INTERNAL ENERGY, HEAT AND WORK

1. Internal energy (U)

Internal energy is the energy stored within the object. It is difficult to state its absolute value. For most processes this is not necessary because we would not be able to release or use it completely, we are interested only in how much the internal energy has changed ($\Delta U = U_{FINAL} - U_{INITIAL}$), if it has risen or decreased and which macroscopic quantities (*p, V, T, ...*) it influenced. Types of internal energy:

a) kinetic (U_k) – representing the chaotic movement of the particles, $\Delta U_k \approx \Delta T$

b) potential (U_p) – representing the strength of bonds, $\Delta U \approx$ change in strength of bonds (state of matter)

c) energy of electrons in electron shells – can be changed when chemicals change, electrons change the energy levels etc

d) nuclear – can be released when nucleus changes (fusion, fission, decay – see Y6)

In thermodynamics only a) and b) are involved!

2. How to change internal energy?

a) to do work (*W*)
        examples:

b) to exchange heat (*Q*)
        examples:

c) both

1st law of thermodynamics: $\qquad Q = \Delta U + W \qquad or \qquad \Delta U = Q + W'$

Heat supplied to a system may raise its internal energy or enable it to do work.

A problem can be sign convention, see later – structure and properties of gases.

3. ΔU because of work done
mainly because of friction, air resistance, compression or expansion of a gas etc.

Questions:
1. Water in a lake seems to be hotter after a heavy storm. Is it true or is it just the feeling related to the changes of temperature of the air?
2. A stone of mass 0.2 kg falls down freely 10 m and it finally hits the ground at 12 m·s^{-1}. How much has the internal energy of both the stone and the ground changed?
3. A book of mass 150 g was sent over a horizontal desk with a speed of 2 m·s^{-1}. It stops because of friction during 0.5 seconds. a) How much work did the friction force? b) How much has the internal energy of both the book and the desk rise? c) How far did the book move? d) What is the size of the friction force?
4. A jumping ball of mass 20 g was dropped from a window 5 m above the ground. It rebounces to the height of 3.5 m. How much mechanical energy was converted into other types? Into what was the energy converted?
5. A ball of mass 150 g hits a vertical wall at 60 km·h^{-1} and it moves off at 45 km·h^{-1}. How much mechanical energy is converted into other types? Into what is the energy converted?

6.   A 0.5 kg stone was dropped from a bridge 20 m above the level of water in the river below. When it hits the water at 15 m·s^{-1}, how much energy is converted into other types? Into what is the energy converted?

7.   The first piece of plasticine has a mass of 0.1 kg and it moves at 4 m·s^{-1}. The second one has a mass of 0.3 kg and it moves at 2 m·s^{-1}. Assume an inelastic collision (the bits couple and move together after the collision) and calculate how much energy was converted into the internal energy of the bits when they originally moved a) in the same direction b) against each other c) at right angles to each other.

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4. ΔU because of heat exchanged

Types of heat exchange:

a)   conduction is the transfer of heat from places of higher temperature to places of lower temperature without movement of matter as a whole (in all substances, mainly in solids, not in vacuum).

good conductors – metals

examples:

bad conductors = insulators – vacuum (the best), plastic, paper, wood, fur, ...

examples:

Explain the process of CONDUCTION using the idea of behaviour of particles

b)   convection is the transfer of heat from places of higher temperature to places of lower temperature by movement of the matter itself (in fluids only).

Usage in real life:

Explain the process of CONVECTION using the idea of behaviour of particles

c) *radiation* is the flow of heat from one place to another by means of electromagnetic wave – see Y6

Questions:

8. Why does paper wrapping keep hot things hot and cold things cold?
9. Some people say that fur coats would keep their owners warmer when worn inside out. Do you agree?
10. As fuel becomes more expensive, more people are finding it worthwhile to reduce heat losses from their homes. Consult different resources and suggest the best way specifically for your house.
11. Explain the following experiment:
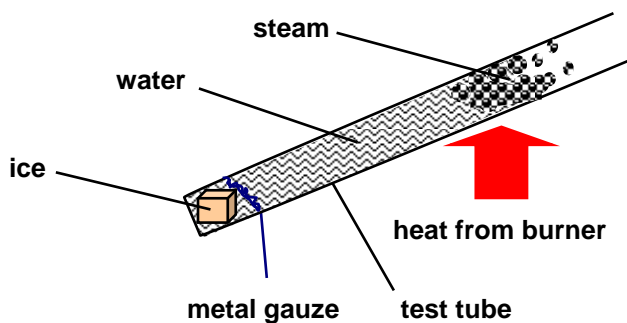
5. The law of conservation of energy applied to a calorimetric equation without the changes in states of matter

