m^2
B. 1.37×10^4 N/m^2
C. 9.80×10^3 N/m^2
D. 5.89×10^4 N/m^2

A lead brick with dimensions **5.0 cm × 10.0 cm × 20.0 cm** rests on the ground on its smallest face.
Lead has a density of **11.8 g/cm³**.
What pressure does the brick exert on the ground?

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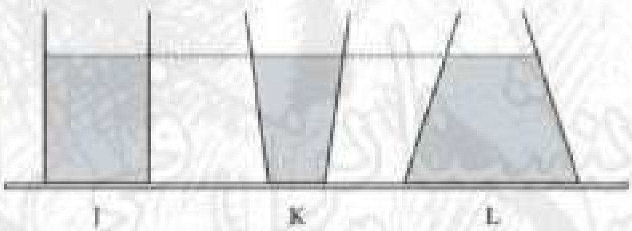
The figure shows three containers (J, K, L) in which the height of the water is equal.

Which of the following relationships describes the **pressure** at the base of the three containers?

A) $P_K = P_L < P_J$
B) $P_K > P_L = P_J$
C) $P_K = P_J > P_L$
D) $P_K = P_L = P_J$



Notes – Pressure

1. Pressure Formula

Pressure is defined as the force applied per unit area:

$$P = \frac{F}{A}$$

2. Mass vs. Weight

When a question gives **mass (m)**, we must convert it to **weight (force)**

$$F = mg$$

Where:

- m= mass (kg) $g \rightarrow \times 10^{-3} kg$
- $g = 9.8\text{m/s}^2$
- F= weight (force) in Newton (N)

3. Area Conversions (Very Important)

A. From centimeters to meters

$$Cm \rightarrow \times 10^{-2} m$$

B. Conversion of area ($cm^2 \rightarrow m^2$)

$$Cm^2 \rightarrow \times 10^{-4} m^2$$

A physics book has a mass of **0.95 kg** and dimensions **0.22 m × 0.26 m**.
What pressure does it exert on the table?

ⓐ 0.05 Pa ⓑ 602 Pa ⓒ 16.6 Pa ⓓ 163 Pa

A student presses on paper with a force of **15 N** using a pencil tip of area **0.01 cm²**.

What is the pressure exerted?

ⓐ 1.15×10^7 Pa ⓑ 1.15×10^5 Pa ⓒ 1.5×10^6 Pa ⓓ 1.67×10^7 Pa

How much pressure is exerted by a force of **600 N** spread vertically over an area of **2.0 m²**?

ⓐ 30 Pa ⓑ 12000 Pa ⓒ 2700 Pa ⓓ 300 Pa

A wooden cube with a side length of **2 cm** has a mass of **3.2 g**.
Calculate:

(a) the weight of the cube.

(b) the pressure it exerts on a flat horizontal surface.

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A block of iron has the following dimensions:

Length: 6 cm **Width:** 8 cm **Depth:** 1.0 cm

The mass of the block is **360** g.

Calculate:

(a) the minimum and maximum contact area of the block.

(b) the greatest pressure it can exert on a flat horizontal surface.

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A car has four tyres, each with a contact area of **6 Cm^2**.

Calculate the pressure exerted by each tyre if the car has a mass of **1 200 kg**.

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A glass slab exerts a maximum pressure of **5 000 N/m^2** on a flat surface.

Its dimensions are: **20 cm × 10 cm × 5 cm**.

Calculate the mass of the glass slab.

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A metal cube has a mass of **68 kg** and exerts a pressure of **17 000 Pa** on a flat horizontal surface.

Calculate:

(a) the area of contact with the ground.

(b) the length of one side of the cube (its dimension).

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The atmospheric pressure at sea level is approximately **1.013×10^5 Pa**.

What is the force that the air exerts on the top of a desk that measures **152 cm** in length and **76 cm** in width?

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A car tire makes contact with the ground over a rectangular area of **12 cm × 18 cm**.
If the car's mass is **925 kg**.

what pressure does the car exert on the ground when resting on all four tires?

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Gas Laws

Gas laws describe the relationship between **pressure, volume, and temperature**.

1. Boyle's Law

Relationship: Pressure ↔ Volume (Temperature is constant)

Boyle's Law says:

- If **volume decreases, pressure increases**.
- If **volume increases, pressure decreases**.

