CfE ENERGY CONVERSIONS – B McMULLEN

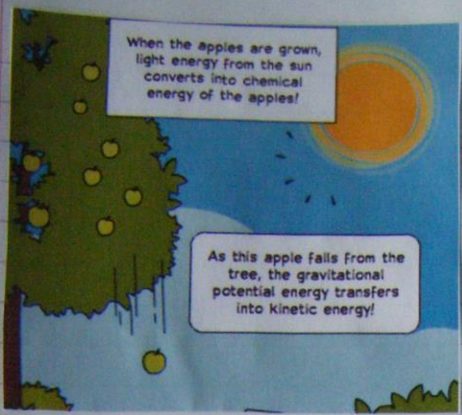
Forms of Energy	Equations
Kinetic Energy	$E_K = \frac{1}{2}mv^2$
Sound Energy	
Light Energy	
chemical Energy	
Heat Energy	$E_H = cm\Delta T$, $E_H = mL$
Gravitational Potential Energy	$E_P = mgh$
Solar Energy	
Geothermal Energy	
Nuclear Energy	
Wave Energy	
Work Done	$E_W = F \times d$

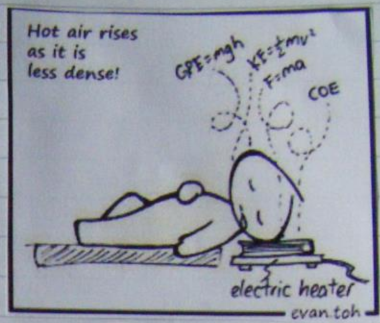
Energy cannot be created or destroyed it can only be converted from one form to another.

eg The food that we eat allows our bodies to take in chemical Energy. The chemical energy is converted into Heat Energy and Kinetic Energy over the course of the day.

Energy changers

1) Electric motor ⇒ Electrical → Kinetic
2) Lamp ⇒ Electrical → Light (+ Heat)
3) Battery ⇒ chemical → Electrical
4) Coal Burning ⇒ Chemical → Heat
5) Uranium in a reactor ⇒ Nuclear → Heat
6) An object falling freely ⇒ Gravitational potential energy → Kinetic Energy
7) Electric cooker ⇒ Electrical → Heat





Work Done

This is the energy required or transferred to an object when moving it from one point to another.

eg When moving a calculator from one point to another on your desk.

This requires a force to be applied on the calculator multiplied by the distance that the calculator moves.

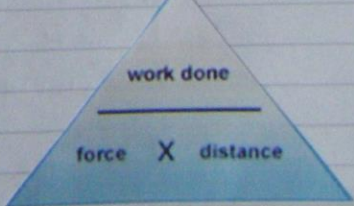
$E_W = F \times d$

- E_W → Work Done (Joules)
- F → Force Exerted (Newtons)
- d → distance travelled (metres).

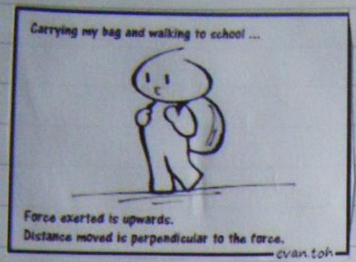
1/ $E_W = F \times d$

2/ $F = E_W / d$

3/ $d = E_W / F$

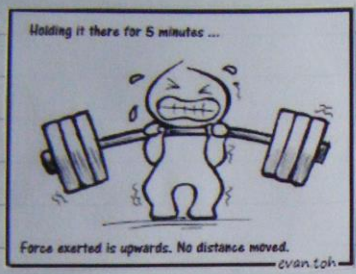


Is Work Done?

- 

✓ Yes!!

- Force Exerted ✓
- distance moved ✓
- ∴ E_W ✓

- 

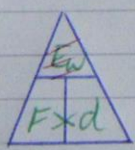
X No!!

- Force Exerted ✓
- distance moved X
- ∴ E_W X

Ex1

A pram is pushed with a force of 140N over a distance of 80m.
Calculate the work done on the pram.

