TOPIC: MECHANICS AND PROPERTIES OF MATTER

SUB-TOPIC: WORK, ENERGY AND POWER.
SPECIFIC OBJECTIVES:

- Define work, energy and power.
- State the units of work, energy and power.
- Define the joule.
- Solve simple numerical problems on work, energy and power.
- Identify primary sources of energy.
- State the law of conservation of energy and use it to explain various energy transformations.
- Define kinetic and potential energy.
- Define power.
- Solve numerical problems involving energy and power.
- Describe how a four stroke petrol engine works and explain the energy transformations involved in a four stroke engine.

INTRODUCTION

In an ordinary conversation the word "work" refers to almost any kind of physical or mental activity for example reading, writing, solving problems, digging, walking, lifting things up, pushing things about, dragging objects etc. In all these activities one feels tired as a result of the activity.

But in science and mathematics it has one meaning only. Work is done when a force produces motion.
Examples of situations in which work is done include;

- A locomotive pulling a train does work; so does a crane when it raises a load against the pull of the Earth.
- A workman who is employed to carry bricks up a ladder and on to a scaffold platform also performs work.
- A person lifting a book from the ground to the top of the cabinet does work.
- A person climbing up the stairs does work.

Examples of situations in which work is **not** done include;

- Pushing a rigid wall.
- Carrying a load on top of the head in one place.

WORK

Therefore, work is said to be done if the point of application of a force moves in the direction of the force.
Work is also done in moving against some opposing force such as gravity and any form of resistance to the motion of the force.
For example:

(i) When a crane is lifting a heavy load, work is done against the force of gravity. Or when a person lifts a load to a given height.

(ii) When a nail being driven into a wooden block by hammering, work is done against the resistance of the wood.

Definition
Work is the product of the force and the distance moved in the direction of the force.
i.e. **Work = force x distance**

Factors which determine the amount of work done
From the formula of work, we can see that the amount of work done depends on:
(i) The magnitude (size) of the force applied.
(ii) The distance moved.

The SI unit of work is the joule (J)
A joule is the work done when the point of application of a force of one newton moves through one metre in the direction of the force.
$\therefore$ 1J = 1Nm

Larger units are: - the kilojoule (kJ) and
- the megajoule (MJ)
1 kJ = 1 000J
1 MJ = 1 000 000J

Examples:

1. A force of 10N moves a body along a straight path and stops after 200J of work has been done. What distance was moved?
Solution:
$$\text{Distance} = \frac{\text{work}}{\text{force}} = \frac{200}{10} = 20 \text{ m}$$

2. A tangential force of 15N is applied to turn a wheel of radius of 70cm about the centre. How much work is done in 2 revolutions?
Solution:
In the 2 revolutions the force moves a distance equal to two circumferences of the circle described, i.e $2 \times 2\pi r = 4\pi \times 0.70$
$\therefore$ Work done = Force x distance = $15 \times 4\pi \times 0.70$ = $\underline{\underline{131.9\text{J}}}$

3. A body of mass 5kg is raised vertically a height of 8m. How much work is done?
Solution:
Work done = weight of body x height raised = $5 \times 10 \times 8$ = $\underline{\underline{400\text{J}}}$

4. Calculate work done by an engine which exerts a force of 9000N over a distance of 6 m.
Solution: Force, F = 9000 N, Distance, s = 6 m, Work done = ?
Work done = Force x Distance
= F x d
= 9000 x 6
$\therefore$ Work done = 54,000J Or 54 kJ

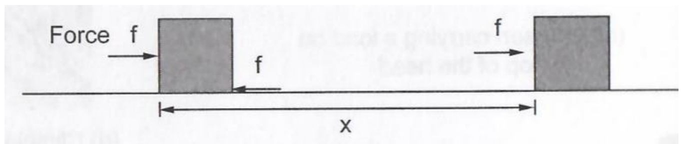
5. A man lifts a box of mass 3 kg vertical upwards through 2m. If the, gravitational field, g is 10 ms^{-2}, calculate the work done by the man in lifting the box.
Solution: Mass of box = 3 kg, gravitational field, g = 10ms^{-2} Force, F = mg, Distance, s = 2 m, Work done = ?

Work done = Force x Distance
= mg x s
= 3 x 10 x 2
∴ Work done = 60J

6. Find the work done by a man of mass 75000g when he climbs 45 steps each 10cm high. (ans =3375J)

WORK DONE BY FRICTIONAL FORCE

When a force is applied on a body resting on a surface, frictional force is developed between the surfaces in contact and tries to oppose the motion of the body. Hence work has to be done overcome friction.