This happens because gas particles collide more often with the container when space is smaller.

Formula:

$$P_1V_1 = P_2V_2$$

A nitrogen gas of volume **0.022 m³**, at a pressure of **10 000 Pa**, is compressed at constant temperature. If the new pressure is **9000 Pa**, what is its new volume?

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2. Charles's Law

Relationship: Volume ↔ Temperature (Pressure is constant)

Charles's Law says:

- If **temperature increases, volume increases**.
- If **temperature decreases, volume decreases**.

This happens because warm gas particles move faster and need more space.

Formula:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Important: Temperature must be in **Kelvin (K)**, not °C.

A gas of volume **6.00 L** at a temperature of **20.0°C** is compressed to a volume of **4.00 L** at constant pressure. What is its new temperature?

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3. Combined Gas Law

This law combines Boyle's and Charles's laws.

It is used when **pressure, volume, and temperature all change at the same time**.

Formula:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Example:

A tank containing **200.0 L** of hydrogen gas at **0.0°C** is kept at **156 kPa**.
The temperature is raised to **95°C**, and the volume is decreased to **175 L**.
What is the new pressure of the gas?

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A gas is at a pressure of **2.0×10^5 Pa** at a temperature of **27°C**.
At what temperature will the gas pressure increase to **3.0×10^5 Pa,** if the volume is constant?

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In a certain internal-combustion engine, **0.0021 m³** of air at atmospheric pressure 1.013×10^5 Pa and **303 K** is rapidly compressed to a pressure of **20.1×10^5 Pa** and a volume of **0.0003 m³**.
What is the final temperature of the compressed gas?

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4. Ideal Gas Law

The most complete gas law.
It connects **pressure**, **volume**, **temperature**, and **number of moles** together.

$$PV = nRT$$

P = pressure **V** = volume **n** = number of moles **T** = temperature (Kelvin)

R = gas constant = 8.31 J/mol·K

10.00 moles of an ideal gas are at a temperature of **250 K** and a pressure of **80 Pa**.
What is the volume of the gas?

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An ideal gas has a volume of **20.0 m³** at a pressure of **101 kPa** and a temperature of **300 K**.
How **many moles** of the gas are in the cylinder?

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A **20.0-L** sample of argon gas at **273 K** is at atmospheric pressure, **101.3 kPa**.
The temperature is then lowered to **120 K**, and the pressure is increased to **145 kPa**.

a. What is the new volume of the argon sample?

b.Find the number of moles of argon atoms in the argon sample.

c.Find the mass of the argon sample.
(The molar mass of argon, **M = 39.9 g/mol**.)

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A tank of helium gas used to inflate toy balloons is at a pressure of **15.5 × 10⁶ Pa** and a temperature of **293 K**.
The tank's volume is **0.020 m³**.
How large a balloon would it fill at **1.00 atmosphere** and **323 K**?

What is the mass of the helium gas if the molar mass of helium gas is **4.00 g/mol**.

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The average molar mass of air (mainly diatomic oxygen gas and diatomic nitrogen gas) is about **29 g/mol**.
What is the volume of **1.0 kg** of air at atmospheric pressure and **20.0°C**?

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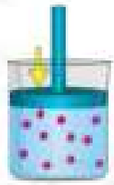
A gas in a container is kept at a constant temperature. If the volume of the gas changes, its pressure changes. Which of the following represents the correct relationship between the pressure and the volume of the gas?



A. PV = constant B. $\frac{P}{V}$ = constant

C. $\frac{V}{P}$ = constant D. $P + V$ = constant

A sample of nitrogen gas has a volume of **200 L** at **273 K** under an atmospheric pressure of **100 kPa**. If the temperature is raised to **320 K**, and the pressure is decreased to **80 kPa**, what is the new volume of the nitrogen?

ⓐ 320 L ⓑ 239 L ⓒ 298 L ⓓ 346 L

A sample of gas at standard atmospheric pressure (**101.3 kPa**) has a volume of **0.080 m³**. If there are **32 moles** of gas, what is the temperature of the gas?

ⓐ 327 K ⓑ 325 K ⓒ 210 K ⓓ 270 K

A sample of argon gas of volume **0.05 m³** at **273 K** and at atmospheric pressure (**101.3 kPa**) is used. What is the number of moles of argon atoms in this sample?