$E_W = ?$
$F = 140N$
$d = 80m$



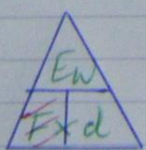
$E_W = F \times d$

$\Rightarrow E_W = 140 \times 80 = 11{,}200J$

Ex2

A person pushes a bike over a distance of 45m with 4000J of work done in the process.
Calculate the force applied to the bike.

$E_W = 4000J$
$F = ?$
$d = 45m$



$F = \frac{E_W}{d} = \frac{4000}{45} = 88.9N$

Ex3

A person of mass 46kg uses 1840J of energy when running up the stairs. Calculate the height of the stairs that the person has to run up.

$m = 46kg$
$E_W = 1840J$
$d = ?$

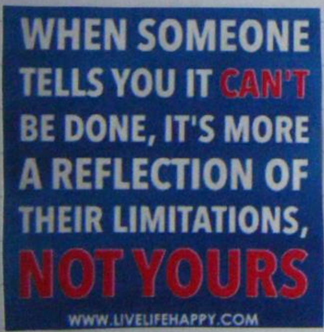
STEP 1 ⇒ Convert mass into weight, which is the force due to gravity.

STEP 2 ⇒ Change $E_W = f \times d$ into $d = \frac{E_W}{f}$

- $W = mg = 46 \times 9.8 = \underline{450.8N}$

$W = F$ ↘

- $E_W = F \times d \Rightarrow d = \frac{E_W}{F} = \frac{1840}{450.8} = \underline{4.08m}$



In life and in Physics you should always have a PMA!!

Positive
Mental
Attitude

This is an understandable reaction to a non-physics day at school!!

Physics is fun!!

Gravitational Potential Energy

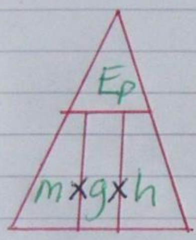
This is the energy that an object has when held at a height.

$$E_p = m \times g \times h$$

- E_p → Gravitational potential energy (J)
- m → mass (Kg)
- g → Gravitational field strength ($N kg^{-1}$)
- h → height (m).

$E_p = mgh$

E_p = Potential Energy
m = Mass
g = Gravitational Field Strength
h = Vertical Height



1. $E_p = mgh$
2. $m = \frac{E_p}{gh}$
3. $g = \frac{E_p}{mh}$
4. $h = \frac{E_p}{mg}$

* g can also be the acceleration due to gravity in ms^{-2} *.

Ex4

A 1400kg car is parked in a multistorey car park.

Calculate the gravitational potential energy of the car at a height of 20m.

$E_p = ?$
$m = 1400 kg$
$g = 9{\cdot}8 N kg^{-1}$
$h = 20m$.

$E_p = mgh = 1400 \times 9{\cdot}8 \times 20$

$\Rightarrow E_p = 2{\cdot}74 \times 10^5 J$

Ex5

An object of mass m has a gravitational potential energy of 1900J when held at a height of 48·5m above the ground.
Calculate the unknown mass m.

$E_p = 1900J$
$m = ?$
$g = 9.8 N Kg^{-1}$
$h = 48.5m$

Ep
m × g × h

$$m = \frac{E_p}{gh}$$

$$\Rightarrow m = \frac{1900}{9.8 \times 48.5}$$

$$\Rightarrow m = \frac{1900}{475.3} = 4Kg$$

Ex6

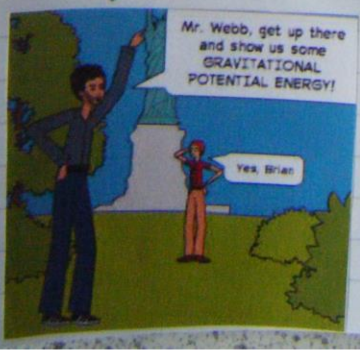
A person of mass 86·7Kg possesses 5100J of gravitational potential energy.
Calculate the height of the person above the ground to have the stated gravitational potential energy.

