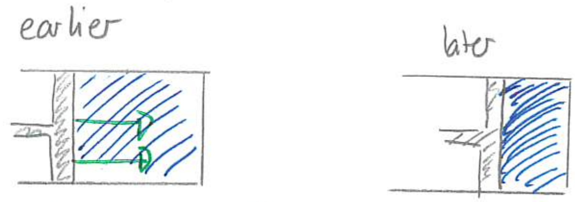
Thurs: ~~Ex~~ Discussion/quiz

Ex: 332, 333, 334, 335
336, 338, 340

## Energy transfer in thermodynamic systems

A thermodynamic system such as a gas has a thermal energy that depends on its state. This thermal energy can be changed by changing the state of the system. There are two basic ways to do this

1) do work on the system
e.g. compress a gas



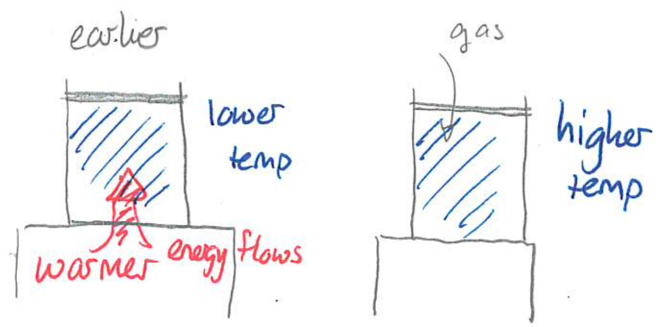

piston exerts force on gas and moves gas (does work)

→ temperature increases
thermal energy of gas increases.

DEMO: PhET Gas Properties
* default setting
* compress gas

DEMO: U Iowa Fire Syringe Video

2) supply energy by placing the system in contact with another system at a different temperature




→ energy of gas increases.

In the second case we say

Heat = energy that flows from one system to another as a result of contact between the systems → Joules

Notes:

1) the symbol for heat is $Q$

2) heat flow often results from contact between two systems at two different temperatures (but there are exceptions)

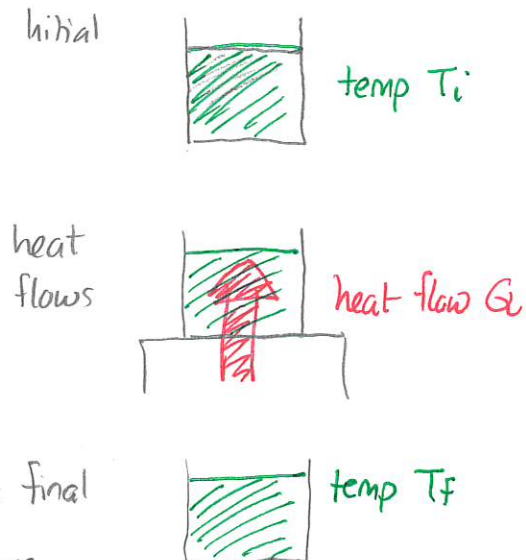
3) heat is distinct from temperature - this concerns a state of the system

Heat results from a change in the state of a system.

## Measuring heat flow

In many situations heat flow can be determined via:

1) the type of material absorbing/losing heat
2) the mass of the material
3) the change in temperature of the material.




## Warm Up 1

To a good approximation, for a pure substance

The heat entering or leaving the system is

$$Q = mc\,\Delta T = mc\,(T_f - T_i)$$

where $m$ = mass of the system kg
$c$ = specific heat of substance $J/kg\cdot K \equiv J/kg\cdot°C$

Specific heats are well determined for many materials in many conditions Table 12.4

Note:

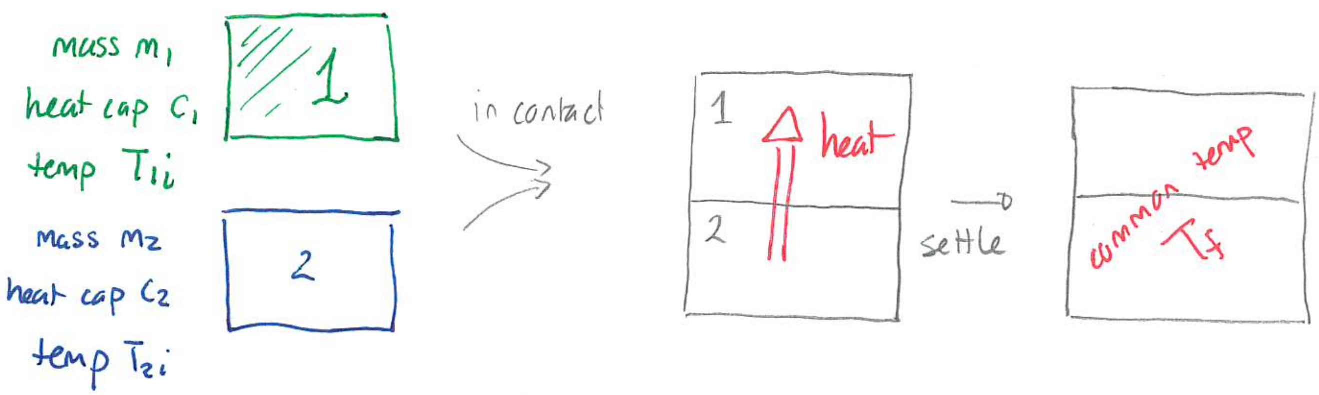
$Q > 0 \Rightarrow$ heat enters system $\Rightarrow$ temp. rises
$Q < 0 \Rightarrow$ heat leaves system $\Rightarrow$ temp drops

Heat capacity describes the extent to which heat flow produces temperature changes.

Quiz 1 50% – 80%

## Calorimetry

In many situations, two objects which are initially at different temperatures are placed into contact. They eventually reach a common equilibrium temperature as the result of heat flow




Calorimetry considers heat flows in such cases. If the two objects are otherwise isolated then energy is conserved

$$Q_1 + Q_2 = 0$$

where $Q_i$ = heat absorbed / lost by object $i$.

Warm Up 2

$$Q_{metal} + Q_W = 0$$

consider 1° drop in metal

$$m_m c_m \underbrace{\Delta T_m}_{-1^\circ C} = - m_w c_w \Delta T_w$$

$$\Rightarrow \Delta T_w = \frac{m_m c_m}{m_w c_w} \times 1^\circ C.$$

larger $c_m$ gives larger $\Delta T_w$

↳ larger for Al.

**337 Gold and water**

A 10.0 kg piece of gold is initially at 100° C. It is immersed in 1.00 kg of water which is initially at 20.0° C. The aim of this exercise is to determine temperature, $T_f$ of the gold and water after they have reached equilibrium. The heat capacity of gold is 129 J/kg K and that of water is 4190 J/kg K. *(111F2023)*

a) Determine an expression for the heat lost by the gold in terms of $T_f$ and the data provided.

b) Determine an expression for the heat gained by the water in terms of $T_f$ and the data provided.

c) Combine your expressions to determine the equilibrium temperature $T_f$.

Answer: a) $Q_g = M_g C_g (T_f - T_{gi})$ this will be energy lost

$M_g$ = mass gold

$C_g$ = heat capacity gold

b) $Q_w = M_w C_w (T_f - T_{wi})$ this will be energy gain

c) $Q_g + Q_w = 0$

$\Rightarrow M_g C_g (T_F - T_{gi}) + M_w C_w (T_f - T_{wi}) = 0$

$\Rightarrow M_g C_g T_f + M_w C_w T_f - M_g C_g T_{gi} - M_w C_w T_{wi} = 0$

$\Rightarrow (M_g C_g + M_w C_w) T_f = M_g C_g T_{gi} + M_w C_w T_{wi}$

$= 10.0\,\text{kg} \times 129\,\text{J}/\text{kg}\,°\text{C}\ 100°\text{C} + 1.00\,\text{kg} \times 4190\,\text{J}/\text{kg}\,°\text{C}\ 20.0°\text{C}$

$(10.0\,\text{kg} \times 129\,\text{J}/\text{kg}\,°\text{C} + 1.00\,\text{kg} \times 4190\,\text{J}/\text{kg}\,°\text{C})\, T_f = 212800\,\text{J}$

$\Rightarrow (1290\,\text{J}/°\text{C} + 4190\,\text{J}/°\text{C})\, T_f = 212800\,\text{J}$

$\Rightarrow 5480\,\text{J}/°\text{C}\ T_f = 212800\,\text{J}$ [redacted] $\Rightarrow T_F = 38.8°\text{C}$