O Level Physics
Unit 11: Thermal Properties of Matter

Internal energy

1) The internal energy of a body is the sum of the kinetic energy and potential energy of atoms in the body.
2) Of the same mass, gases have most internal energy while solids have least internal energy.
3) When a body is heated, the particles gain thermal energy, causing the kinetic and potential energy of the particles to increase. Thus, the internal energy of the body also increases.

Symbols, Representations and Units

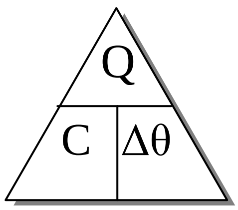
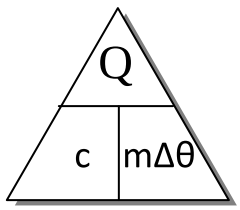
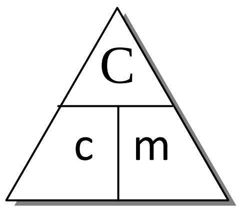
4)

Symbol	Representation	Unit
Q	Thermal energy absorbed	J
m	Mass	kg
Δθ	Change in temperature	°C
C	Heat capacity	J/°C
c	Specific heat capacity	J/k °C
ℓ	Specific latent heat	J/kg

(Candidates are advised to state the representation of the symbols used in their calculations.)

Specific Heat Capacity

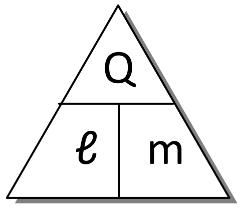
5)

	Heat Capacity, C	Specific Heat Capacity, c
Definition	The amount of thermal energy required to raise the temperature of a body by 1°C.	The amount of thermal energy required to raise the temperature of 1 kg of a substance by 1°C.
SI Unit	J/°C	J/kg °C
Dependent on	The mass and material of the object.	The material of the object.
Formula		
Relationship		

6) For the same mass, materials with a lower specific heat capacity will gain thermal energy faster than materials with a higher specific heat capacity.

Specific Latent Heat

7)

	Latent Heat, L	Specific Latent Heat, ℓ
Definition	(**L_f**/*L_v*) is the amount of thermal energy required to change a substance from (**solid to liquid**/ *liquid to vapour*) state or vice versa, without changes in temperature.	(**ℓ_f**/*ℓ_v*) is the amount of thermal energy required to change 1kg of a substance from (**solid to liquid**/*liquid to vapour*) state or vice versa, without changes in temperature.
SI Unit	J	J/kg
Formula	Amt of heat absorbed/released	

Melting, Freezing and Boiling

8)

Melting	
Stage 1	• As a solid is heated, heat energy absorbed by the particles is converted into kinetic energy. • The particles vibrate more vigorously in their fixed positions.
Stage 2	• When the melting point is reached, the solid absorbs latent heat of fusion to break the intermolecular bonds between the particles. They begin to break away from their fixed positions. • During the process, there is no temperature change and a mixture of solid and liquid is present.
Stage 3	• Once the melting process has ended, the particles will move out of their fixed positions. • The solid has melted to become a liquid.

9)

Freezing	
Stage 1	• As a liquid is cooled, the particles lose their kinetic energy and slow down.
Stage 2	• When the freezing point is reached, latent heat of fusion is released to the surroundings to form intermolecular bonds between particles and for them to take up fixed positions. • During the process, there is no temperature change and a mixture of liquid and solid is present.
Stage 3	• Once the freezing process has ended, the particles become attracted to each other in fixed positions. • The liquid has solidified.

10)

Boiling	
Stage 1	• As a liquid is heated, heat energy absorbed by the particles is converted into kinetic energy. • The particles move faster as the temperature rises.
Stage 2	• When the boiling point is reached, latent heat of vaporisation is absorbed by the liquid to break the intermolecular attraction between particles and to push back on the surrounding atmosphere. • During the process, there is no temperature change and a mixture of liquid and gas is present.
Stage 3	• Once the boiling process has ended, the particles are separated with negligible attractive forces. • The liquid has boiled off to become a gas.