ⓐ 6.14 mol ⓑ 1.23 mol ⓒ 0.45 mol ⓓ 2.23 mol

A quantity of gas has a volume of **100 cm³**.

What happens to the volume if both pressure and temperature change double?

ⓐ Volume increases ⓑ Volume decreases ⓒ Volume remains constant

ⓓ Volume depends on both pressure and temperature

A cylinder contains oxygen gas at **101.3 kPa**, with a volume of **0.080 m³**.
If the gas expands to a volume of **3.6 m³**, what is the new pressure?

ⓐ 1.23×10^4Pa ⓑ 2.10×10^5Pa ⓒ 1.90×10^3Pa ⓓ 1.20×10^4Pa

Which of the following equations expresses **Boyle's Law**?

ⓐ $V_1T_1 = V_2T_2$ ⓑ $PV = nRT$ ⓒ $P_1V_1 = P_2V_2$ ⓓ $P_1T_1 = P_2T_2$

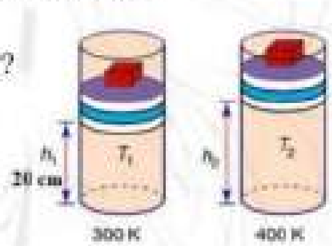
Which of the following equations expresses **Charles's Law**?

ⓐ $P_1V_1 = P_2V_2$ ⓑ $PV = nRT$ ⓒ $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ ⓓ $P_1T_1 = P_2T_2$

Experiments in the eighteenth century indicated that "the volume of a sample of gas under constant pressure changes in direct proportion to its temperature in kelvin."
What is the name of the law that expresses this relationship?

ⓐ Avogadro's Law ⓑ Charles's Law ⓒ Ideal Gas Law ⓓ Boyle's Law

An amount of air is kept in a cylinder with a piston under a constant pressure of **100 kPa**.
Initially, the height of the piston is **20 cm** above the base at **300 K**.
What will be the height of the piston if the temperature is increased to **400 K**?



ⓐ 6.70 cm ⓑ 26.7 cm

ⓒ 60.0 cm ⓓ 15.0 cm

At what temperature would **2.5 moles** of neon gas occupy a volume of 20×10^{-3} m^3 at a pressure of 1.95×10^5 Pa?

ⓐ 1.6×10^3 K ⓑ 4.26×10^2 K ⓒ 2.3×10^2 K ⓓ 1.9×10^2 K

Thermal expansion occurs in **most fluids**, including liquids.
Although liquids do not have a fixed shape, they can be modeled as tiny clusters of particles that move together, similar to very small pieces of a solid.

When a liquid is heated, the particles move faster. This motion makes the clusters of particles **push farther apart**, increasing the spacing between them. As a result, the **entire liquid expands**.

With the **same change in temperature, liquids expand more than solids**, but **less than gases**.

Thermal expansion is greatest in:

ⓐ Solids ⓑ Gases ⓒ Liquids ⓓ All of them expand equally

The figure shows the circulation of air in the room, which occurs as a result of a property known as "thermal expansion", which results from the expansion of a fluid when its temperature increases.

Which statements in the table are consistent with this property?

Figure الشكل

Option	Statement
a	The gas becomes less dense
b	Applicable to gases only
c	Hot air rises upward
d	A convection current is formed from it

ⓐ a, b, c ⓑ a, c, d ⓒ a, b, d ⓓ b, c, d

When the temperature of fluids increases, they expand, and this property is known as "thermal expansion."

Which of the following statements is not consistent with this property?

ⓐ The gas becomes less dense ⓑ Hot air rises upward

ⓒ A convection current is formed from it ⓓ Applicable to gases only

Correct Answer: d. Applicable to gases only

These forces strongly influence how liquids behave.

There are two main types of forces in liquids:

- **Cohesive forces** — attraction between particles of the *same* substance.
- **Adhesive forces** — attraction between particles of *different* substances.

1. Cohesive Forces

Definition

Cohesive forces are the attractive forces between molecules of the *same liquid*.
They cause the liquid to "stick to itself."

Surface Tension

Surface tension is the result of cohesive forces pulling surface molecules tightly together, forming a "stretchy skin" on the liquid.

