National 5 Physics

"DYNAMICS"

'Work' and 'Energy'

Name: ______________________________

This section of the "Dynamics" unit covers calculations involving 'work done/energy transferred', 'gravitational potential energy' and 'kinetic energy'. It ends with the 'principle of conservation of energy' and calculations involving the transfer of energy between gravitational potential and kinetic (and vice versa).

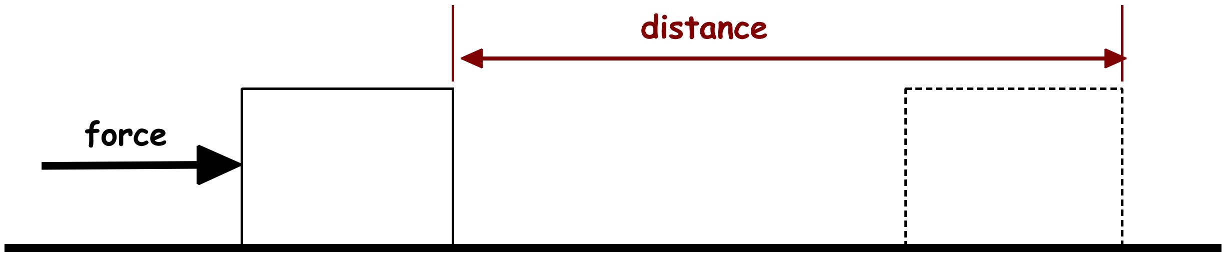
By the end of this section, you should be able to:

- ☐ state that when a force moves an object through a distance, the force does work on the object
  - the work done leads to a transfer of energy
- ☐ carry out calculations using the formula $E_w = F\ d$
- ☐ state that 'gravitational potential energy' is the energy an object possesses due to its position (height) above the ground
- ☐ state that the 'gravitational potential energy' of an object depends on its mass, the value of the gravitational field strength where the object is and the height of the object above the ground
- ☐ explain the term 'gravitational field strength'
- ☐ carry out calculations involving 'gravitational potential energy' using the formula $E_p = m\ g\ h$
- ☐ state that 'kinetic energy' is the energy an object possesses due to its movement
- ☐ state that the 'kinetic energy' of an object depends on its mass and speed
- ☐ carry out calculations involving 'kinetic energy' using the formula $E_k = 1/2\ m\ v^2$
- ☐ state the 'principle of conservation of energy' - "we cannot make or destroy energy, but we can transform (change) it from one type to another"
- ☐ use the 'principle of conservation of energy' to carry out calculations involving the change of 'gravitational potential energy' to 'kinetic energy' (and vice versa), assuming no other energy change takes place

Work Done = Energy Transferred

When a **force** moves an object through a **distance**, the **force** does **work** on the object. This means that **energy** is transferred.

work done = energy transferred



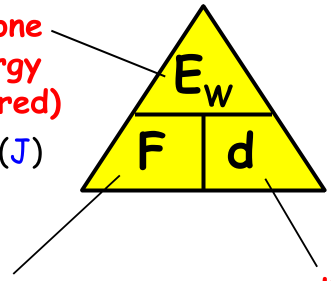
work done (or energy transferred)	=	force	×	distance moved in direction of force

$$E_W = F\ d$$

E_w =

F =

d =



The **work done** by the **force** on the object leads to a **transfer of energy**.
One form of **energy** is transferred (changed) to one or more different forms of **energy**.

E_W = Fd Calculations

1) Calculate the **work done** when a constant force of 2 000 N is applied over a distance of 15 m to move a barrow full of sand.

2) A constant force of 200 N is applied to a pram to move it a distance of 50 m. Calculate the **work done**.

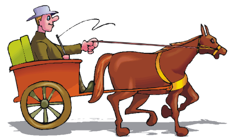
3) In order to move a sledge 75 m across the snow, a constant force of 1 000 N is required. How much **work** is done?

4) Calculate the **energy transferred** when a constant force of 230 N moves a suitcase a distance of 25 m.