<u>Effect of impurities and pressure on melting and boiling points</u>

11)

	Freezing/Melting point		Boiling point
	Freezing point	Melting point	
Adding Impurities	Lowered		Increased
Increased Pressure		Lowered	Increased

<u>Evaporation</u>

12) Evaporation is due to energetic liquid molecules at the liquid surface having greater than average kinetic energy to escape into the surroundings as a gas.

- At the liquid surface, energetic liquid molecules with greater kinetic energy are able to overcome the downward attraction forces of liquid molecules.
- They escape into the air carrying thermal energy away through evaporation.
- This leaves less energetic molecules behind and thus the liquid is at a lower temperature.

13) A liquid with less energetic/slower moving molecules is cooler as the temperature of liquids is directly proportional to the average kinetic energy of the molecules.

14)

Differences between Boiling and Evaporation	
Boiling	**Evaporation**
1) Occurs only at boiling point	1) Occurs at all temperatures
2) Occurs throughout liquid	2) Occurs only at liquid surface
3) Rapid process	3) Slow process

15)

Ways of increasing rate of evaporation	
Increasing surface area	With more molecules near liquid surface, more molecules have a chance to escape from the liquid into the air as evaporation only occurs at the liquid surface.
Increasing temperature of liquid	Increasing the temperature of the liquid also increases the average kinetic energy of molecules; hence more molecules gain the required kinetic energy to escape.
Increasing wind conditions	Moving air (wind) carries vapour molecules away, reducing the number of molecules returning to the liquid surface through collisions with vapour molecules. This allows more liquid molecules to escape.

Examination Type Questions- Unit 10 & 11

1) **Which material, plastic or metal, is more suitable for making a container to store ice?**
Plastic. Plastics are poorer conductors of heat than metals. As the temperature in the box is lower than the surroundings, the plastic wall acts as an insulator to prevent heat from being conducted into the box.

2) **Explain how windows made of double-layered glass can keep a house warm in cold countries.**
The air trapped between the double-layered glass is a poor conductor of heat. As the temperature in the house is higher than the surroundings, the air trapped between the glasses will act as an insulator of heat to reduce the amount of thermal energy conducted out of the house through windows.

3) **A door with a metal knob and wooden frame is cooled in an air-con room.**
   (a) Explain which part of the door will take a shorter time to cool to a fixed temperature.
   Metal knob. Metals have lower specific heat capacity than wood and thus the metal knob will lose thermal energy faster.
   (b) After 1 hour, the metal knob and the wooden frame are at the same temperature. Which part of the door will feel warmer? Why?
   The wooden frame. The wooden frame is a poorer conductor of heat and takes a longer time to conduct thermal energy away from our hands, compared to the metal knob. Thus the wooden frame will feel warmer.

4) **Water cools down upon evaporation. Explain, in molecular terms, how evaporation causes a loss of energy from water.**
Molecules that have more energy will be closer to the water surface. Energetic water molecules with greater kinetic energy are able to overcome the downward attraction forces of other molecules and escape the water-air boundary carrying thermal energy away. This leaves less energetic molecules in the liquid and thus the water cools as a result of a loss of thermal energy through evaporation.

5) **Explain why the liquid filling of an apple pie can burn your tongue but not the crust.**
The filling, being liquid, has a higher specific heat capacity than the solid crust. More energy is released by the filling to lower its temperature by 1°C. Hence, more time is needed for the liquid filling to cool down than the crust. While the crust has cooled, the filling will still be hot and can burn your tongue.

6) **Use the thermal properties of matter to explain how steam can be more dangerous than boiling water even though both are at 100°C.**
When steam condenses at 100°C, a large amount of latent heat of vaporisation is released to the surroundings. This extra energy of steam makes it more dangerous than the boiling water.

Notes: