**13. Specific Heat Capacity**

 **National 5**

In this section you can use the equation:

 **heat energy = specific heat capacity x mass x temperature change**

also written as

 **Eh = c m ΔT**

Where **Eh** = heat energy in joules (J)

 **c** = specific heat capacity in joules per kilogram per degree Celsius (Jkg-1 oC-1)

 **m** = mass in kilograms (kg)

 **ΔT** = change in temperature (oC).

 *Helpful Hint*

 You will need to look up values for the specific heat capacity of different materials These values can be found on the data sheet on page 1.

1. Find the missing values in the following table.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | ***Heat energy* (J)** | ***Specific heat capacity* (Jkg-1 oC-1)** | ***Mass* (kg)** | ***Temperature change* (oC)** |
| **(a)** |  | 4 200 | 2 | 65 |
| **(b)** |  | 902 | 5·5 | 15 |
| **(c)** | 2·4 x 10 3 | 386 | 1·6 |  |
| **(d)** | 4 250 |  | 17 | 0·5 |
| **(e)** | 1·6 x 103 |  | 1·5 | 2 |
| **(f)** |  | 128 | 50 x 10-3 | 30 |

2. How much heat energy is required to raise the temperature of 3 kg of aluminium by 10oC?

3. 3 kJ of heat is supplied to a 4 kg block of lead. What would be the rise in temperature of the block?

4. In an experiment on specific heat capacity an electric heater supplied 14 475 J of heat energy to a block of copper and raised its temperature by 15oC. What mass of copper was used in the experiment?

5. 6900 J of heat is supplied to 0.5 kg of methylated spirit in a plastic beaker and raises its temperature by 1.5oC. What is the specific heat capacity of methylated spirit?

6. How much heat energy would be required to raise the temperature of 2 kg of alcohol from 20oC to 65oC?

7. A 0.25 kg block of copper is allowed to cool down from 80oC to 42oC. How much heat energy will it give out?

8. 254 400 J of energy are required to heat 2 kg of glycerol from 12 oC to 65 oC . What is the specific heat capacity of glycerol?

9. Which of the following would give out more heat energy:

 A - a 2 kg block of aluminium as it cools from 54 oC to 20oC

 or

 B - a 4 kg block of copper as it cools from 83oC to 40oC?

10. 2500 J of heat is supplied to a quantity of alcohol and raises its temperature from

 22oC to 45oC. What mass of alcohol was being heated?

11. Each concrete block in a storage heater has a mass of 1·4 kg. The blocks are heated to 85oC at night when the electricity is cheaper and cool down during the day to 20oC. If each block releases 77 000 J of energy during the day calculate the specific heat capacity of the concrete.

12. An immersion heater is used to heat 30 kg of water at 12oC. The immersion heater supplies 8 600 000 J of heat. Ignoring heat losses to the surroundings calculate the final temperature of the water.

|  |  |
| --- | --- |
| 13. A kettle supplies 262 **kJ** of energy to 800 **g** of water in order to heat it to 90 oC . What was the temperature of the water before the kettle was switched on? |  |

|  |  |
| --- | --- |
| 14. | A cup containing 140 **g** of water is heated in a microwave oven. The microwave supplies 4·9 x 104 J of heat to the water which was originally at 10oC. What is the final temperature of the water? |

15. A 400 **g** block of lead is heated to 45oC by an electric heater which supplies 1·2 **kJ** of heat. What was the initial temperature of the lead block?

**14. Specific Latent Heat**

**National 5**

In this section you can use the equation:

 **heat energy = mass x specific latent heat**

also written as

**Eh = m L**

where **Eh** = heat energy in joules (J)

 **m** = mass in kilograms (kg)

*Helpful Hint*

Value for ‘L’ described above can be found in the data sheet on page 1.

When you are solving a problem using this formula it is important to use the **correct value of ‘L’** from the data sheet.

To do this:

Read the question carefully.

