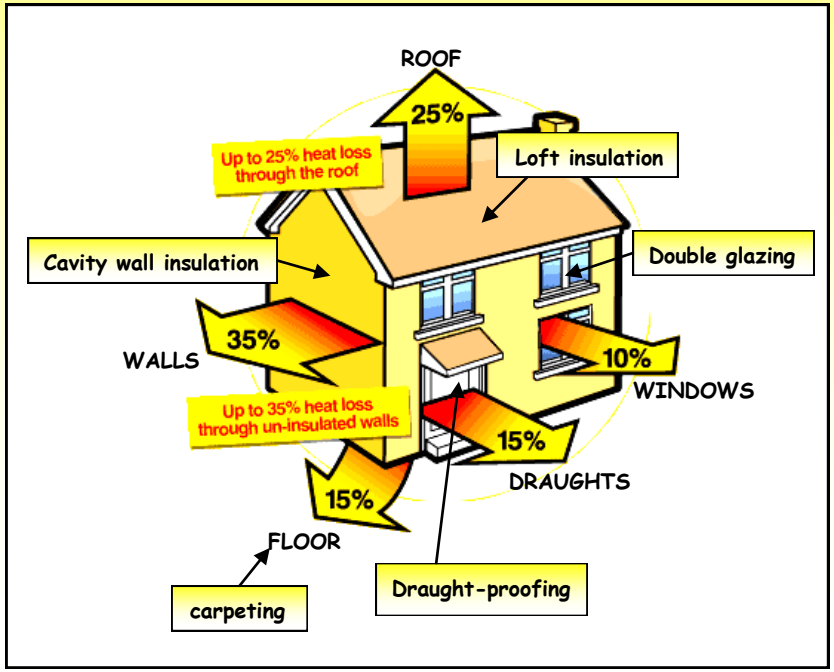
- Effectiveness, cost effectiveness and payback time of methods used to reduce energy consumption. This can include :
  - *Building insulation to minimise heat loss.*
  - *Low energy light bulbs and LED lighting.*
  - *Temperature control.*
  - *Replacing old devices with energy efficient devices.*
  - *Ways in which 'waste' energy can be useful e.g. heat exchangers.*
  - *Travelling by public transport.*
  - *Replacing old vehicles with new, more energy efficient ones.*
- Energy cannot be created or destroyed. It can only be transformed from one form to another form.
- When energy is transferred or transformed, part of it may be usefully transferred or transformed, the rest is 'wasted'. In both cases, the energy is eventually transferred to the surroundings, which become warmer.
- The energy becomes increasingly spread out and so more difficult to use for further energy transformations.
- Describe the intended energy transfers/transformations and the main energy wastages that occur with a range of devices.
- Interpret and draw a Sankey diagram. Use a Sankey diagram to calculate the efficiency of a device.
- The greater the percentage of the energy that is usefully transformed in a device, the more efficient the device is.
- The efficiency of a device is calculated using :

$$\text{Efficiency} = \frac{\text{useful energy out}}{\text{total energy in}} \times (100\%)$$

$$\text{Efficiency} = \frac{\text{useful power out}}{\text{total power in}} \times (100\%)$$

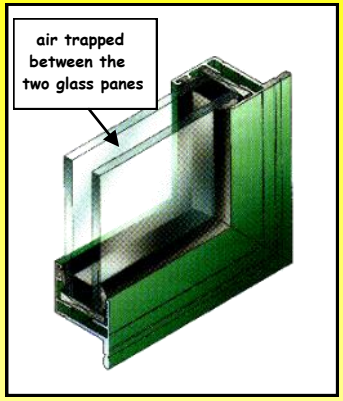
HEAT LOSS FROM BUILDINGS

- Heat is lost from buildings because it is transferred out to the environment by **CONDUCTION**, **CONVECTION** and **RADIATION**.
- The diagram below shows :
  - The main ways in which heat is lost from an **UNINSULATED** house.
  - The methods employed **to reduce these heat losses.**



HEAT LOSS REDUCTION METHODS

1. DOUBLE GLAZING



- This consists of two sheets of glass with a layer of trapped air in between.

