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GCSE Physics

Edexcel Energy – Forces doing work

Overview
Edexcel Topic 7

Energy – Forces doing work

Part 1
- Work done
- GPE and KE

Part 2
- Power
- Efficiency

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Part 1

- Work done
- GPE and KE

Work Done

When a force causes an object to move through a distance, WORK IS DONE on the object. So a force does work on an object when the force causes a displacement of the object.

Work done can be calculated using the equation:

work done (J) = force (N) x distance moved in the direction of the force (m)

$$E = F \times d$$

Note: Energy transferred (joule, J) is equal to work done (joule, J)

Work Done Calculations

A box is pushed 3 m across the floor with a force of 120 N.

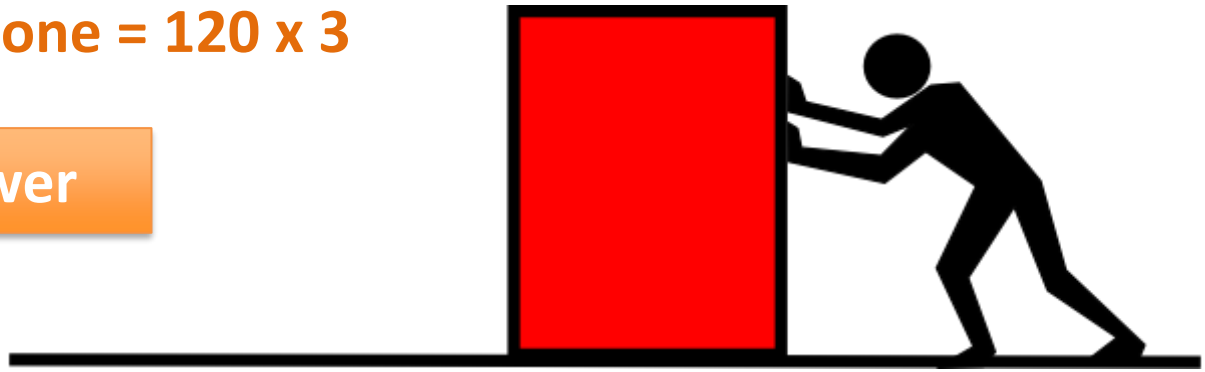
Work out the work done in moving the box.

Solution

Equation: work done = force x distance travelled

Substitution: work done = 120 x 3

Click to reveal answer



Work Done Calculations

A man with a mass of 70 kg gets onto a moving escalator.
The escalator moves 15 m horizontally and 8 m vertically.
Calculate the work done by the motor against gravity.

Take g = 10 N/kg.

Solution

Gravity acts downwards, so the distance moved against gravity is 8 m.
Since W = mg; the weight of the man is 700 N.

Using: **work done = force x distance travelled**
work done = 700 x 8

Click to reveal answer

Gravitational potential energy

When an object is raised above ground level it gains **gravitational potential energy** (GPE). This **stored energy** can be released if the object is allowed to **fall**.

A pile driver is a machine that lifts a heavy weight then drops it on a post to drive it into the ground.

Recall and use the equation to calculate the change in gravitational PE when an object is raised above the ground:

change in G.P.E (J) = mass (kg) × gravitational field strength (N/kg) × change in height (m)

$$\Delta GPE = m \times g \times \Delta h$$

The pile driver hammer has a mass of 120 kg and it is raised to a height of 4 m above the ground. How much G.P.E will it have?

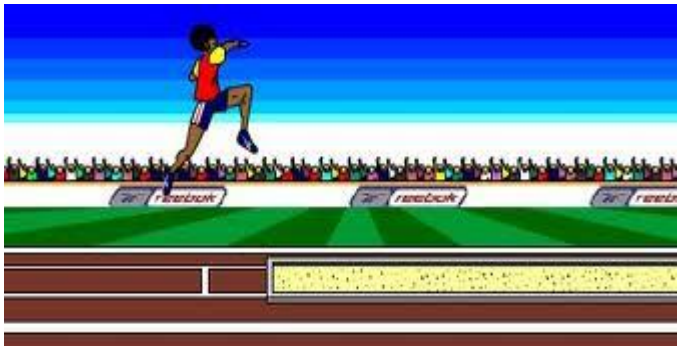
$$\Delta GPE = m \times g \times \Delta h$$

$$\Delta GPE = 120 \times 10 \times 4$$

From topic 3

The G.P.E gained is: Click to reveal answer

Kinetic Energy



Moving objects have kinetic energy.