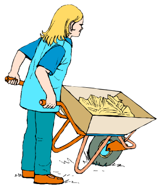
5) Calculate the **energy transferred** when a rickshaw is moved a distance of 200 m due to a constant force of 1 200 N.

6) How much **energy** is **transferred** when a constant force of 1 500 N moves a car a distance of 15 m?

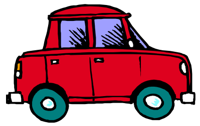
7) Calculate the size of the **constant force** applied to a cart when 75 000 J of work is done to move the cart a distance of 25 m.



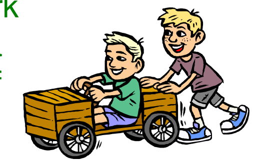
8) A wheelbarrow is moved 12 m when 13 800 J of work is done on it. Calculate the size of the **constant force** applied to the wheelbarrow.



9) A car is moved 500 m along the road due to the transfer of 1 800 000 J of energy. Calculate the size of the **constant force** acting on the car.

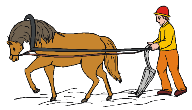


10) 5 600 J of work are done when a constant force of 700 N moves a box-cart. Calculate the **distance** travelled by the box-cart.

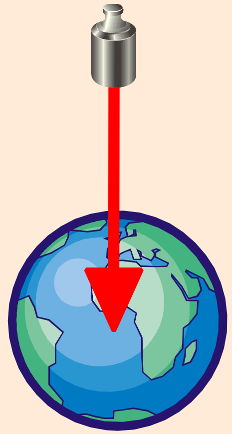


11) 3 870 J of work are done moving a golf trolley when a constant force of 215 N is applied to it. Calculate the **distance** the golf trolley moves.

12) 360 000 J of energy are transferred to a plough when it is acted upon by a constant force of 4 000 N. Calculate the **length** of the furrow produced.



Gravitational Field Strength



The **force of gravity** pulls every object near or on the Earth's surface down towards the centre of the Earth with a **force** of **9.8 newtons for every kilogram of mass**.

This **downwards force** (**weight**) **per kilogram of mass** is called the

g _ _ _ _ _ _ _ _ _ _ _ _ _ _
f _ _ _ _ **s** _ _ _ _ _ _ _ _. (Symbol __).

Near the Earth's surface,

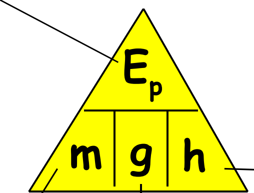
g = ____ newtons per kilogram (**N kg^{-1}**).

Gravitational Potential Energy

Gravitational potential energy is the energy an object stores due to its position above the ground.

gravitational potential energy = mass × gravitational field strength × height

$\boxed{E_p = mgh}$



gravitational potential energy (or change in gravitational potential energy)
joules (J)

mass of object
kilograms (kg)

gravitational field strength
newtons per kilogram (N kg^{-1})
Near Earth's surface,
g = 9.8 N kg^{-1}

height of object above ground (or object's change in height)
metres (m)

E_p =

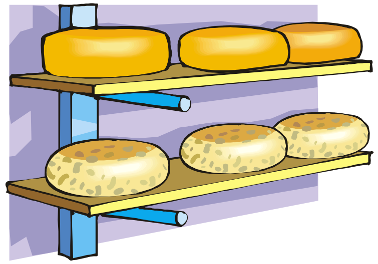
m =

g =

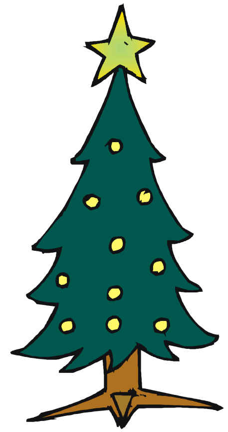
h =

E_p = mgh Calculations

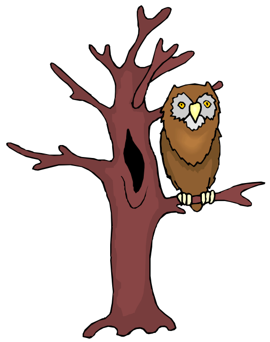
13) Calculate the **gravitational potential energy** of a 15 kg cheese which is sitting on a 1.5 m high shelf.



15) A star (mass 0.75 kg) sits on top of a 12 m high Christmas tree. Calculate the **gravitational potential energy** of the star.



14) 'Hoot' the owl has a mass of 2.8 kg. Calculate her **gravitational potential energy** when she is sitting 9.5 m up a tree.

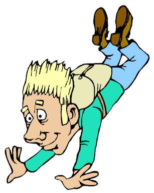


16) Calculate the **gravitational potential energy** of Graham's golf ball (mass 0.045 kg) which is stuck 1.8 m up a tree.

17) Kayleigh has a mass of 62 kg. She climbs 2.5 m up a ladder. Determine Kayleigh's ***increase*** in **gravitational potential energy**;

18) A helicopter (mass 6 200 kg) increases its height above the ground by 115 m. Determine the ***increase*** in **gravitational potential energy** of the helicopter.

19) Ally the abseiler descends 35 m down a rope. His mass is 70 kg. Determine Ally's ***decrease*** in **gravitational potential energy**.

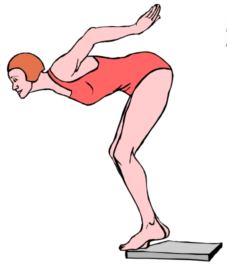


20) A skydiver (mass 68 kg) falls 350 m through the air. Determine the ***decrease*** in **gravitational potential energy** of the skydiver.

21) When Boris holds a set of weights 1.9 m above the floor, the weights have a gravitational potential energy of 3 800 J. Calculate the **mass** of these weights.

22) When Alana climbs 8.5 m up a rope, her gravitational potential energy increases by 4 675 J. Determine Alana's **mass**.

23) During a 'strong man' competition, Hamish holds a 150 kg boulder above the ground. If the boulder has a gravitational potential energy of 1 650 J, calculate its **height** above the ground.



24) When Shona, mass 66 kg, dives from a high board into a swimming pool, her gravitational potential energy decreases by 16 500 J. Determine the **height** Shona falls through.

Kinetic Energy

Kinetic energy is the energy an object possesses due to the fact it is moving.

A moving object's **kinetic energy** depends on its **mass** and **speed**:

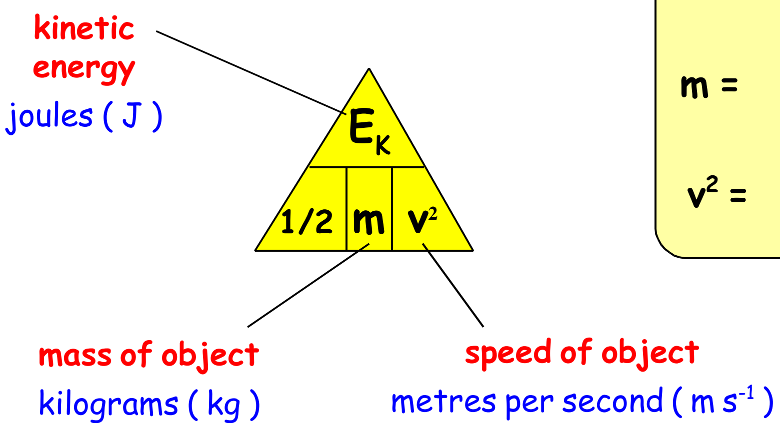
● The greater the **mass** of a moving object, the ____________ is the value of its **kinetic energy**.

● The greater the **speed** of a moving object, the ____________ is the value of its **kinetic energy**.

Kinetic energy, **mass** and **speed** are related by the formula:

$$\boxed{\text{kinetic energy} = 1/2 \times \text{mass} \times \text{speed}^2}$$

$$\boxed{E_K = 1/2\, m\, v^2}$$



E_k =

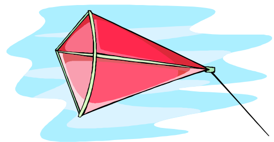
m =

v^2 =

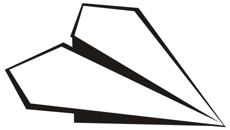
$E_K = 1/2\, mv^2$ Calculations

25) Quasim, who has a mass of 60 kg, is jogging at a speed of 5 m s^{-1}. Calculate Quasim's **kinetic energy**.

27) Kevin's kite has a mass of 0.02 kg. It is travelling through the air with a speed of 3 m s^{-1}. Calculate the **kinetic energy** of the kite.

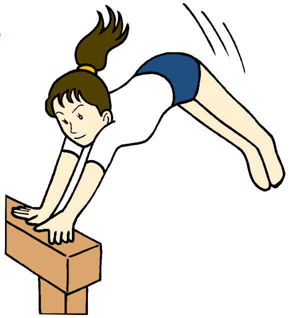


26) Calculate the **kinetic energy** of a 0.12 kg arrow which is travelling through the air with a speed of 50 m s^{-1}.



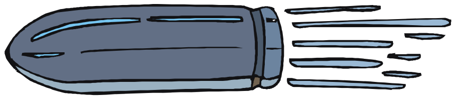
28) Ryan throws a paper aeroplane of mass 0.001 kg. The plane leaves his hand with a speed of 5 m s^{-1}. Calculate the **kinetic energy** of the plane at this instant.

29) Dominique has a mass of 55 kg. During her gymnastics display, she springs off the end of a beam with a speed of 4 m s^{-1}. Calculate the **kinetic energy** of Dominique at this instant.

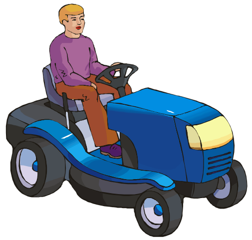


30) Ross fires a 0.002 kg stone from a catapult. If the stone leaves the catapult with a speed of 10 m s^{-1}, calculate the **kinetic energy** of the stone at this instant.

31) A bullet, travelling through the air with a speed of 1 200 m s^{-1}, has 11 520 J of kinetic energy. Calculate the **mass** of the bullet.



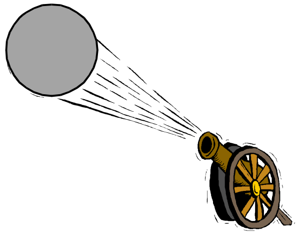
32) When driven at 2.5 m s^{-1}, Graeme's grass cutting machine and Graeme have a total kinetic energy of 3 750 J. Calculate the combined **mass** of Graeme and the machine.



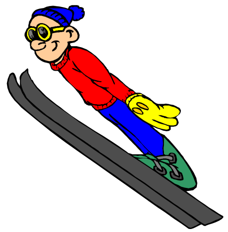
33) A golf ball leaves the face of a golf club at 40 m s^{-1} with 36.8 J of kinetic energy. Calculate the **mass** of the golf ball.

34) Duncan (mass 64 kg) has 72 J of kinetic energy while swimming the butterfly stroke. Calculate Duncan's **speed** at this instant.

35) A 1.25 kg cannonball is fired from a cannon with 6 250 J of kinetic energy. Calculate the **speed** at which the cannonball leaves the cannon.



36) Daniel and his skis have a combined mass of 60 kg. Daniel takes off from a ski jump with a kinetic energy of 18 750 J. Calculate his take off **speed**.



The Principle of Conservation of Energy

We cannot make or destroy energy - but we can transform (change) it from one type to another.

A **car crash** is a good example of one type of energy being converted (changed) into other types of energy.

A moving car has **kinetic energy**. If the car crashes into a post, the car stops moving - the **kinetic energy** of the car is changed into other types of energy.

All of the car's **kinetic energy** is changed mainly to:

- **heat** (due to **friction** when the bodywork is crushed)
- **sound** and **light** (sparks created when the bodywork is crushed).