  The air is an excellent insulator and the glass is also an insulator, so this reduces heat loss by ……

  The fact that the air is trapped means that it cannot move and so heat loss by …… is also reduced.

The heat loss is reduced from **10% to 5%**, giving an annual saving of about **£100** for an installation cost of about **£4000**.

PAYBACK TIME : ____

2. LOFT INSULATION

- A thick layer of fibreglass wool is laid between the floor joists in the loft.

  This acts as an excellent insulator which reduces heat loss by …… and the fact that the air in the wool cannot move also means that heat loss by …… is also reduced.

The heat loss is reduced from **25% to 5%**, giving an annual saving of about **£200** for an installation cost of about **£600**.

PAYBACK TIME : ____

3. CAVITY WALL INSULATION

- Insulating foam is injected into the cavity between the outer brick wall and the inner breeze block wall.

  The air which is trapped in the foam acts as an insulating layer which reduces heat loss by …… and the fact that the air is unable to move minimizes heat loss by ……

The heat loss is reduced from **35% to 15%**, giving an annual saving of about **£150** for an installation cost of about **£1000**.

PAYBACK TIME : ____

4. FLOOR INSULATION

- Thick carpeting with its underlay provides a layer of thermal insulation which reduces heat loss by ……

The heat loss is reduced from **15% to 5%**, giving an annual saving of about **£100** for an installation cost of about **£1000**.

PAYBACK TIME : ____

5. DRAUGHT-PROOFING

- Strips of plastic and foam are glued around door frames and windows so as to stop cold draughts of air blowing into the house.

The heat loss is reduced from **15% to 5%**, giving an annual saving of about **£50** for an installation cost of **£25**.

PAYBACK TIME : ____

"EFFECTIVENESS" AND "COST EFFECTIVENESS"

The most **"EFFECTIVE"** methods for reducing heat loss are those which give the **greatest saving per annum**.

Write down the heat loss reduction methods we have described in descending order of **"EFFECTIVENESS"**.

Most effective ……..	1	
	2	
	3	
	4	
Least effective …….	5	

The **"COST EFFECTIVENESS"** or **"PAYBACK TIME"** is calculated from :

$$\text{PAYBACK TIME (YEARS)} = \frac{\text{INITIAL COST}}{\text{SAVING PER ANNUM}}$$

Write down the heat loss reduction methods we have described in descending order of **"COST EFFECTIVENESS"**.

Most effective ……..	1	
	2	
	3	
	4	
Least effective …….	5	

OTHER WAYS OF IMPROVING ENERGY EFFICIENCY

- There are other things which we can do to improve **energy efficiency** in our homes, schools and places of work.
- **Thermostats** and **computer control systems for central heating** can further reduce the heating needs of a building. They stop rooms from being heated too much by switching the heating off when a specific optimum temperature is reached.
- **Energy saving light bulbs** can give the same light brightness as incandescent filament bulbs using a lot less energy. A **40 W** energy saving bulb will give out the same amount of light as a **150 W** filament bulb.

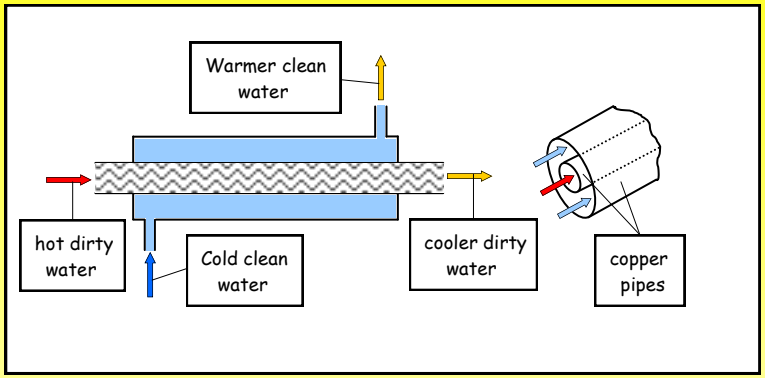
They also have the added advantage of a much longer lifespan (**6000—15000 hours** compared to the maximum **1000 hours** of ordinary bulbs).