2. Adhesive Forces

Definition

Adhesive forces are attractive forces between particles of **different substances**.

Capillary Action

Capillary action happens when adhesive forces between a liquid and the walls of a narrow tube pull the liquid upward inside the tube.

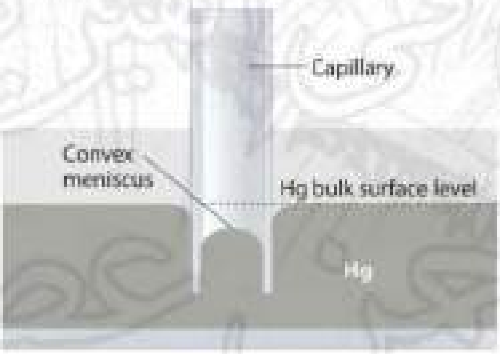
How it works

- If adhesive forces > cohesive forces → liquid rises (water in glass).
- If cohesive forces > adhesive forces → liquid sinks (mercury in glass).

Contrast with Mercury

Mercury behaves differently because:

Cohesive forces (mercury–mercury) are **stronger** than **adhesive forces (mercury–glass)**
→ Mercury does **not** rise in the tube
→ Its surface curves **downward**, forming a **convex meniscus**



(a)

(b)

Water spilled on a table dries after some time. This indicates that the state of water changes from liquid to gas during the process of drying.

If water changes to water vapor at its boiling point,

what makes the spilled water dry at room temperature?

ⓐ In this case, water boils at room temperature.

ⓑ In this case, water changes to vapor at its melting point.

ⓒ Water molecules at the surface absorb heat from the surroundings and break away from adhesive forces.

ⓓ Water molecules at the surface absorb heat from the surroundings and break away from cohesive forces.

Water spilled on a table dries after some time but mercury does not.
Based on this, which of the following statements is true?

ⓐ The cohesive forces in mercury are stronger than those in water.

ⓑ The cohesive forces in water are stronger than those in mercury.

ⓒ The adhesive forces in mercury are stronger than those in water.

ⓓ The adhesive forces in water are stronger than those in mercury.

Mercury is poured out of a glass container onto a glass surface.
Based on the image, which of the following statements is true?

ⓐ The cohesive forces between mercury molecules are weaker than the adhesive forces between mercury and glass.

ⓑ The adhesive forces between mercury and glass are stronger than the cohesive forces in mercury.

ⓒ The cohesive forces between mercury molecules are stronger than the adhesive forces between mercury and glass.

ⓓ Mercury spreads out on glass because adhesive forces are greater than cohesive forces.

Section 13.4 Solids

1. How Do Solids Differ from Liquids?

Solids and liquids differ mainly in **shape, particle arrangement, and movement**:

- **Solids are stiff** and keep their shape.
- You can **push on a solid**, and it resists the force.
- Liquids **flow** and do not hold a fixed shape.
- If you place your finger in water, it moves through it easily.

Sometimes, the boundary between solids and liquids is not obvious.
For example, when warm butter softens, it still looks like a solid but starts to behave like a liquid.

2. Solid Bodies (Types of Solids)

Solids can be classified into two major types:

A. Crystalline Solids

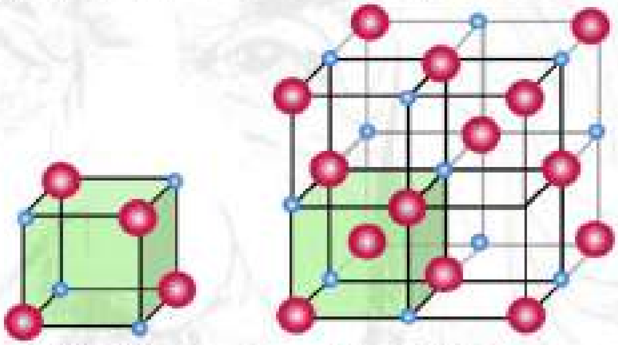
These solids have particles arranged in a **regular, repeating pattern** called a **crystal lattice**.

Characteristics:

- Particles are neatly lined up.
- They form geometric shapes.
- Have clear melting points.