$E_p = 5100J$
$m = 86.7Kg$
$g = 9.8 N Kg^{-1}$
$h = ?$

Ep
m × g × h

$$h = \frac{E_p}{mg} = \frac{5100}{86.7 \times 9.8}$$

$$\Rightarrow h = \frac{5100}{850} = 6m$$



Kinetic Energy

This is the energy that an object of mass m moving with a speed v possesses.

$$E_K = \frac{1}{2} \times m \times v^2$$

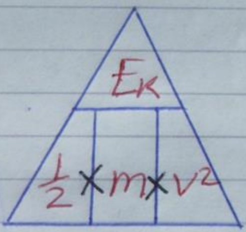
- E_K → Kinetic Energy (J)
- m → mass (kg)
- v^2 → Speed / Velocity squared

$$E_k = \frac{1}{2}mv^2$$

E_k = kinetic energy of object

m = mass of object

v = speed of object



1. $E_K = \frac{1}{2}mv^2$
2. $m = \frac{E_K}{\frac{1}{2}v^2}$
3. $v^2 = \frac{E_K}{\frac{1}{2}m}$

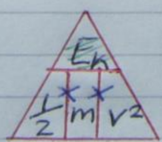
Ex 7

Calculate the kinetic energy of a 85kg rugby player if he sprints to the try line at $8ms^{-1}$.

$E_K = ?$

$m = 85kg$

$v = 8ms^{-1}$



$E_K = \frac{1}{2}mv^2$

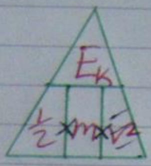
$\Rightarrow E_K = \frac{1}{2} \times 85 \times 8^2 = 2720J$

*Always remember to square the speed in the calculation. *

Ex8

A car of mass 1500kg has a kinetic energy of 432,000J.
Calculate the speed of the car.

$E_K = 432{,}000J$
$m = 1500kg$
$v = ?$

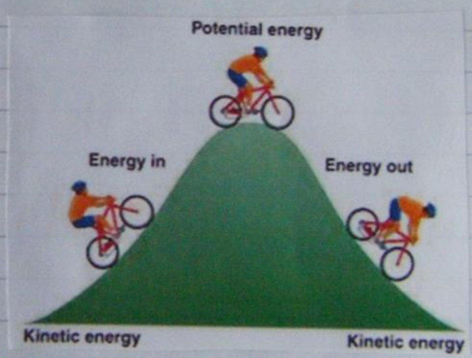


$$v^2 = \frac{E_K}{\frac{1}{2} \times m} = \frac{432{,}000}{\frac{1}{2} \times 1500}$$

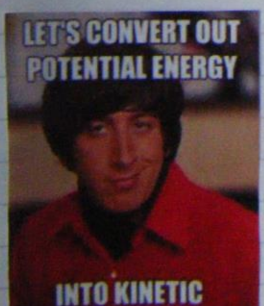
$$\Rightarrow v^2 = \frac{432{,}000}{750} = 576$$

$$\Rightarrow v = \sqrt{576} = 24ms^{-1}$$

CONVERSION OF $E_P \rightarrow E_K$



HOWARD FROM 'THE BIG BANG THEORY'.



FALKIRK WHEEL

Falkirk Wheel

The Falkirk Wheel can transport boats from one height to another with very little excess energy needed.

As each boat moves on to the platform, water will spill out over the side. This allows the mass of the platform to stay constant.

As one side of the wheel starts to move downwards this kinetic energy can be used to raise the other side of the wheel and allow it to gain gravitational potential energy.

* To keep the wheel operating requires the same energy as boiling 8 kettles of water. *

Cyclist on the hill

- At the bottom approaching the hill
  Kinetic Energy MAX + $E_p = 0$
- When climbing the hill
  Kinetic Energy decreases + $E_p > 0$ increasing
- At the top of the hill
  Kinetic Energy min + E_p at MAX
- When coming down the hill
  Kinetic Energy increases + E_p decreasing
- At the bottom of the hill
  Kinetic Energy MAX + $E_p = 0$.