If the question is about the change of state: **liquid to gas** or **gas to liquid**

then

 **‘L’ = latent heat of vaporisation**

If the question is about the change of state : **liquid to solid** or **solid to liquid**

then

 **‘L’ = latent heat of fusion.**

 **L** = specific latent heat in joules per kilogram (J kg-1).

1. Find the missing values in the following table.

|  |  |  |  |
| --- | --- | --- | --- |
|  | ***Energy* (J)** | ***Mass* (kg)** | ***Specific latent heat* (J kg-1)** |
| **(a)** |  | 2·0 | 0·99 x 105 |
| **(b)** |  | 35·5 | 8·3 x 105 |
| **(c)** | 1·08 x 106 | 6·0 |  |
| **(d)** | 4·032 x 105 |  | 11·2 x 105 |
| **(e)** | 22·6 x 105 |  | 22·6 x 105 |
| **(f)** | 1·837 x 108 | 550 |  |

2. Calculate the heat energy released when 2 kg of ice melts into 2 kg of water without a change in temperature.

3. How much heat energy is released when 56 kg liquid carbon dioxide changes into solid form without a change in temperature?

4. What mass of steam is produced when 7 232 000 J is supplied to water at 100oC?

5. What mass of turpentine condenses when 168 200 J of heat energy is removed from a supply of gaseous turpentine at its boiling point?

6. Calculate the specific latent heat of fusion of aluminium given that 10⋅27 **MJ** is required to change 26 kg of it from molten form into solid form.

7. How much heat energy is required to change 40 kg of solid carbon dioxide into liquid form with no change in temperature?

8. How much heat energy is required to evaporate 0.6 kg of water at 100 oC ?

9. The melting point of a certain chemical substance is 137oC. How much heat is required to melt 0·7 kg of this substance if it is known to have a specific latent heat of fusion of

 1 300 J kg-1?

10. How much water would evaporate at 100 oC if you supplied it with 28 500 J of heat energy?

11. Liquid alcohol vaporises when used to make flambees. Calculate the heat energy required to change 0·5 kg of liquid alcohol into its gaseous form without a change in temperature.

12. Calculate the specific latent heat of fusion of lead if it takes 500 000 J of heat to convert 20 kg of solid lead into molten form at its melting point.

13. What mass of liquid glycerol is converted to vapour when 8 300 000 J of heat energy is supplied to it at its boiling point?

14. A steam wallpaper stripper can be used to help with the tedious task of preparing walls before decorating. The stripper contains 15 kg of water which turns to steam when boiled. Assuming the stripper is 100 % efficient, how much boiling water is converted to steam, if 100 x 10 5 J of energy is supplied to it?

15. During an experiment 0·02 kg of steam was converted to ice. The temperature was recorded at various times throughout the experiment and plotted on a graph. The graph of results is shown below.



**C**

**A**

**E**

**F**

**D**

**B**

 (a) Between which 2 letters on the graph is the steam changing to water?

 (b) How much heat energy does the steam lose at 100 oC to become water at

 100 oC?

 (c) How much heat energy does the water lose at 100 oC to become water at 0 oC?

 (d) How much heat energy does the water at 0 oC lose to become ice?

**15. Re-Entry**

**National 5**

In this section you can use the following equations:

|  |
| --- |
|  **Ek = 1 m v2** **2** **Eh = c m ΔT****Eh = m L****Ew = F d** |

Where **Ek** = kinetic energy (J)

 **Eh** = heat energy (J)

 **Ew** = work done (J)

 **m** = mass (kg)

 **v** = velocity (ms-1)

 **c** = specific heat capacity (J kg-1 oC-1)

 **L =** specific latentheat (J kg-1)

 **ΔT** = change in temperature (oC)

 **F** = force (N)

 **d =** distance (m).

 *Helpful Hint*

 Energy cannot be created or destroyed. It can be changed from one form into another. When an object re-enters the Earth’s atmosphere it heats up. **Some or all of its kinetic energy changes to heat energy as work is done against friction**. The shuttle has heat resistant tiles covering its body to stop it burning up as it re-enters the atmosphere.



heat resistant tiles

 In order to stop the shuttle when it touches down, work must be done by frictional forces. This changes its kinetic energy into heat energy.