The long-jumper is using her **kinetic energy** to carry her body as far as possible. The more kinetic energy she has, the longer her jump will be. Her kinetic energy depends on her mass (which she can not change) and her velocity (she can run faster!).

Recall and use the equation to calculate the amounts of energy associated with a moving object:

$$\text{kinetic energy (J)} = \tfrac{1}{2} \times \text{mass (kg)} \times \text{speed}^2\text{ (m/s)}$$

$$KE = \tfrac{1}{2}\, m\, v^2$$

If her mass is 46 kg and she is travelling at 8 m/s, her kinetic energy during her jump will be:

$$KE = \tfrac{1}{2}\, m\, v^2$$

$$KE = \tfrac{1}{2} \times 46 \times 8^2$$

From topic 3

The energy transferred in the jump is: Click to reveal answer

Work Done Against Frictional Forces

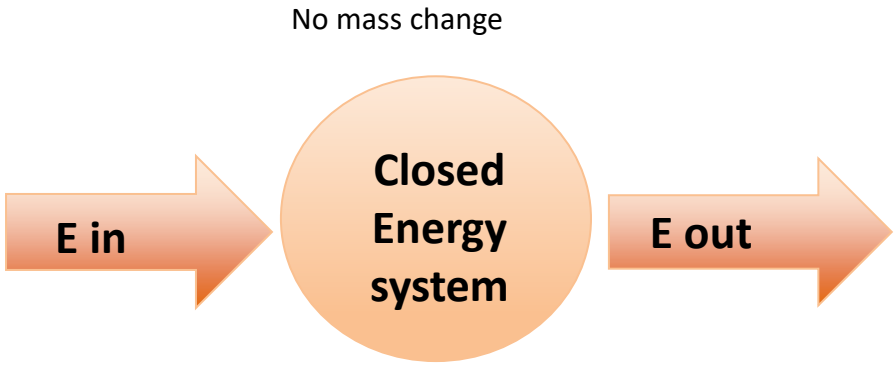
When work is done against frictional forces on an object there is a temperature increase of the object.

A bicycle pump gets hot in use as work is done in compressing the gas, causing the pump to get hotter.

Energy transfers in a system

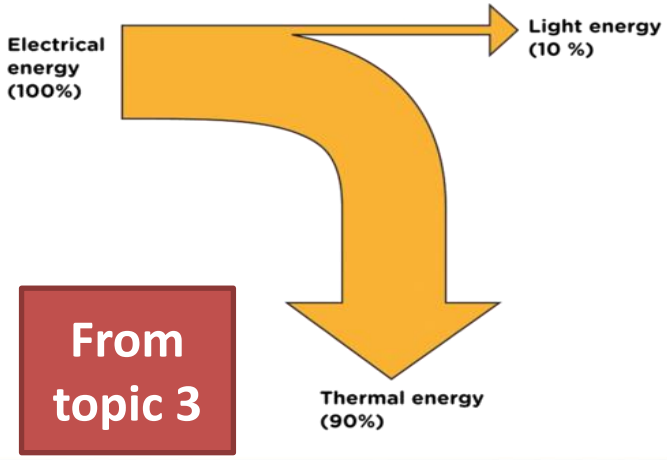
Energy can be stored, transferred or dissipated - but can not be created or destroyed.

In a closed energy system there can be transfer of energy but not mass. There is **no change to the total energy in the system.**



In a **closed energy system** all the energy can be accounted for even when energy stores change.

The diagram shows the energy transfer for a light bulb. All the electrical energy store can be accounted for as light energy and thermal energy.
The thermal energy is not useful in this case and can be considered to be dissipated or "waste" energy.