A force f is applied to a body so that the body moves with a **uniform speed**, through a distance x in the direction of the force. **Since the body moves with uniform speed**, the frictional force is also f. Therefore;

Work done by the applied force $= f \times x$

Work done against friction $= f \times x$

In this case the useful work done is zero and the work done by the applied force is dissipated as heat and sound energy.

Now if the force F ($F > f$) is applied such that the body is displaced through a distance x in the direction of the applied force.

Now work done by the applied force $= F \times x$ → (total work done, work done by the effort)

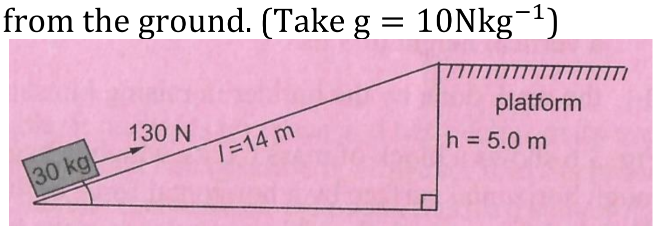
Work done against friction $= f \times x$ →(energy wasted, useless work done)

Useful work done $= Fx - fx$ → (work done actually on the load)

This work done by unbalanced force **accelerates** the body in the direction of the motion.

Example

A box of mass 30kg is pushed with a force of 130N up an inclined track of length of 14m onto a platform at a height of 5m from the ground. (Take $g = 10Nkg^{-1}$)



Calculate

(a) work done by the force of 130N

(b) work done, if the box was lifted vertically upwards.
Comment on the answer in part (a) and (b).

(c) frictional force between the box and the track.

Solution

(a) work done by force of 130N

$$W = F \times x$$
$$= 130 \times 14$$
$$= 1820J$$

(b) work done in lifting the box vertically upwards

$$W = F \times x$$
$$W = mg \times x$$
$$W = 30 \times 10 \times 5$$
$$W = 1500J$$

The two are different. Some work is used to overcome friction.

(c) Total work = work done by the force + work done against friction.

Work done against friction $= 1820 - 1500 = 320J$

Work done against friction = Friction force $\times$ distance

$320 = f \times 14$

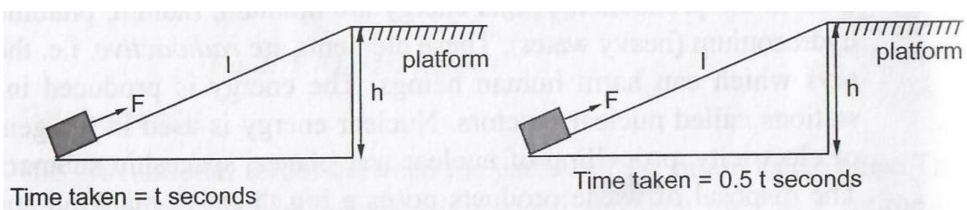
$f = \frac{3201}{14}$

$f = 22.9N$

Attempt exercise 3.1 on pages 60 – 61 in Longhorn book two.

POWER

Consider an object of mass m being pulled along an inclined plane of length l to a platform at height h by two students, one at a time. One students takes t seconds while the other takes o.5t seconds.



Both students do the same amount of work. However, the second student does the work faster than the first student. Therefore, power measures how quickly work is done.

Definition.

Power is the rate of doing work.

$$\text{Power} = \frac{\text{work done}}{\text{time}}$$

The SI unit of power is the watt (W)

1Watt = 1 joule per second

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

A watt is the rate of doing work at 1 joule per second.

In the sense of power being defined as rate of transfer of energy, we can also mathematically express power as:

$$\text{Power} = \frac{\text{change in energy}}{\text{time}}$$

Larger units of power are:

- The Kilowatt (kW) and
- Megawatt (MW)

1 kW = 1000W (10^3 W)
1MW = 1 000 000W (10^6 W)
1 MW = 1 000 kW

NB:

1. Engine power is sometimes measured in horse power (hp).
   hp = 746 W ≈ ¾ kW
2. From $\text{Power} = \frac{\text{work done}}{\text{time}}$

   But Work done = Force x Distance

   $$\text{Power} = \frac{\text{Force x Distance}}{\text{time}}$$

   $$\text{Power} = \text{Force} \times \frac{\text{Distance}}{\text{time}}$$

   But speed (velocity) $= \frac{\text{Distance}}{\text{time}}$

   $\therefore$ **Power = Force x Velocity**

Examples

1. Calculate the power of a water pump which can fill a water tank 10 m height with 3000 kg of water in 20 s. (Assume g = 10 ms^{-2}).