- heat exchanged between some objects (2-3)
- now – none of them changes the state of matter (included later this year)

Heat capacity (*C*) of an object

= the amount of heat needed for the object to release/absorb to change its temperature by 1K

$$C = \frac{Q}{\Delta T}$$ $$[C] = \text{J} \cdot \text{K}^{-1}$$

Specific heat capacity (*c*) of a material

= the amount of heat needed for 1 kg of some material to release/absorb to change its temperature by 1K

$$c = \frac{Q}{m \Delta T} \qquad [c] = \text{J} \cdot \text{kg}^{-1} \cdot \text{K}^{-1}$$

material constant, in the book of data

$c_{WATER} = 4180 \text{ J} \cdot \text{kg}^{-1} \cdot \text{K}^{-1}$, big number, used in central heating or as a coolant in motors

$c_{ICE} = 2100 \text{ J} \cdot \text{kg}^{-1} \cdot \text{K}^{-1}$

$c_{STEEL} = 450 \text{ J} \cdot \text{kg}^{-1} \cdot \text{K}^{-1}$

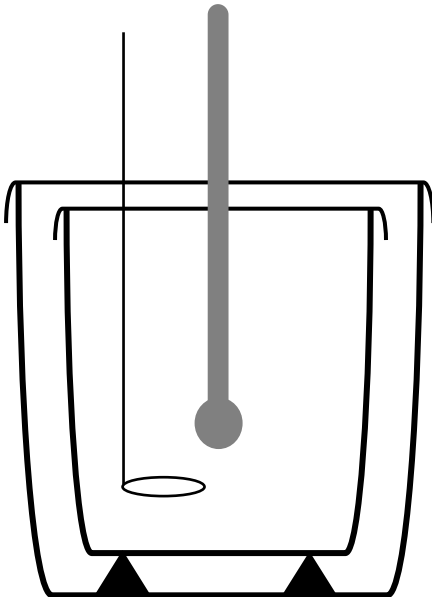**Molar heat capacity** (c_m) of a material

= the amount of heat needed for 1 mole of some material to release/absorb to change its temperature by 1K

$$c_m = \frac{Q}{n \Delta T} \qquad [c_m] = \text{J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$$

Dulong-Petit's law: $c_m \approx 25 \text{ J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$ for many solids, which supports the kinetic theory, because

....

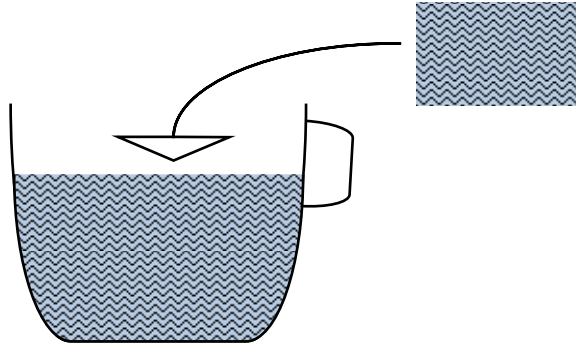Calorimeter – a device with minimum heat needed to change its temperature - C_k

Calorimetric equation: **HEAT TAKEN IN = HEAT GIVEN OUT**

Practical example:

State the heat capacity of the cup.

INTERNAL ENERGY, HEAT AND WORK

Questions:

12. A waterfall is 40 m high. What would be the change of the temperature of the water assuming all the energy is converted into heat?

13. A steel projectile moves at 150 m·s^{-1} and then it hits the target. How much will its temperature rise assuming 50% of its mechanical energy can be used to heat the projectile?

14. A steel block of mass 0.6 kg is put into a vessel containing 5.65 kg of water at 7.2 °C. The balanced temperature is 13.2 °C. Calculate the initial temperature of the steel block. Take the heat capacity of the container to be 20 J·K^{-1}.

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Answers:
2. 5.6 J
3. a) 0.3 J b) 0.3 J c) 0.5 m d) 0.6 N
4. 0.3 J
5. 9.1 J
6. 43.75 J
7. a) 0.15 J b) 1.35 J c) 0.75 J
12. 0.1 °C
13. 12.5 °C
14. 538.5 °C