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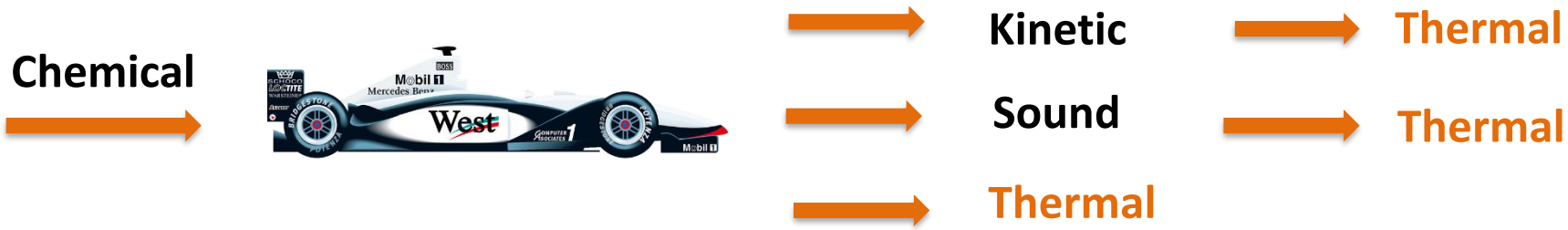
Energy transfers in a system

Unwanted energy transfers result in energy stores that are not useful.

The F1 car below shows that eventually all the chemical energy (fuel) put in the car ends up as unwanted thermal energy which is dissipated to the surroundings. Unwanted energy is often described as being 'wasted'



Kinetic energy is dissipated by the tyres, brakes and air resistance to become unwanted thermal energy stores.

Sound energy is absorbed by materials and becomes thermal energy.

Thermal energy is produced by the engine as fuel is burnt.

From topic 3

Oil is used in the engine, gearbox and other moving parts as a lubricant to reduce friction and reduce unwanted thermal energy in these parts.

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QuestionIT!

Part 1

- Work done
- GPE and KE

1. A piano is pushed across a wooden floor with a force of 2500 N. The piano moves a distance of 3.5 m. Calculate the work done moving the piano.

2. Work done is usually measured in joules. An alternative unit for work done is (circle the correct answer).

   kg/m^3 Nm W N/m2 N/kg

3. Why does a bicycle pump get hotter when used to pump up a tyre?

4. A box with a weight of 120 N is lifted up 1.8 m onto a shelf. Calculate the work done in lifting the box.

5. When a book is lifted 3 m the work done on the book is 1.2 J. Calculate the weight of the book.

6. Javier Sotomayor is the current men's record holder with a jump of 2.45 m His mass is 82 kg.
(g = 10N/kg)

a. What type of stored energy does he have as he clears the bar?

b. Work out how much stored energy Javier Sotomayor has due to his position above the ground.

c. As he falls back to the ground, this energy store will be transferred into a new energy store. Name this new energy store.

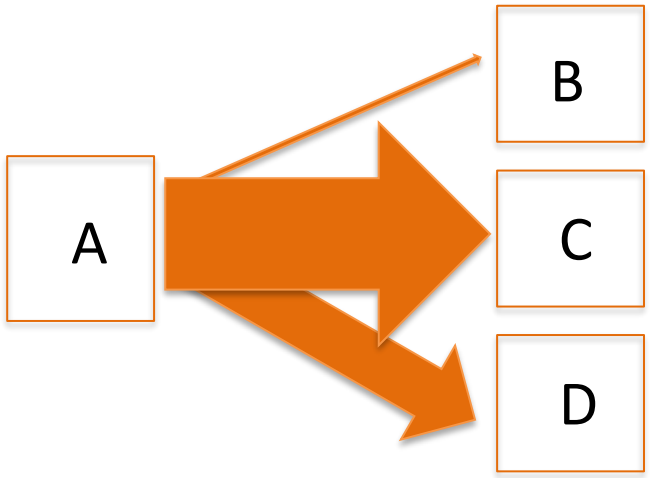
7. When a tennis ball is hit with a racket it gains **kinetic energy**.

a. What is the **formula** used to calculate kinetic energy?

b. The tennis ball has a mass of 56 g and hit has a velocity of 48 m/s. Work out the **kinetic energy** of the moving ball?