   Solution: m = 3000 kg, h = 10 m, g = 10 m^{-2}, P = ?
   We can solve this problem by using any one of the methods below.
   Method I
   Step I: First calculate the work done.
   Work done = Force x Distance
   = mg x s
   = 3000 x 10 x 10
   $\therefore$ **Work done = 300,000 J or 3 x 10^5J**

   Step II: Now calculate the power from the formula:

   $$\text{Power} = \frac{\text{work done}}{\text{time}}$$

   $$\text{Power} = \frac{300000}{20}$$

   $\therefore$ **Power = 15,000 W**

   Method II Substitute the values in the data collected directly as shown below.

   $$\text{Power} = \frac{\text{work done}}{\text{time}}$$

$$\text{Power} = \frac{\text{force} \times \text{distance}}{\text{time}}$$

$$\text{Power} = \frac{\text{mg} \times \text{d}}{\text{t}}$$

$$\text{Power} = \frac{3000 \times 10 \times 10}{20}$$

$\therefore$ **Power = 15,000 W**

2. A man lifts a box of mass 10 kg through a vertical height of 2 m in 4 seconds. Calculate the power he developed.
   Solution: m = 10 kg, h = 2 m, t = 4 s, g = 10 m^{-2}, P = ?
   Using the formula

$$\text{Power} = \frac{\text{work done}}{\text{time}}$$

$$\text{Power} = \frac{\text{force} \times \text{distance}}{\text{time}}$$

$$\text{Power} = \frac{\text{mg} \times \text{d}}{\text{t}}$$

$$\text{Power} = \frac{10 \times 10 \times 2}{4} = 50 \text{ W}$$

3. A pump delivers water at a rate of 1 litre per hour to a tank 20m above a well. Find the power of the pump.
   Solution:
   1 litre of water has a mass of 1 kg, and 1 hour = 3600 seconds
   Work done every hour = weight raised per hour x height

$$\text{Power} = \frac{\text{Workdone}}{\text{Time}} = \frac{1 \text{ x } 10 \text{ x } 20}{3600} = 0.556 \text{ W}$$

4. A man of mass 75kg walks up 12 steps each 20cm high in 5s. Find the power he develops.
   Solution:
   Work done = weight of man x total height risen = 750 x 12 x 0.20 = 180 J
   $\therefore \text{Power} = \frac{180}{5} = \underline{\underline{36\text{W}}}$

An experiment to measures one's own power output.

Working in groups of twos, one times the other, in turns, as one runs up a flight of stairs as fast as he or she can.

The time t taken is recorded.

The weight of the person is measured using a weighing machine.

The power is determined as follows:

The height x, of one step of the staircase is measured. The number of steps is counted and noted as n.

Height moved up h = number of steps n $\times$ height of one step x

$$h = n \times x$$

$$\text{Work done} = \text{Force} \times \text{Distance}$$

$$= F \times h \text{ (F is the weight of the person)}$$

$$= W \times h$$

The time taken to move a height h = t

$$P = \frac{\text{work done against gravity}}{\text{time taken}}$$
$$P = \frac{w \times h}{t}$$
$$\text{But } h = n \times x$$
$$P = \frac{w \times n \times x}{t}$$
$$P = \frac{wnx}{t}$$
Note: Every quantity must be in its SI unit.

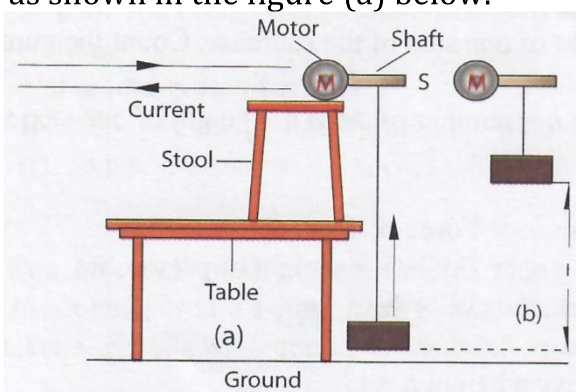
Examples

1. A student of mass 45kg runs up a flight of 40 steps in a stair case each 15cm in 12s. Find the power output of the student. (Ans = 225W)
   Leave 15 lines for the working.

2. A boy of mass 60 kg runs up a flight of 60 steps in 10 seconds. If the height of one step is 20 cm, calculate the power he developed. (Ans = 72W)

Power of a motor

The shaft rotates when a current flows through a motor, M. A mass attached to the shaft with a thread will be lifted upwards as shown in the figure (a) below.