Ex9

A ball of mass 250g is dropped from a height of 125cm.
Calculate the speed at which the ball hits the ground.

HINT!!

When the ball is at rest at a height h it contains gravitational potential energy only.
At the instant just before the ball hits the ground it will contain kinetic energy only.

During the fall the ball will have a gradual energy conversion from Gravitational potential energy to kinetic energy.

ie (1·25m from A down to E)

A ———	A ⇒ E_p only
B ———	B ⇒ $E_p > E_K$
C ———	C ⇒ $E_p = E_K$
D ———	D ⇒ $E_p < E_K$
E ———	E ⇒ E_K ONLY.

In conclusion

E_p at height h = E_K at instant just before hitting the ground.

E_p at top = E_K at bottom

$\Rightarrow \quad mgh = \frac{1}{2}mv^2$

$\Rightarrow \quad 0.25 \times 9.8 \times 1.25 = \frac{1}{2} \times 0.25 \times v^2$

$\Rightarrow \quad 3.0625 = 0.125v^2$

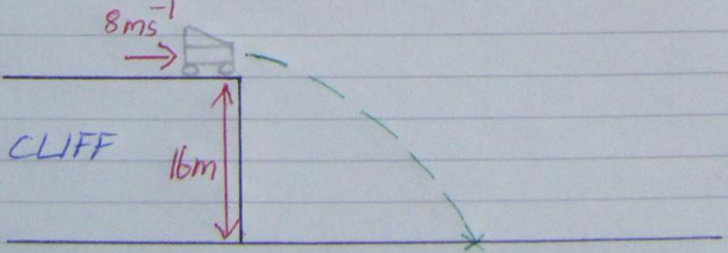
$\Rightarrow \quad 0.125v^2 = 3.0625$

$\Rightarrow \quad v^2 = \frac{3.0625}{0.125} = 24.5$

$\Rightarrow \quad v = \sqrt{24.5} = \underline{\underline{4.95 ms^{-1}}}$

Ex10

A car of mass 1250kg drives horizontally with a speed of $8ms^{-1}$ off the edge of a cliff.
If the cliff is 16m above the ground then calculate the speed of the car as it hits the ground.



HINT!!
- At the top of the cliff $\Rightarrow E_{K_1} + E_p$
- At the bottom of the cliff $\Rightarrow E_{K_2}$

$(E_{K_2} > E_{K_1})$

Total energy at top = Total energy at btm

$\Rightarrow E_{K_1} + E_P = E_{K_2}$

$E_{K_1} = \frac{1}{2}mv_1^2 = \frac{1}{2} \times 1250 \times 8^2 = 40{,}000\,J$

$E_P = mgh = 1250 \times 9.8 \times 16 = 196{,}000\,J$

$\therefore$ Total energy at top $= 40{,}000 + 196{,}000$
$= 236{,}000\,J$

$\therefore$ Total energy at btm $= 236{,}000\,J$

$E_{K_2} = \frac{1}{2}mv_2^2 \Rightarrow 236{,}000 = \frac{1}{2} \times 1250 \times v_2^2$

$\Rightarrow 236{,}000 = 625v_2^2 \Rightarrow 625v_2^2 = 236{,}000$

$\Rightarrow v_2^2 = \frac{236{,}000}{625} = 377.6$

$\Rightarrow v_2 = 19.4\,ms^{-1}$

Efficiency

(max efficiency = 1·0 or 100%)

$$\text{Efficiency} = \frac{\text{Energy output}}{\text{Energy Input}} \Rightarrow Eff = \frac{E.O}{E.I}$$

OR

$$\text{Efficiency} = \frac{\text{Power Output}}{\text{Power Input}} \Rightarrow Eff = \frac{P.O}{P.I}$$

To convert Efficency to % Efficiency multiply by 100%.

What is efficiency?

Efficiency is a comparison of the energy or power input with the energy or power output.