1. A small piece of metal of mass 2 kg falls from a satellite and re-enters the Earth’s atmosphere at a velocity of 4 000 ms-1. If all its kinetic energy changes to heat calculate how much heat is produced.

2. How much work must be done by the brakes on a shuttle of mass 2 x106 kg to bring it to rest if it lands with a touch down velocity of 90 ms-1?

3. The space shuttle Columbia re-entered the Earth’s atmosphere at a speed of

 8 000 ms-1 and slowed down to a speed of 200 ms-1. The shuttle’s mass was

 2 x106 kg.

 (a) How much kinetic energy did the shuttle lose?

 (b) How much heat energy was produced during this process?

4. A ‘ shooting star’ is a meteoroid that enters the Earth’s atmosphere and is heated by the force of friction which causes it to glow. A certain meteoroid has a mass of 30 kg and enters the atmosphere at a velocity of 4 000 ms-1.

 Calculate the heat energy produced if all of the meteoroid’s kinetic energy is converted to heat.

5. A small spy satellite of mass 70 kg is constructed from a metal alloy. The satellite has a short lifetime of two weeks before it re-enters the Earth’s atmosphere at a speed of

 5 000 ms-1.

 Calculate how much heat energy is produced when all of the satellite’s kinetic energy changes to heat energy.

6. The nose section of a shuttle is covered with 250 kg of heat resistant tiles which experience a rise in temperature of 1 400 oC during the shuttle’s journey back through the Earth’s atmosphere.

 The shuttle is slowed from 2 250 ms-1 to 100 ms-1  during this part of the journey.

|  |  |
| --- | --- |
| shuttle enters Earth’s atmospherev = 2 250 ms-1 v = 100 ms-1 |  |

 (a) How much kinetic energy do the tiles on the nose of the shuttle lose?

 (b) How much heat energy is produced at the nose during re-entry?

 (c) Calculate the specific heat capacity of the material used to make the nose tiles.

|  |  |
| --- | --- |
| 7. A multistage rocket jettisons its third stage fuel tank when it is empty. The fuel tank is made of aluminium and has a mass of  4 000 kg. ( specific heat capacity of aluminium is 900 J kg-1 oC-1) (a) Calculate the kinetic energy lost by the fuel tank as it  slows down from 5 000 ms-1 to 1 000 ms-1 during its  journey through the Earth’s atmosphere. (b) How much heat energy is produced? |  |

8. In 1969 Apollo 11 returned to Earth with a velocity of 11 200 ms-1 on entering the Earth’s atmosphere. It had a mass of 5 500 kg and slowed down over a distance of

 10 000 000 m in the atmosphere, before splashing into the ocean .

 (a) Calculate the kinetic energy of Apollo 11 as it entered the Earth’s atmosphere.

 (b) How much work was done by the frictional forces which brought it to rest?

 (c) Calculate the average force it experienced as it slowed down over

 10 000 000 m in the atmosphere.

9. Re-entry for a certain shuttle begins 75 miles above the Earth’s surface at a speed of

 10 **km s-1**. It is slowed to a speed of 100 ms-1 by frictional forces during which time it has covered a distance of 4 x107 m. The mass of the shuttle and its payload is

 2·4 x 106 kg.

 (a) Calculate the loss in kinetic energy of the shuttle.

 (b) How much work is done by friction?

 (c) Calculate the average size of the frictional forces exerted by the atmosphere on

 the shuttle as it slows down.

1. At touch down a shuttle is travelling at 90 ms-1. The brakes apply an average force of

 4 x 106 N in total to bring the shuttle to a stand still. The mass of the shuttle is

 2 x 106 kg .

 (a) How much kinetic energy does the shuttle have at touch down?

 (b) How much work must be done by the brakes to stop the shuttle?

 (c) Calculate the length of runway required to stop the shuttle.