If the mass is lifted through a distance, h, in a time t, as shown in figure (b) above, then,

$$\text{Power of the motor} = \frac{\text{Workdone}}{\text{Time}} = \frac{\text{Mass of body (m)} \times g \times \text{height(h)}}{t}$$

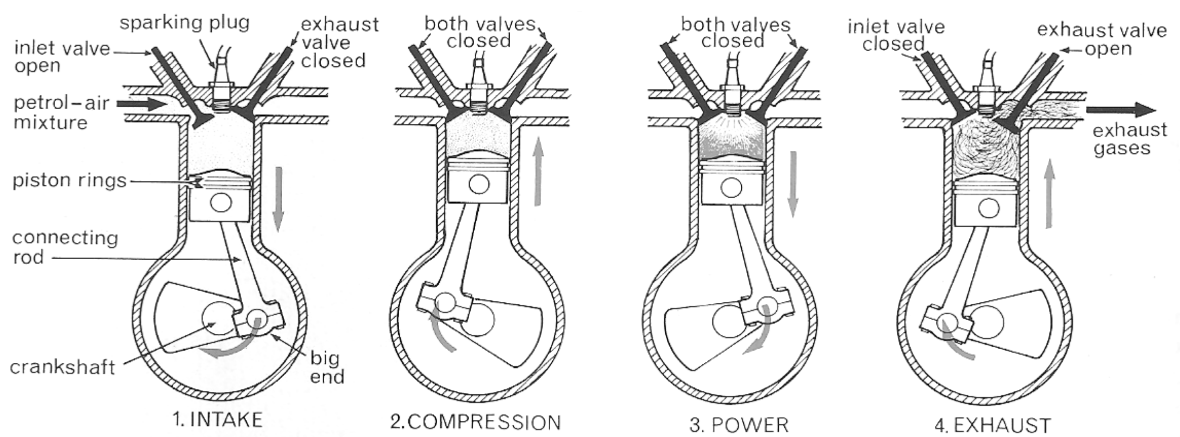
Knowing the mass, m, of the body, the time taken, t, to lift the mass through a height h, the approximated power of the motor can be calculated.

Attempt Exercise 3.3 on page 71 in Longhorn book 2.

Four stroke engine

A four stroke petrol engine is commonly used in motor vehicles. The substance used a mixture of petrol and air.
The cylinder of this engine is provided with an **inlet valve** and an **outlet valve**.
The valves are opened at the right moment by means of **cams** and **camshafts** driven directly by the **crankshaft**.

The petrol vapour and air are mixed outside the cylinder in a device known as **carburetor** and the mixture is **fed into** the cylinder by means of the **inlet valve**.
There is a **spark plug** inserted into the cylinder which **produces an electric spark** at the right moment **to ignite** the mixture to produce combustion.
The figure above shows the operation of a four-stroke cycle engine.



The four strokes are called;

(i) Intake, charging or suction stroke.
(ii) Compression stroke
(iii) Power stroke or working stroke.
(iv) Exhaust stroke.

The necessary action during these strokes is explained below: -

(i) **Intake, charging or suction stroke**
During intake (the first stroke of the cycle), the **piston moves down** (i.e. away from the cylinder head), the **intake valve** opens. A quantity of a fuel and air mixture is drawn into the combustion chamber.

(ii) **Compression stroke**
During the compression stroke, both valves close, **piston moves up** and the fuel-air mixture is compressed.

(iii) **Power stroke or working stroke**
In the power stroke, **both valves close** and the volume of the combustion chamber is at a minimum, the **spark plug produces electric spark**, the fuel mixture ignites and burns. The expanding gaseous products exert pressure on the **piston** and **force it down**.

(iv) **Exhaust stroke**
During the final stroke (exhaust stroke), the **exhaust valve opens** and the **piston moves up**, driving the exhaust gases out of the combustion chamber and leaving the cylinder ready to repeat the cycle.

Energy transformation in a four-stroke petrol engine
The energy transformation in a four-stroke petrol engine can be summarised as shown below.

$$\boxed{\text{Chemical energy (in petrol)}} \rightarrow \boxed{\text{Heat energy}} \rightarrow \boxed{\text{Kinetic energy}}$$

Some kinetic energy from the engine is converted to electrical energy in the alternator which is then converted to light energy in the car head lights.

Four Stroke Diesel Engine
A four-stroke diesel engine also performs the four stages of a cycle except:
During the **inlet stroke ONLY AIR enters the cylinder**.
During the **compression stroke only air is compressed**.
Instead of a **spark plug** a **FUEL INJECTOR** is used. At the end of the compression stroke diesel is injected into the cylinder and it burns automatically because the temperature of the compressed air is very high then.

Differences between petrol engine and diesel engine.

PETROL ENGINE	DIESEL ENGINE
-fuel is ignited on /in the engine by electric spark plug.	- fuel is ignited by compression
-Has a carburetor for mixing air and petrol	Lack a carburetor
Has spark plugs	Lacks spark plugs
-operates at lower compression ratio of 8:1and therefore less powerful	Operates at higher compression and therefore ratio of 16:1 and therefore more powerful
Power occurs when petrol and air mixture is ignited	Only diesel is ignited
Has no injector pump	Has injectors which atomize diesel
Petrol engine is lighter	Its heavier
Produces less noise	Produces a lot of noise
Maintenance is more frequent and usually have problems in starting.	Maintenance is less frequent and causes no problem in starting.