- A **light-emitting diode (LED)** is a semiconductor light source.

LED's are used as indicator lamps in a huge variety of electrical devices (e.g. TV sets, DVD players etc.) and because modern versions can give very bright light, they are increasingly being used in lighting.

LED lighting has a much lower energy consumption than ordinary light bulbs or fluorescent tubes and although it is relatively expensive, it has a very long lifespan and it is very reliable.

- **Heat exchangers** are devices used to transfer heat from one fluid to another.



The diagram above shows a double pipe heat exchanger of the type used to improve energy efficiency in hospital laundry systems. Hot dirty water from the washing flows along the central pipe and clean cold water is passed through a cylindrical jacket surrounding the hot pipe. In this way, heat is transferred to the clean water which then requires less heating for use in the washing process.

The heat from the hot dirty water is transferred through the pipe wall by **conduction**. So the pipe is made of a **good thermal conductor** (copper) and its wall is of **large surface area** and **thin** so as to maximise conduction. The heat is then transferred through the cold water by **convection**. More heat is extracted from the hot water if it **flows slowly** through the heat exchanger.

- Energy efficiency can also be improved by **replacing older electrical appliances with more modern, energy efficient versions**.

- **Turning the TV, DVD player or games console off when it is not in use** saves energy and reduces harmful CO_2 emissions. In the UK around **15 million** TV's are left on standby for **20 hours** a day. If they were all switched off we would save enough energy to decommission an entire power station.
There are now devices available which will prevents anything being left on standby by automatically switching things off when they are not in use.

- People who are really serious about reducing their carbon footprint and also saving money can use an energy monitor to check their daily energy use and hence take steps to improve their energy efficiency.

These meters show how much electrical energy is being used in a home and the effect of turning things on and off.

ENERGY

- Is the capacity of a body for doing work.
- Is measured in: **JOULE (J)**
- **CANNOT BE CREATED OR DESTROYED BUT IT CAN BE CONVERTED FROM ONE FORM INTO ANOTHER**

  This is the **The principle of conservation of energy**
- Exists in a variety of different forms :

FORMS OF ENERGY

- **MECHANICAL ENERGY**

  KINETIC ENERGY

  This is the energy possessed by a moving object.

  GRAVITATIONAL POTENTIAL ENERGY

  This is the energy a body has as a result of its position or height above the ground.

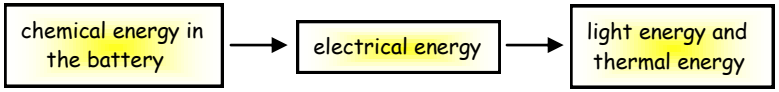
  ELASTIC POTENTIAL ENERGY

  This is the energy stored in a body as a result of being stretched or compressed.
- **LIGHT ENERGY**
- **HEAT (THERMAL) ENERGY**
- **ELECTRICAL ENERGY**
- **CHEMICAL ENERGY**
- **SOUND ENERGY**
- **NUCLEAR ENERGY**

ENERGY TRANSFORMATIONS

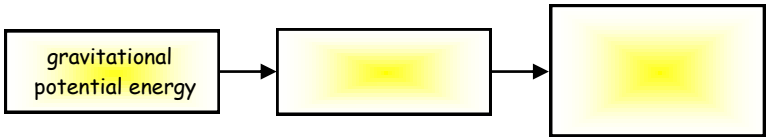
Energy changes can be shown using an **ENERGY FLOW DIAGRAM.**

Example : When a torch battery drives a current through the bulb, the filament of the bulb gives out heat and light.
The flow diagram is as shown below :



Complete the following energy flow diagrams :

(1) A book **falls** from a shelf and hits the floor with a **thud.**

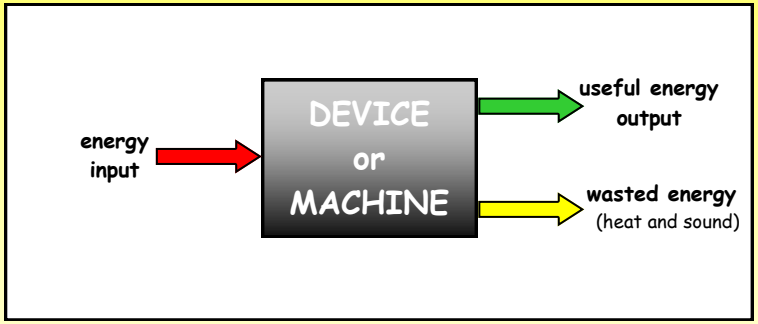


(2) A car engine when it is running.