Examples:

- Quartz (SiO_2) – Salt- Metals



Crystal Lattice

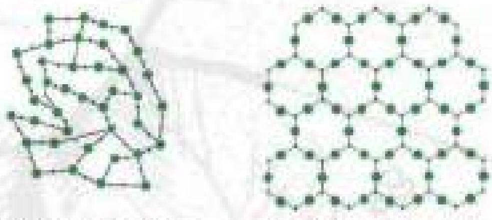
A crystal lattice is the fixed, orderly arrangement of particles in a solid.

B. Amorphous Solids

These solids do **not** have a regular arrangement of particles.

Characteristics:

- No fixed crystal pattern.
- Particles are arranged randomly.
- No sharp melting point—rather, they soften gradually when heated.



Examples:

- Glass – Butter – Plastic- Wax

Amorphous solids sometimes behave *slightly like liquids* because their particles are not strongly locked in place.

3. What Happens When Liquids Become Solids? (Cooling & freezing)

When a liquid cools:

1. **Average kinetic energy of particles decreases.** → particles move more slowly.
2. **Cohesive forces become stronger.** → particles get closer together.
3. The particles start arranging themselves into fixed positions.→ forming a **solid structure**.

Crystalline Solids

When cooled slowly, the particles organize into a **crystal lattice**.

Amorphous Solids

When cooled quickly, particles **do not have time** to align in a crystal structure → they form a **random arrangement**.

4. Pressure and Freezing

Expanding the key idea:

- **Most liquids expand when they freeze.**
- But **water is unusual** — it **expands** as it freezes.

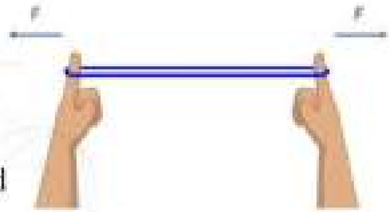
Why?
Because when water molecules freeze, they arrange into a **crystal** with more **open space**, making ice less dense.

Effect of Pressure

- When pressure increases → freezing becomes harder.
  Pressure **pushes molecules closer together**, preventing them from forming the open crystal structure of ice.

This is why the **freezing point of water decreases slightly under pressure**.

A. What Is Elasticity?



Elasticity is the ability of a solid object to:

- **Return to its original shape**
- After an external force (twisting, pulling, bending) is removed

If the force is too large, the object is **permanently deformed** and cannot return to its shape this means its *elastic limit* has been exceeded.

Elasticity depends mainly on:

1. Electromagnetic forces between particles

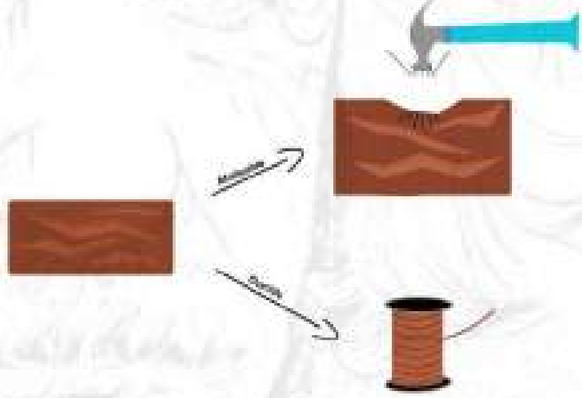
These forces hold the particles of the solid close together.

2. Structure of the material

Solids differ in how their atoms are arranged:

- **Crystalline solids** → strong, orderly bonds → high elasticity
- **Amorphous solids** (glass, plastic) → irregular structure → lower elasticity

C. Malleability and Ductility



Malleability

Ability of a material to be shaped into **thin sheets**.
Example: **Gold** → very malleable.

Ductility

Ability to be pulled into **thin wires**.
Example: **Copper** → highly ductile.

These properties depend on how easily particles in the solid can slide under applied forces.

2. Thermal Expansion of Solids

Solids Expand When Heated?

When temperature increases:

1. Particles move faster
2. They vibrate more strongly
3. The distance between them increases→ **The solid expands**

Stronger vibrations weaken attractive forces slightly → more spacing → expansion.

B. Why Engineers Design Expansion Joints?

Structures expand when heated.
If no space is provided, the structure may:

- **Buckle, Warp, Crack,**
- Or even **break** under stress.

Examples

- Expansion joints in **bridges**
- Gaps in **railway tracks**
- Support for **ceramic tiles, glass, mirrors**

High temperature causes large expansions—ignoring this leads to damage.