Factors limiting the efficiency heat engines
The efficiency of a modern engine is limited by a number of factors. These include;
(i) Energy losses y cooling and
(ii) Energy losses Friction.

Improving the efficiency of heat engines.
The efficiency of heat engines is increased by equipping all engines with:
(i) Cooling system and
(ii) Lubricating system.

Cooling System
Cooling in engines is achieved by circulating water. A water pump circulates engine coolant, a mixture of water and antifreeze, through the non-moving parts of the engine to absorb heat. The coolant routes through tubes in the radiator, where heat passes through the tubes into the metal fins. A fan blows air through the fins to increase the rate of cooling. In addition to this, the radiator is painted black in order to increase the rate of cooling since 'black colour' is a good emitter of heat energy.

Lubricating System

In the lubricating system, a pump circulates motor oil, the main lubricant in an auto mobile engine is called **galleries.** It is circulated to all the moving parts of the engine. The lubricating system reduces the friction produced by the engine's moving parts, which rub against each other thousands of times per minute.

NB: Before the oil circulates, it passes through an oil filter which strains particles from the oil.

ENERGY

All living things need energy. The machines that help us to do work also need energy. Anything that possesses energy is capable of doing work.

Definition

Energy is the ability to do work.

The SI unit of energy is joules (J).

TYPES OF ENERGY

Energy is not visible, it occupies no space and it has neither mass nor any other physical property that can describe it. However, it exists in many forms.

Examples of forms of energy include; mechanical energy, electrical energy, chemical energy, heat (thermal) energy, light energy, nuclear energy, sound energy etc.

1. **Mechanical Energy**

   This is energy possessed by a body due to movement and location. It is made up of two parts;

   (i) **Potential Energy:**

   This is energy possessed by a body due to its position in the gravitational field.

   It is equal to the work done in raising a body to that position above the reference level.

   The body is capable of doing work equal to the potential energy if it returns to the reference level.

   Therefore, a body of mass m, at a height h, above the reference level has potential energy equal to mgh.

$$\therefore \mathrm{P.E} = \mathrm{mgh}$$

   (ii) **Kinetic energy**

   This is the energy possessed by a body by due its motion.

   All moving bodies have kinetic energy. A moving car, a running horse, a soccer ball in motion, the earth moving around the sun are few examples of bodies having kinetic energy.

   Kinetic energy of a body at rest is zero.

   A body of mass m, is moving at a speed v, has kinetic energy equal to $\frac{1}{2}\mathrm{mv}^2$.

$$\therefore \mathrm{K.E} = \frac{1}{2}\mathrm{mv}^2$$

   Note: If a body is moved from rest to acquire a speed v, then the gain kinetic energy is equal to the work done by the external force that makes it acquire this velocity. This is known as the **work-energy theorem** which states that the work done by the sum of forces acting on a body is equal to the gain in kinetic energy.

If a bicycle is set in motion, the work done by the cyclist results in the increased kinetic energy. On the other hand, if the cyclist applies the brakes and the bicycle is brought to rest, the kinetic energy of the bicycle is equal to the work done against friction between the tyres and the road.

2. **Chemical energy**

This is a form of stored energy that is released through chemical reactions. Food is our source of chemical energy. Fossils fuels like coal, petrol, oil and natural gas are sources of energy. The stored energy in them is released by burning process. For example, when petrol is burnt in the engine, it releases energy that drives a car. All batteries are stores of chemical energy. the chemical reactions between the electrodes and the electrolyte releases the stored energy.

3. **Thermal (heat) energy**

   This is energy due to difference in temperature. Energy flows from the end at high temperature to the end at low temperature.

4. **Sound energy.**

   This is energy due to vibrating objects.

5. **Light energy.**

   This is energy which enables us to see.

6. **Electrical energy.**

   This is energy due to flow of charges in an electrical circuit.

7. **Nuclear energy**

   This is energy released when a heavy nucleus of an atom is split into lighter nuclei. The nuclear energy may also be released when smaller nuclei combine to form a larger.

Examples:

1. An object of mass 3kg is moving at a speed of $5ms^{-1}$. If it is to be stopped in 5s using a uniform force, find the power to do so.