8. Describe how the thermal energy applying the brakes on a bike while riding along a road is dissipated.

a. The diagram shows the main energy transfers for an electric kettle. Complete boxes A to D showing the energy stores involved. Use the size of the arrows to help you.



b. State why the total energy supplied to an electric kettle must always equal the total

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AnswerIT!

Part 1

- Work done
- GPE and KE

Part 1– AnswerIT

1. A piano is pushed across a wooden floor with a force of 2500 N.
   The piano moves a distance of 3.5 m.
   Work out the work done moving the piano.
   Using E = F x d
   Work done = 2500 x 3.5
   Work done = 8750 J

2. Work done is usually measured in joules. An alternative unit for work done is (circle the correct answer).

   kg/m^3 **Nm** W N/m2 N/kg

3. Why does a bicycle pump get hot when used to pump up a tyre?
   Work is done in compressing the air
   Causing the molecules to increase the frequency of their collisions
   Causing frictional heating and an increase in the temperature.

4. **A box with a weight of 120 N is lifted up 1.8 m onto a shelf. Calculate the work done in lifting the box.**

   Using

   Work done = force x distance travelled

   Work done = 120 x 1.8

   Work done = 216 J

5. **When a book is lifted 3 m the work done on the book is 12.6 J. Calculate the weight of the book.**

   Using

   Work done = force x distance travelled

   Rearranging gives

   Force = work done / distance

   Substitution gives

   Force = 12.6 / 3

   Answer

   Force = 4.2 N

6. Javier Sotomayor is the current men's record holder with a jump of 2.45 m His mass is 82 kg.

(g = 10N/kg)

a. What type of stored energy does he have as he clears the bar?

gravitational potential energy

b. Work out how much stored energy Javier Sotomayor has due to his position above the ground.

ΔGPE = m× g ×Δh = 82 x 10 x 2.45 = 2009 J

c. As he falls back to the ground, this energy store will be transferred into a new energy store. Name this new energy store.

kinetic energy

7. When a tennis ball is hit with a racket it gains **kinetic energy**.

a. What is the **formula** used to calculate kinetic energy?

KE = ½ m v^2

b. The tennis ball has a mass of 56 g and hit has a velocity of 48 m/s. Work out the **kinetic energy** of the moving ball?

Convert 56 g into kg = 0.056 kg

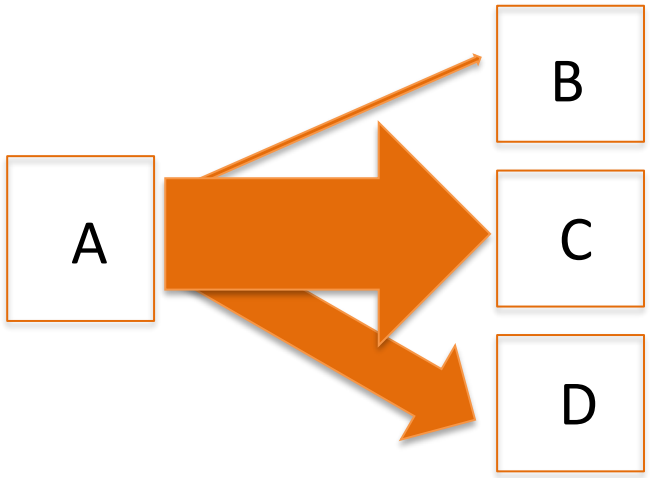
KE = ½ x 0.056 x 48^2

KE = 64.52 J

8. Describe how the thermal energy applying the brakes on a bike while riding along a road is dissipated.

The friction between the brake block and bike wheel transfer thermal energy to the air particles surrounding them

a. The diagram shows the main energy transfers for an electric kettle. Complete boxes A to D showing the energy stores involved. Use the size of the arrows to help you.