USEFUL AND WASTED ENERGY

- When a device transfers energy, only part of the energy is **usefully** transferred to where it is wanted and in the form that's wanted.

- The rest of the energy is transformed in a **non-useful** way, mainly as **heat** and **sound** energy. This non-useful energy is called **wasted** energy.



- The wasted energy and the useful energy eventually end up warming the air around us. In this way the energy becomes more and more spread out into the surroundings and it is then more difficult to use for further energy transfers.

- The **efficiency** of a device refers to the proportion of the **input energy** which the device transforms into **useful output energy**.

  The **greater** the efficiency, the **greater** is the proportion of the input energy which is transformed into useful energy.

- The **efficiency** of a device, expressed as either a **percentage** or a **decimal number**, is calculated using the following equations :

$$\text{efficiency} = \frac{\text{useful energy out}}{\text{total energy in}} \quad (\times 100\%)$$

AND

$$\text{efficiency} = \frac{\text{useful power out}}{\text{total power in}} \quad (\times 100\%)$$

- Some energy is always 'wasted' so **no device is 100% efficient.**

- The **'wasted'** energy is nearly always dissipated as **heat** and **sound.**

- Electric heaters are the exception, since all the electrical energy supplied is transformed into useful heat energy (although in practice some is transformed into non-useful light energy).

- Use the **efficiency** formula to complete the table below :

Total energy Input (J)	useful energy output (J)	% effficiency
2000	1500	
	2000	60
6000		15
250	200	

ENERGY TRANSFER EXAMPLES

- Complete the table of **energy transfers** shown below :

DEVICE	ENERGY INPUT	USEFUL ENERGY OUTPUT	'WASTED' ENERGY
filament bulb			
car engine			
loudspeaker			
bow and arrow			
wind turbine			
hair drier			
electric fan			
electric heater			
television set			
gas cooker ring			
wind-up radio			

ENERGY ARROW (SANKEY) DIAGRAMS

- These diagrams give us a very clear picture of an energy transfer situation.
- The **width of each segment of the arrow** shows the proportion of the input energy which has been transformed into each different form.
- The **Efficiency** of a given device can then be worked out from such a diagram.
- **Fig.1** opposite is the Sankey diagram for an **ordinary filament bulb.**

  Its **% efficiency** is :

  $\frac{10}{100} \times 100 =$ **10%**

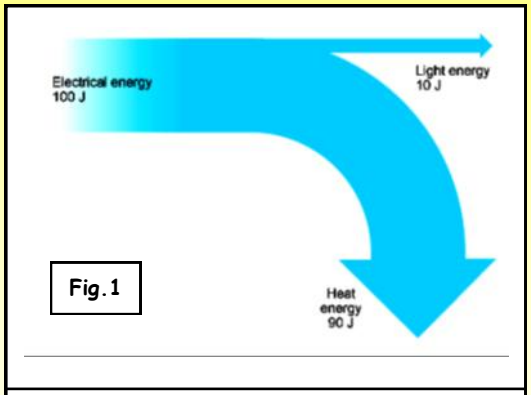


Fig.1

- **Fig.2** is the Sankey diagram for a modern **energy efficient light bulb.**

  Its **% efficiency** is :