   Solution:

   Work done to stop the object = Original kinetic energy

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

$$= \frac{1}{2} \times 3 \times 5^2 = 37.5 \text{ J}$$

$$\therefore \text{ Power } = \frac{37.5}{5} = 7.5 \text{ W}$$

2. In the previous example suppose the stopping force acted over a distance of 4m, what was the force?

   Solution:

$$\text{Force} = \frac{\text{Workdone}}{\text{Distance}} = \frac{37.5}{4} = 9.375 \text{ N}$$

3. A box of mass 5 kg is raised to a height of 2 metres above the ground. Calculate the potential energy stored in the stone (take $g = 10\ ms^{-2}$)
Solution: Mass of box = 5 kg, gravitational field, $g = 10 m/s^2$ Height, h = 2 m,
Applying P.E = mgh
= 5 x 10 x 2
$\therefore$ **P.E = 100J or 0.1 kJ**

4. A man has raised a load of 25 kg on a platform 160 cm vertically above the ground. If the value of gravity is $10 m/s^2$, calculate the potential energy gained by the box when it is on the platform.
Solution: Mass of stone = 25 kg, gravitational field, $g = 10 ms^{-2}$
Height, h = 160 cm = $\frac{160}{100}$ = 1.6 m, P.E = ?
P.E = mgh
= 25 x 10 x 1.6
$\therefore$ **P.E = 400 J or 0.4 kJ**

5. Calculate the k.e of a bullet of mass 0.05 kg moving with velocity of $500\ ms^{-1}$.
Solution: m = 0.05 kg, v = $500\ ms^{-1}$, k.e = ?
Kinetic Energy = $\frac{1}{2}m v^2 = \frac{1}{2} \times 0.05 \times 500^2$ **= 6,250 J or 6.25 kJ**

6. A 10 g bullet traveling at $400\ ms^{-1}$ penetrates 20 cm into a wooden block. Calculate the average force exerted by the bullet.
Solution: m = 10 g = $\frac{10}{1000}$ kg, v = $400\ ms^{-1}$, distance = 20 cm = $\frac{20}{100}$ m, k.e = ?
Note: This question seem to be difficult and quite different.
Hint: The work done in penetrating the block is related to the average force by the formula:
Work Done = $F \times d$, so find the work done first and then use the above formula to find F.
Kinetic Energy = $\frac{1}{2}mv^2$

$$= \frac{1}{2} \times 10 \times 400^2 = \frac{1 \times 10 \times 400 \times 400}{2 \times 1000} = 5 \times 40 \times 4 = \mathbf{800\ J}$$

Complete the answer.

Principle of conservation of energy
This principle states that e**nergy is neither be created nor destroyed but can change from one form to another**.

In other words, **in a closed system the total energy is always constant**

Energy transformations.
Interchange of Energy in the Gravitational Field
A body moving under the influence of gravity possesses constant mechanical energy made up of two parts i.e.

Mechanical energy = kinetic energy + potential energy = constant

Thus a particle projected upwards keeps on losing kinetic energy and gaining potential energy such that

Kinetic energy lost = potential energy gained.

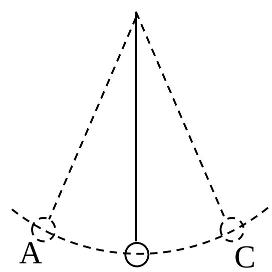
At the highest point, the particle has no kinetic energy but has maximum potential energy. On falling it keeps on gaining kinetic energy but losing potential energy

The Simple pendulum

A mass freely suspended on a string forms a simple pendulum.
When the mass is pulled to one side and then released, it swings between extreme points A and C.
It has maximum potential energy at A and C but zero kinetic energy there.
At point B, the kinetic energy is maximum while the potential energy is minimum there.

Since mechanical energy is conserved, it implies that a simple pendulum would swing forever with a constant amplitude.
However, in practice, the amplitude keeps on decreasing until it is completely zero i.e. it stops.
This is because of

(i) Air resistance
(ii) Friction at the point of support.



Example:

1. A particle of mass 2 kg is at rest, freely suspended on a string. It is then struck horizontally and starts off with a velocity of $10ms^{-1}$.
   (a) Find how high above the initial position is rises.
   (b) What kinetic energy does it have on returning to the initial position?

   Solution:

   (a) Let h = height risen
   Potential energy gained = kinetic energy lost

   $$\therefore \ mgh = \frac{1}{2}mv^2$$

   $$\therefore \ h = \frac{v^2}{2g} = \frac{10^2}{2\times 10} = 5 \text{ m}$$

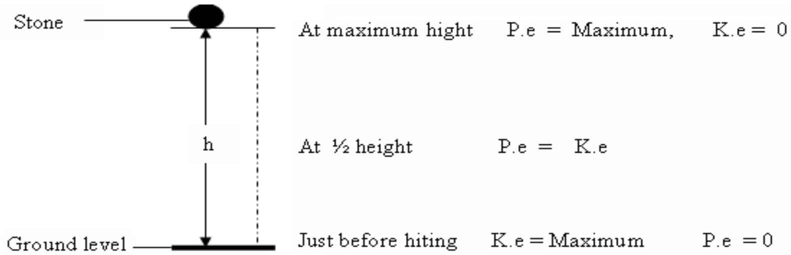
   (b) When the particle returns to the point of projection it will have the same kinetic energy as it had when it was leaving equal to $\frac{1}{2}mv^2$