A - Electrical energy

B - Sound energy

C - Thermal energy to heat the water

D - Thermal energy to heat the surroundings

b. State why the total energy supplied to an electric kettle must always equal the total energy transferred by the electric kettle.

Energy can not be created or destroyed so:

total energy in = total energy out

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Part 2

- Power
- Efficiency

Power

Power - the rate at which energy is transferred

the rate at which work is done (rate means "how quickly")

Power is measured in joules per second 1 J/s = 1 Watt

An object which transfers energy does so at a certain rate.
The metal filament in this light bulb transfers the electrical energy store into heat and light.
This bulb transfers 2400 joules of energy in 60 seconds.

Power can be calculated using the following equation:

$$\text{power (W)} = \frac{\text{work done (J)}}{\text{time taken (s)}}$$

$$P = \frac{E}{t}$$

P= 2400 / 60 = 40 J/s

From topic 3

Click to reveal answer

Power

Power - the rate at which energy is transferred
the rate at which work is done (rate means "how quickly")

Mechanical power

Power = work done / time

The crane lifts the 2000 kg container through a height of 5.4m in 30s.
The power of the crane is:

Power = work done / time

But: Work done = force x distance
= 20 000 N x 5.4 m = 108 000 J

Power = 108 000 J / 30 s

The Power of the crane is 3600 J/s or 3600 Watts

From topic 3

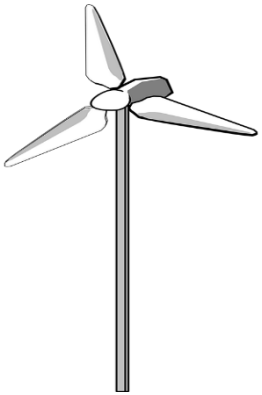
Efficiency

The amount of useful energy you get from an energy transfer, compared to the energy put in, is called the **EFFICIENCY**

$$\text{Efficiency} = \frac{\text{(useful energy transferred by the device)}}{\text{(total energy supplied to the device)}}$$

This calculation will result in a decimal value which can be multiplied by 100 to give a percentage efficiency.

A wind turbine energy transfer



The wind turbine produces 120 MW of electrical energy for every 500 MW of kinetic energy provided by the wind.

Efficiency = (useful energy transferred by the device) / (total energy supplied to the device)

$= \frac{120}{500}$

Click to reveal answer

Click to reveal answer

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QuestionIT!

Part 2

- Power
- Efficiency

1. Give two alternative units of power?

2. A blowtorch burns butane gas to heat metal pipes.

a. Describe the energy transfers which occur as it is used.

…… energy is transferred into

…… energy usefully and

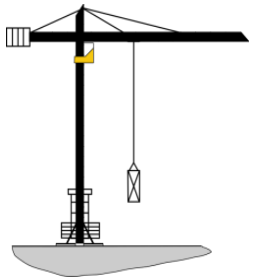
…… energy is wasted.

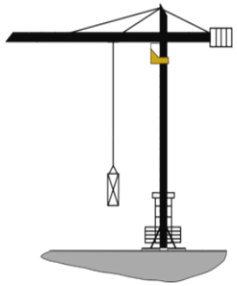
b. Explain how some of the transferred energy is wasted.

c. The blowtorch transfers 2 kJ of energy in 4 mins. Work out the power of the blowtorch?