  $\frac{75}{100} \times 100 =$ **75%**

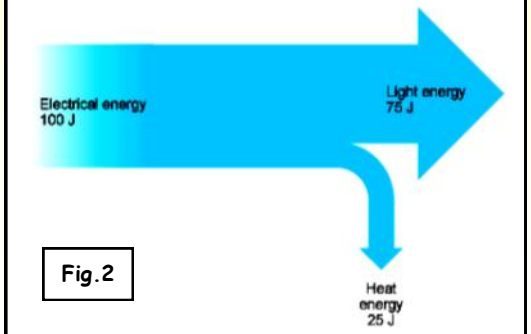


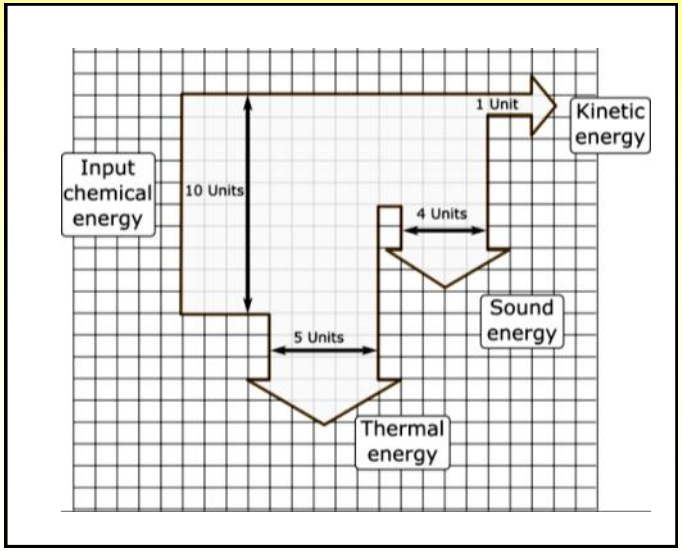
Fig.2

- In exams, the **Sankey** diagram is **drawn on graph paper** and you will need to count squares on the grid in order to work out how much of the **energy supplied** has been transferred into **useful energy** and **wasted energy**.

  The % efficiency can then be calculated using the normal % efficiency formula.

- The diagram below is an example of what you might be faced with in the exam.

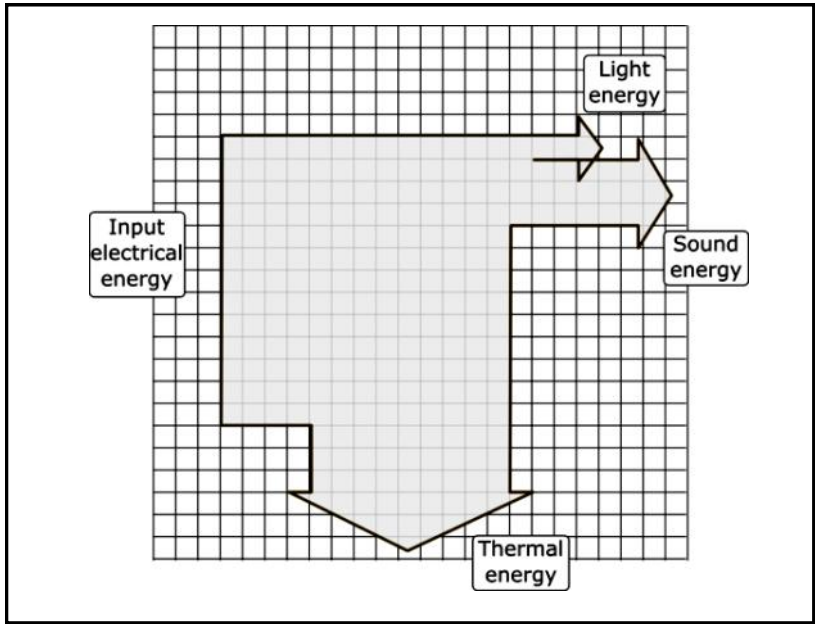
  It is the **Sankey** diagram for an internal combustion engine. The **useful energy** is the **kinetic energy** and the **sound and heat energy** produced is **'wasted' energy**.



$$\% \text{ efficiency} = \frac{\text{useful energy output}}{\text{total energy input}} \times 100 = \frac{1}{10} \times 100 = \boxed{10\ \%}$$

The Sankey diagram for an **ipod** is shown below. Calculate :