   $$= \frac{1}{2} \times 2 \times 10^2 = 100\text{J}$$

Falling object e.g stone

Consider a piece of stone raised to a certain height above the ground level and let to fall.
At the maximum height, it possesses potential energy and no kinetic energy.
As the stone falls, its velocity increases. Since kinetic energy is directly proportional to the square of the velocity, then the k.e of the stone increases at the expense of the p.e (i.e at any particular moment, the stone possesses both p.e and k.e).
Ignoring the energy losses due to the air resistance, then the loss in p.e is equal to the gain in k.e in accordance with the Law of Conservation of Energy.

Consider the diagram below



Note that: Potential energy decreases from maximum to zero and the kinetic energy increases to maximum. This is because as the h value decreases to zero, the velocity increases to maximum.

By means of suitable mechanisms and apparatus, energy can be transformed from one form to another. This is shown in the table below.

Activity	**Energy Transformation**
1. A boy running up a stair case	Chemical energy in the muscles is converted to K.E and then to P.E. (C.E $\rightarrow$ K.E $\rightarrow$ P.E)
2. Running water at a hydroelectric power station (water turning turbine which finally drives a generator)	P.E is converted to K.E (for both running water and rotation of turbines) and then electrical energy. (P.E $\rightarrow$ K.E $\rightarrow$ E.E)
3. A stone dropped from rest at a certain height until it hits the ground.	P.E is converted K.E then to heat and sound energy. (P.E $\rightarrow$ K.E $\rightarrow$ H.E + S.E)
4. A moving car	Chemical energy due to the burning of fuel in the engine is converted to heat energy which is converted by pistons to kinetic energy. (C.E $\rightarrow$ H.E $\rightarrow$ K.E)
5. A coal fired engine drives a dynamo which lights a bulb.	Chemical energy is converted to heat energy, kinetic energy, electrical energy and lastly to light energy. (C.E $\rightarrow$ H.E $\rightarrow$ K.E $\rightarrow$ E.E $\rightarrow$ L.E)
6. Lighting a bulb using a battery.	Chemical energy is converted to electrical energy, light energy and radiant heat energy. (C.E $\rightarrow$ E.E $\rightarrow$ L.E + H.E)
7. Hammering a nail	Chemical energy is converted to potential energy, kinetic energy + heat + sound. (C.E $\rightarrow$ P.E $\rightarrow$ K.E + H.E + S.E)
8. Microphone	Sound energy is converted to electrical energy.
9. Loudspeaker	Electrical energy is converted to sound energy.
10. Filament Lamp	Electrical energy is converted to light and heat energy.
11. Steam engine	Heat energy is converted to mechanical energy.
12. Generator	Mechanical energy is converted to electrical energy.
13. Solar cell	Heat energy is converted to electrical energy
14. Electrical heater	Electrical energy is converted to heat energy in electrical heaters used in geysers at home, hot plate, electrical kettle etc.
15. Nuclear power station	Fission energy or fusion energy called the nuclear energy which comes out as heat energy is converted to electrical energy.

16. A ball projected vertically upwards	The kinetic energy of the ball is converted to gravitational potential energy at the top most point, when the ball momentarily comes to rest.

Sources of Energy

Sources of energy are the raw materials for production of energy.
Primary sources of energy are those in which energy is mainly obtained. These include solar, nuclear, oil, wind, water, biological and geothermal energy.
These may be classified into two main categories namely:

(i) Renewable energy sources
(ii) Non-renewable energy sources.

Renewable energy sources

These are energy sources which cannot easily be exhausted.
They can be replaced fairly fast.

Examples of renewable sources of energy include:

Solar energy

This is energy from the sun. The energy is used by plants and animals. Solar energy comprises of light and heat energy. Solar energy can be trapped in solar cells and can be stored in accumulators as electrical energy. Heat may be trapped in solar heaters which are used to heat the water.

Wind energy

Wind contains energy which is trapped to provide driving energy to a number of machines. Such machines include wind mills which drive water pumps or dynamos.

Geothermal

Some regions of the earth's core have very high temperatures. Water trapped between rocks may get near these regions. The vapour from the heated water which is at very high pressure may find its way to the earth's surface. This vapour can be used to generate electricity called geothermal electricity.