3. Two cranes are lifting the same load of 120 kg to a height of 15 m.

Crane A



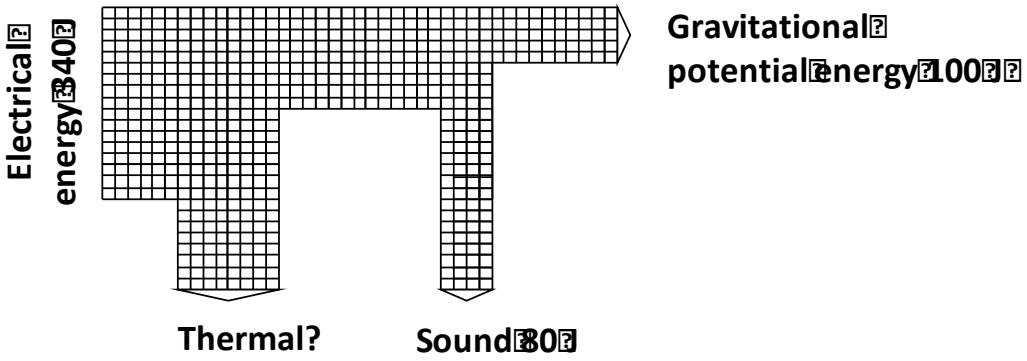


Crane B

Crane A takes 30 s to lift the load. Crane B lifts the same load in 9 s.

Calculate the **difference in power** of the two cranes.

4. The diagram represents the energy store transfers when a motor is lifting a weight.



a. How much electrical energy is transferred to a thermal energy store?

b. What is the total amount of dissipated energy?

c. Calculate the efficiency the of the useful energy transfer

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AnswerIT!

Part 2

- Power
- Efficiency

Part 2 – AnswerIT

1. Give two alternative units of power?

Joules/second or Watts

2. A blowtorch burns butane gas to heat metal pipes.

a. Describe the energy transfers which occur as it is used.

Chemical energy is transferred into **thermal** energy usefully and **light** energy is wasted.

b. Explain how some of the transferred energy is wasted.

As thermal energy to the environment

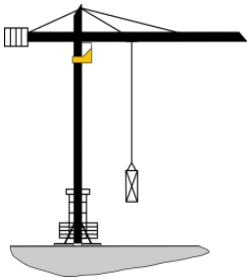
c. The blowtorch transfers 2 kJ of energy in 4 mins. Work out the power of the blowtorch?

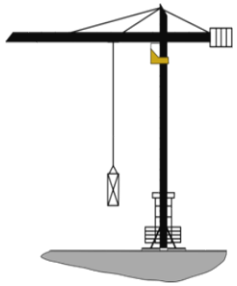
Power = work done / time taken = 2000 / 240

Power of the blowtorch = 8.33Watts

3. Two cranes are lifting the same load of 120 kg to a height of 15 m.

Crane A





Crane B

Crane A takes 30 s to lift the load. Crane B lifts the same load in 9 s.

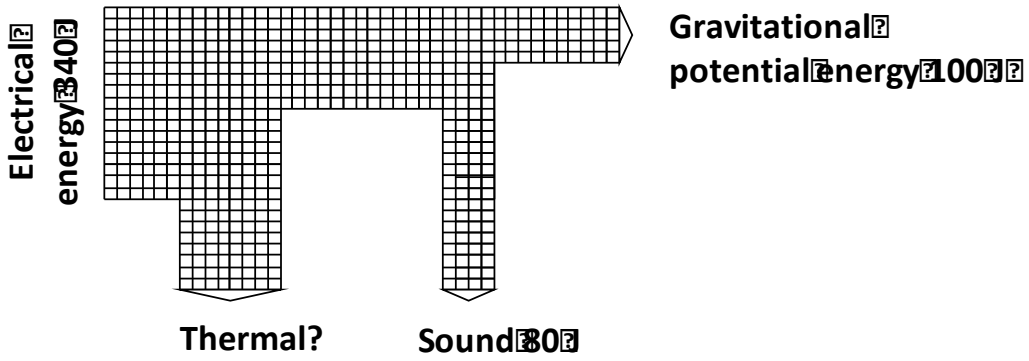
Calculate the **difference in power** of the two cranes.

Crane A power = 1200 x 15 / 30 = 600 W

Crane B power = 1200 x 15 / 9 = 2000W

Difference in power = 2000 – 600 = 1400 Watts

4. The diagram represents the energy store transfers when a motor is lifting a weight.



a. How much electrical energy is transferred to a thermal energy store?

340 – (100 + 80) = 160 J

b. What is the total amount of dissipated energy?

160 + 80 = 240 J

c. Calculate the efficiency the of the useful energy transfer

Efficiency = (useful energy transferred by the device) / (total energy supplied to the device) = 100 / 340 = 0.294