(a) Its **efficiency**, simply **as a decimal**. **(b)** Its **% efficiency**



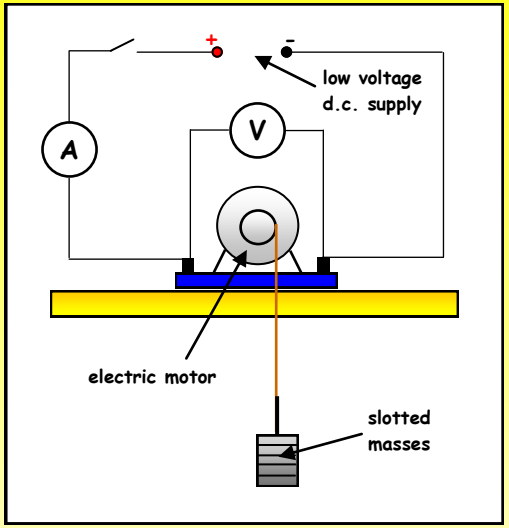
PRACTICAL INVESTIGATION - EFFICIENCY OF AN ELECTRIC MOTOR

The apparatus is set up as shown in the diagram opposite and the electric motor is used to lift the slotted masses through a measured **height, h.**

h = **m**

A stopclock is used to measure the **time, t** taken for the masses to be lifted through height h.

t = **s**



The **current, I** in the motor and the **potential difference, V** across it are also measured using an ammeter and voltmeter respectively.

I = **A**

V = **V**

Electrical energy supplied to the motor, E_I = **V x I x t**

= x x

= **J**

Gravitational potential energy gained by the lifted masses, E_O = **m x g x h**

= x x

= **J**

% efficiency of the motor = $(E_O/E_I) \times 100$

= x 100

= **%**

• PRACTICE QUESTIONS 37

1 The devices listed below transfer energy in different ways.

1. Car engine **2. Electric bell** **3. Electric light bulb** **4. Gas heater**

Match words A, B, C and D with the devices numbered 1 to 4.

A. Heat (thermal) energy **B. Light energy**
C. Movement (kinetic) energy **D. Sound energy**

2 Use words from the list to complete the sentences given below :

USEFUL **WASTED** **THERMAL** **LIGHT** **ELECTRICAL**

When a light bulb is switched on ..... energy is changed into ..... energy and into ..... energy of the surroundings. The energy that radiates from the light bulb is ..... energy. The rest of the energy supplied to the light bulb is ..... energy.

3 On a building site a machine is used to lift a bag of sand from the ground to the top of a building. What type of energy has the bag of sand gained ?

A. Elastic potential energy **B. Gravitational potential energy**
C. Kinetic energy **D. Thermal energy**

4 What type of energy is stored in a stretched rubber band ?

A. Chemical energy **B. Elastic strain energy**
C. Gravitational potential energy **D. Kinetic energy**

5 An electric fan is used to move air around a room.

(a) The fan usefully transforms electrical energy into :

A. Elastic energy **B. heat energy**
C. kinetic energy **D. Sound energy**

(b) Energy that is not usefully transformed by the fan is wasted as :

A. Heat and sound energy **B. Heat energy only**
C. Kinetic and sound energy **D. Sound energy only**

(c) Which of the following statements about the energy wasted by the fan is **not true?**

A. It makes the surroundings warmer
B. It can no longer be transformed in useful ways
C. It becomes very thinly spread out
D. It makes the surroundings cooler

(d) A second design of fan transforms useful energy at the same rate, but wastes less of the energy supplied to it. This means that the second fan :

A. Is 100% efficient **B. Is less efficient**
C. Is more efficient **D. Has the same efficiency**

6 A chair lift carries skiers to the top of a mountain.

(a) When the skiers get to the top of the mountain they have gained gravitational potential energy. As they ski back down the mountain, what type of energy is this transformed into?

(b) The chair lift is powered by an electric motor. What useful energy transformation takes place in the motor?

(c) Some of the electrical energy supplied to the motor is wasted as heat. Why does this happen?

(d) The energy required to lift two skiers to the top of the mountain is **240 000J**. The energy supplied to the motor is **800 000 J**. Calculate the **% efficiency** of the motor.

7 A car engine is found to be **21%** efficient. If the total energy supplied to the engine in a given time is **750 000 J**, calculate how much of this is **usefully** transformed.