3. Linear Expansion

A solid expands in length when heated.

$$\Delta L = \alpha L_1 \Delta T$$

$$\Delta L = L_2 - L_1$$

Where:

- ΔL= change in length $\quad$ L_1= original length
- ΔT= temperature change $\quad$ α= coefficient of linear expansion

Coefficient of Linear Expansion

$$\alpha = \frac{\Delta L}{L_1 \Delta T}$$

Unit: $°C^{-1}$

Each material has its own value of α.

4. Volume Expansion

Solids expand in **three dimensions**, so the coefficient of volume expansion is:

$$\beta = \frac{\Delta V}{V_1 \Delta T}$$

A metal bar is 1.60 m long at 21°C. It is heated in an oven to **84°C**, and its length is then found to be **1.7 mm longer**.
Determine the **coefficient of linear expansion** $\alpha$of the metal.

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A piece of Aluminum house siding is 3.66 m long on a cold winter day of −28°C.

Given material: Aluminum — $\alpha = 25 \times 10^{-6}\ {}^{\circ}\mathrm{C}^{-1}$.
Calculate the **increase in length** at 39°C.

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A piece of steel is 11.5 cm long at 22°C. It is heated to **1221°C** (near its melting point).
Given material: Steel — use $\alpha = 11 \times 10^{-6}\ {}^{\circ}\mathrm{C}^{-1}$.
Determine the **final length** at 1221°C.

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A 400-mL glass beaker at room temperature is filled to the brim with cold water at 4.4°C. When the water warms up to **30.0°C, how much water will spill from the beaker?**
Given materials and coefficients:

- **Beaker (soft glass):** $\alpha_{\text{glass}} = 9 \times 10^{-6}\ {}^{\circ}\mathrm{C}^{-1}$, $\beta_{\text{glass}} = 27 \times 10^{-6}\ {}^{\circ}\mathrm{C}^{-1}$
- **Water:** $\beta_{\text{water}} = 210 \times 10^{-6}\ {}^{\circ}\mathrm{C}^{-1}$
  Compute the **net volume overflow** (spillage) at 30.0°C.

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A tank truck takes on a load of **45,725 L of gasoline** in Houston at **28.0°C**. The truck delivers its load in Minneapolis at **−12.0°C**.

Given material: Gasoline — $\beta = 950 \times 10^{-6}\ ^{\circ}C^{-1}$.

- (a) Determine the **delivered volume** at −12.0°C.
- (b) Explain the **physical reason** for the change.

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At 25°C, the length of a glass rod is 50.0 cm. After heating to a temperature of 225°C, the length increases to 50.1 cm.
What is the coefficient of linear expansion of the glass rod?

ⓐ $1 \times 10^{-5}\ ^{\circ}C^{-1}$ ⓑ $5 \times 10^{-5}\ ^{\circ}C^{-1}$ ⓒ $3 \times 10^{-5}\ ^{\circ}C^{-1}$ ⓓ $9 \times 10^{-5}\ ^{\circ}C^{-1}$

An Aluminum sphere is heated from 30°C to 260°C. Initially, the volume of the sphere is 30.0 cm³. Upon heating, it increases to 30.5 cm³.
What is the coefficient of volume expansion of Aluminum?

ⓐ $9 \times 10^{-5}\ ^{\circ}C^{-1}$ ⓑ $5 \times 10^{-5}\ ^{\circ}C^{-1}$ ⓒ $7 \times 10^{-5}\ ^{\circ}C^{-1}$ ⓓ $2 \times 10^{-5}\ ^{\circ}C^{-1}$

An iron rod is 115.0 cm at 30.0°C.
If the linear expansion coefficient of iron is $1.2 \times 10^{-5}\ ^{\circ}C^{-1}$,

what is the rod's length at 103.0°C?

ⓐ 115.1 cm ⓑ 115.2 cm ⓒ 114.9 cm ⓓ 116.0 cm

A glass rod initially at 25°C is heated to a temperature of 225°C.
The length increases to 62.12 cm.
If the coefficient of linear expansion of the glass rod is $9 \times 10^{-6}\ ^{\circ}C^{-1}$

what is the rod's initial length?

ⓐ 61.21 cm ⓑ 63.12 cm ⓒ 62.01 cm ⓓ 60.02 cm