Ex11

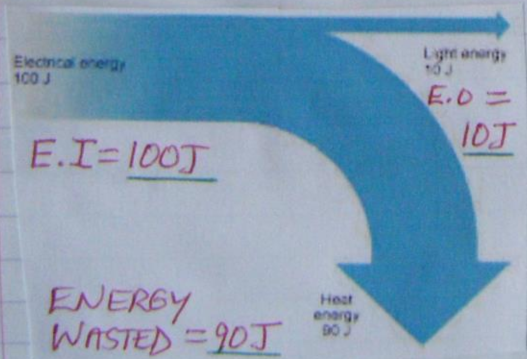
An electric motor is supplied with 80J of electrical energy. If the kinetic energy output from the electric motor is 20J then calculate its efficiency.

E.O = 20J
E.I = 80J
Eff = ?

$$Eff = \frac{E.O}{E.I} = \frac{20}{80} = 0{\cdot}25$$

To find the efficiency in terms of a percentage then

$$\%Eff = Eff \times 100\% = 0{\cdot}25 \times 100\% = 25\%$$

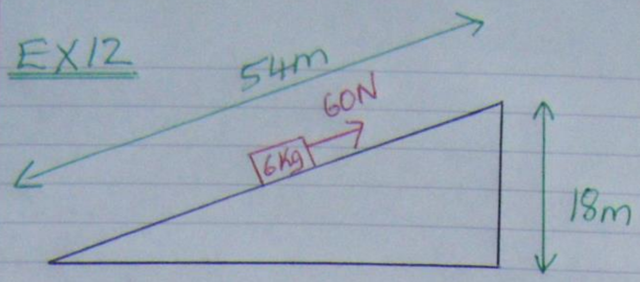


The efficiency of this lamp would be 0·1 or 10% in % efficiency.

$$\text{ie } Eff = \frac{E.O}{E.I} = \frac{10}{100} = 0{\cdot}1$$

$$\therefore \%Eff = 0{\cdot}1 \times 100\% = 10\%$$

EX12



A 6Kg mass is pulled up an incline of 1 in 3 by a 60N force.

Calculate or find:

Q a) Energy Input
b) Energy Output
c) Efficiency
d) % Efficiency

A a) E.I = Work Done $\Rightarrow E_W = F \times d = 60 \times 54$

$E_W = 3240J$

b) E.O = Gravitational potential energy gained $\Rightarrow E_p = mgh$

$\Rightarrow E_p = 6 \times 9.8 \times 18$

$\Rightarrow E_p = 1058J$

c) $\text{Efficiency} = \frac{E.O}{E.I} = \frac{E_p}{E_W} = \frac{1058}{3240} = 0.327$

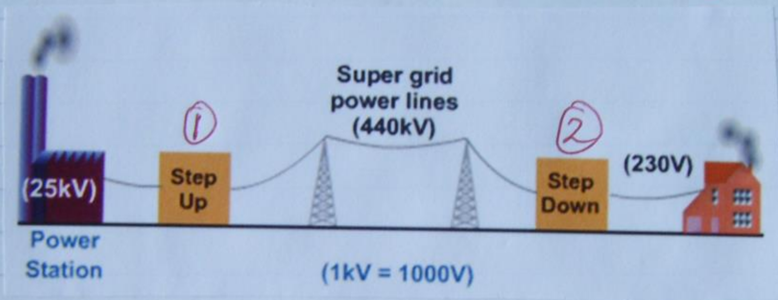
d) $\% \text{Efficiency} = \text{Efficiency} \times 100\%$

$= 0.327 \times 100\% = 32.7\%$

Transformers

Electrical Energy is generated before being transmitted and distributed across the country. This network of electrical energy distribution is called the NATIONAL GRID.

To reduce the power loss in the cables transformers are used to step up (increase) the voltage.

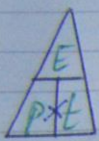


- ① ⇒ Step-up transformer
  Voltage increases from 25kV to 440kV.
- ② ⇒ Step-down transformer
  Voltage decreases from 440kV to 230V.

The common sight of pylons through the towns and in the countryside.

Electrical Power

The electrical power is the electrical energy transformed per second.