The fraction of the energy supplied to the engine which is not usefully transformed is called the wasted energy. Name the **two forms of energy** produced by the engine which are classed as wasted energy.

8 An electric motor is used to raise a weight. When **60 J** of electrical energy is supplied to the motor, the weight gains 24 J of gravitational potential energy.

(a) What is the **energy wasted** by the motor?

(b) Calculate the **% efficiency** of the motor.

9 Complete the table shown below to show what happens to the energy transferred in each case.

ENERGY TRANSFER BY :	USEFUL ENERGY	WASTED ENERGY
An electric motor		
A television set		
An electric kettle		
Headphones		

10 When a television set is supplied with **2000 J** of electrical energy, it produces **1190 J** of light energy, **800 J** of thermal energy and **10 J** of sound energy.

(a) What form of energy is transferred as **waste energy** by the television set?

(b) What does the waste energy do to the air around the television set?

(c) Calculate the **efficiency** of this television set :

(i) As **a decimal.**

(ii) As **a percentage.**

- **HOMEWORK QUESTIONS (1)**

1 Heat is lost from a house through its **roof, walls, windows, floor** and **doors**.

Write down **one** measure which could be taken to **reduce thermal energy loss** through **each** part of the house.

2 Explain briefly how each of the following methods of insulation work :

(a) Loft insulation, **(b) Cavity wall insulation.**

3 When we are discussing the relative benefits of heat loss reduction methods for a house, the terms '**effective**', '**cost effective**' and '**payback time**' are used.

Explain what each of these terms means.

4 The table below gives information about ways of reducing energy loss from a house.

method of reducing energy loss	fitting cost	annual saving
Draught-proofing	£80	£80
Hot-water tank jacket	£25	£20
Loft insulation	£400	£80
Thermostatic control on radiators	£150	£30

(a) Which method of reducing energy loss saves money by **preventing the house becoming too warm?**

(b) Which method reduces energy loss by the **smallest** amount?

(c) Which method pays for itself in the **shortest time?**

(d) What is the **payback time on loft insulation?**

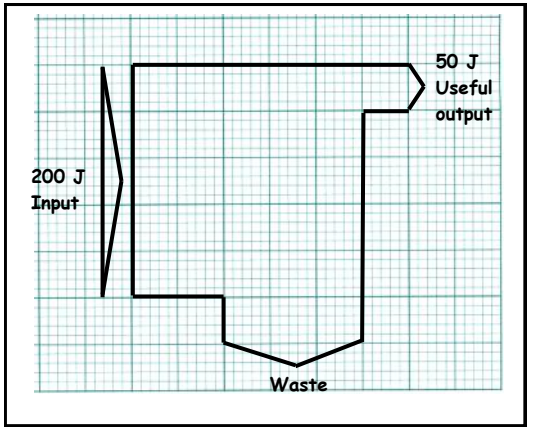
5 The **Sankey** diagram opposite shows the energy changes in a Lego toy car.

(a) How much energy does **one small square** represent?

(b) How much energy is **wasted?**

(c) What **energy forms** is this wasted energy mostly likely to take?

(d) Calculate the **% efficiency** of the toy car.



6 BMW are testing a new, revolutionary, high-efficiency engine for their latest car. It is found that for every **1000 J** of energy supplied to the engine, **750 J** are transformed into **kinetic energy** in the moving car, **5 J** are wasted as **sound energy** and the rest is is transformed into **waste thermal energy**.

(a) Using graph paper, draw a **Sankey energy transformation diagram** to illustrate the results of BMW's research.

(b) Calculate the **% efficiency** of this new engine.

7 **(a)** Name the **two** forms of **useful** energy transferred by a laptop p.c. What energy form is '**wasted**' energy in a laptop p.c.?

(b) Which of the statements shown below about the energy transfer in a laptop is **false?**

(i) The energy is spread out to the environment.
(ii) The energy is used up.
(iii) The energy warms up the surroundings.
(iv) It is difficult to use the energy again.

(c) A laptop uses **1500 J/s** of energy of which only **950 J/s** is usefully transferred. Calculate the **% efficiency** of the laptop.