37) (a) Calculate the **kinetic energy** of a 1 000 kg car when it has a speed of:

13.4 m s^{-1} (30 miles per hour)	31.3 m s^{-1} (70 miles per hour)

(b) At which of these speeds would the car do most damage if it crashed into a wall? _______________

(c) Explain why: ____

____

____

Calculations Involving The Conservation of Gravitational Potential and Kinetic Energy

Gravitational potential energy can be converted to **kinetic energy** (and vice versa) as objects fall through the air or are fired upwards from the ground.

Using the **Principle of Conservation of Energy**, we can perform calculations to find out the speed of a falling object just before it hits the ground and the maximum height reached by an object fired upwards from the ground.

Example 1

A brick falls from the top of a 20 m high chimney. Calculate the **speed** of the brick at the instant before it hits the ground. *Assume there is only **one** energy transformation (change).*

decrease in gravitational potential energy = increase in kinetic energy

$\therefore$ mgh = 1/2 mv^2

$\therefore$ gh = 1/2 v^2 cancelling mass (m) on both sides

$\therefore 9.8 \times 20 = 1/2\ v^2$

$\therefore 196 = 1/2\ v^2$

$\therefore v^2 = \dfrac{196}{1/2}$

$= 392$

$\therefore v = \sqrt{392} = \underline{19.8 \text{ m s}^{-1}}$

Example 2

A cannonball is fired vertically upwards from ground level with a speed of 30 m s^{-1}. Calculate the **maximum height** above the ground the cannonball will reach.
Assume there is only ***one*** *energy transformation (change).*

decrease in kinetic energy = increase in gravitational potential energy

$\therefore$ 1/2 $mv^2 = mgh$

$\therefore$ 1/2 $v^2 = gh$ cancelling mass (m) on both sides

$\therefore$ 1/2 $\times 30^2 = 9.8\ h$

$\therefore 450 = 9.8\ h$

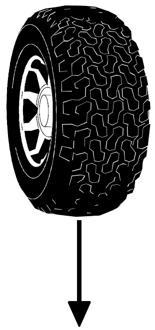
$$\therefore h = \frac{450}{9.8}$$

$= \underline{45.9 \text{ m}}$

In this type of calculation, the effect of 'air resistance' is not taken into account.

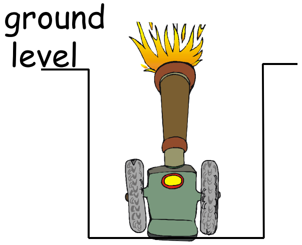
Note that the mass of the object has no affect on its landing speed or the maximum height it reaches above the ground.

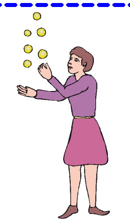
38) Clumsy Colin drops a 1 kg brick onto his foot from a height of 1.25 m.
Calculate the **speed** of the brick at the instant before it hits his foot. (Give your answer to 1 decimal place.)
Assume there is only ***one*** *energy transformation (change).*



39) A wheel drops off a helicopter which is hovering at a height of 45 m.
Calculate the **speed** of the wheel at the instant before it strikes the ground. (Give your answer to 1 decimal place.)
Assume there is only ***one*** *energy transformation (change).*

40) A 5 kg cannonball is fired straight up from ground level with a speed of 50 m s^{-1}.
Calculate the maximum **height** the cannonball reaches.(Give your answer to 1 decimal place.)
*Assume there is only **one** energy transformation (change).*





41) Jane the juggler throws a ball straight up in the air with a speed of 4 m s^{-1}.
Calculate the ball's maximum increase in **height** above Jane's hand. (Give your answer to 1 decimal place.)
*Assume there is only **one** energy transformation (change).*

42) (a) A rubber ball of mass 0.05 kg is dropped from a height of 1.5 m onto a concrete floor.
Calculate the **speed** of the ball at the instant before it hits the floor.
(Give your answer to 1 decimal place.)
*Assume there is only **one** energy transformation (change).*

(b) Due to some of the rubber ball's kinetic energy being changed into sound and heat energy on hitting the floor, the ball rebounds upwards with a speed of 5.0 m s^{-1}.
Calculate the **maximum height** the ball will rebound to.
(Give your answer to 1 decimal place.)
*Assume there is only **one** energy transformation (change).*

Notes

Notes