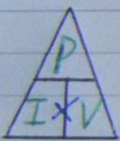


$$\text{Power} = \frac{\text{Energy}}{\text{time}}$$

- Power → Watts (W)
- Energy → Joules (J)
- time → Seconds (s)

$\therefore$ $1W = 1Js^{-1}$

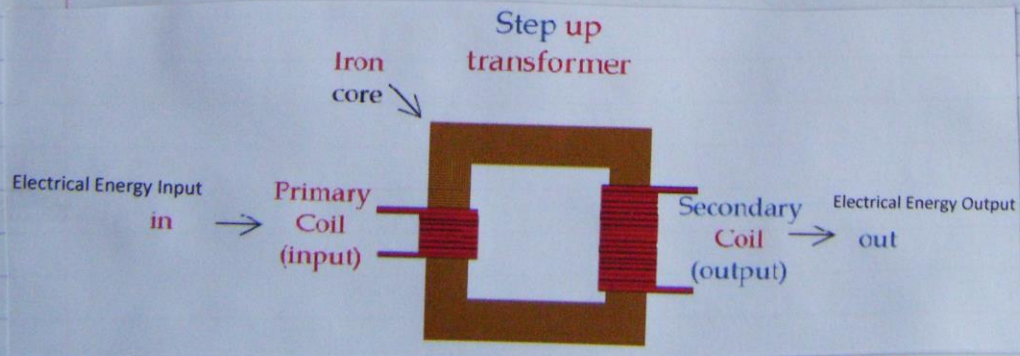
Electrical power can be calculated using current and voltage.



$$\text{Power} = \text{Current} \times \text{Voltage}$$

- Power → Watts (W)
- Current → Amperes (A)
- Voltage → Volts (V)

Applying power calculations to transformers



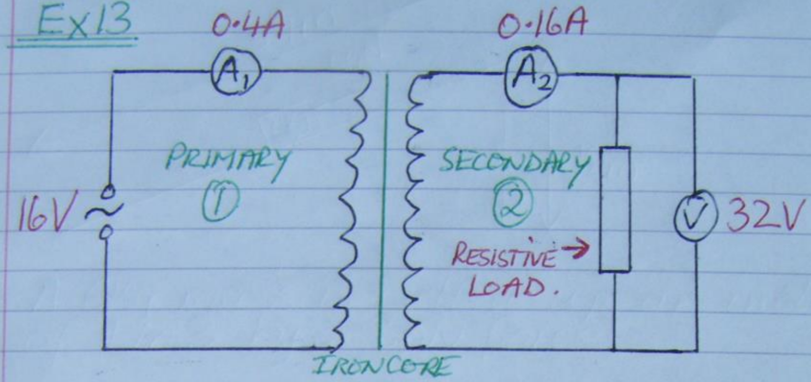
Power Input

$$P_{IN} = I_{IN} V_{IN}$$

Power Output

$$P_O = I_O V_O$$

Ex13



Q Calculate or find:

a) The power in the primary

b) The power in the secondary

c) The Efficiency of the transformer

d) The % efficiency of the transformer.

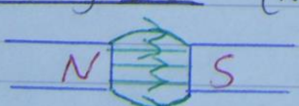
A a) $P_P = I_P V_P = 0{\cdot}4 \times 16 = \underline{6{\cdot}4W}$

b) $P_S = I_S V_S = 0{\cdot}16 \times 32 = \underline{5{\cdot}12W}$

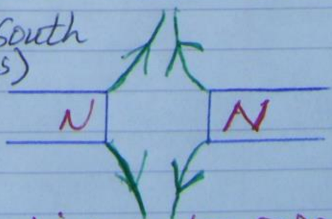
c) $\text{Efficiency} = \frac{P_O}{P_I} = \frac{P_S}{P_P} = \frac{5{\cdot}12}{6{\cdot}4} = \underline{0{\cdot}80}$

d) % Efficiency $= 0{\cdot}80 \times 100\% = \underline{80\%}$

Magnets (North and South poles)



Opposites attract



Like poles repel.