Biomass and biogas

This is energy obtained from degradation of organic materials such as animal waste, agricultural waste and industrial effluents.
Biogas may be trapped using a biogas plant. A biogas plant is made up of a fermentation chamber, a floating gas chamber, an inlet and outlet pipe.
Animal wastes are fed into fermentation chambers. The gas formed by fermentation process is called methane. The by-product of fermentation (sludge) is collected from the bottom of the fermentation chamber by an outlet pipe.

Tidal energy

The gravitational forces between the earth and the moon cause tides. The high-level of water at high-tide is trapped and then used as a source of potential energy.

Non-renewable energy sources.

These are energy sources which once used cannot be effectively replaced.

Examples of non-renewable sources of energy include:
Fossil fuels (oil, coal and natural gas.)
This is the energy trapped by plants from the sun through the process of photosynthesis millions of years ago. Through the decay process many millions of years ago, plants have been converted to **coal**, **oil** and **natural gas**. Fossil fuels are the main source of energy for motor vehicles and industrial manufacturing plants.

Nuclear energy.
Nuclear energy is increasingly replacing the fossil fuel. This energy is available in limitless quantity. However, its harnessing, management and risk of damage to life are very high.
Some of the most common elements used in the production of this energy are uranium, radium, plutonium and hydrosonium (heavy water). These elements are **radioactive**. They emit rays which can harm human beings. The energy is produced in power stations called nuclear reactors.
Nuclear energy is used generation of electricity, propelling of nuclear war planes, spaceship submarine etc.
The disposal of waste products possesses a big threat to mankind and other forms of life.

Attempt Revision Exercise 3 on pages 74 -76 in Longhorn book two.
More revision questions on Work, power and energy

Section A

1. A crane raises a mass of 500 kg vertically upwards at a speed of 10 ms^{-1}. Find the power developed
A. 5.0×10^0 B. 5.0×10^1 C. 5.0×10^2 D. 5.0×10^4

2. A girl whose mass is 50 kg runs up a staircase 25 m high in 4 s. Find the power she develops.
A. $\frac{50 \times 4}{25}W$ B. $\frac{50 \times 10}{25 \times 4}W$ C. $\frac{50 \times 25}{4}W$ D. $\frac{50 \times 10 \times 25}{4}W$

3. A train traveling at a constant speed of 20 m/s overcomes a resistive force of 8 kN. The power of the train is
A. (8 x 20) W B. (8x10x20) W C. (8 x 100 x 20) W D. (8 x 1000 x 20) W

4. A pump is rated at 400W. How many kilograms of water can it raise in one hour through a height of 72m?
A. 0.8kg B. 5.6kg C. 33.3kg D. 2000kg

5. A boy carrying a load of 6 kg runs upstairs. If the work that the boy does is 300 J, find the height of the stairs.
A. 3m B. 5m C. 6m D. 10m

6. Tony can pull a box 2m in 5 sec. Ever (Tony's sister) can pull the same box in 10 sec. Assuming both apply the same force, what is the ratio of Tony's power to the sister's power = ?
A. 1 B. 2 C. ½ D. 4

7. An engine exerts a force of 2000N at a speed of 15ms^{-1}. Find the power developed by the engine in kW.
A. 30 000 B. 3 000 C. 300 D. 30

8. A constant force of 5N acts on a body and moves it through a distance of 20m in 10 seconds. Calculate its power.
A. 2.5W B. 10W C. 40W D. 100W

9. A mouse of mass 0.03 kg climbs through a distance of 2 m up a wall in 4 s. The power expended in watts is
A. 0.03 x 2 x 4 x 10 B. $\frac{0.03 \times 4 \times 2}{10}$ C. $\frac{0.03 \times 4 \times 10}{2}$ D. $\frac{0.03 \times 10 \times 2}{4}$

10. A bullet of mass 0.02kg is fired with a speed of 40m s^{-1}. Calculate its kinetic energy.
A. 0.4 J. B. 0.8 J. C. 16 J. D. 32 J.

11. Which of the following statements is true about an electric motor? It changes
A. Kinetic energy to electric energy B. Electrical energy to light energy
C. Electrical energy to kinetic energy D. Chemical energy to electrical energy

12. A body pulls a block of wood with a force of 30N through a distance of 300m in 2 minutes. Find the power he develops, if he pulls the block at a constant speed.
A. $\frac{30 \times 300}{2}$ B. $\frac{30 \times 300}{2 \times 60}$ C. $\frac{30 \times 2 \times 300}{300}$ D. $\frac{300}{2 \times 60 \times 30}$

13. A ball of 1kg bounces off the ground to a height of 2m after falling from a height of 5m, find the energy lost.
A. 5 J B. 20 J C. 30 J D. 50 J

14. A man weighing 800N climbs a vertical distance of 15m in 30s. What is the average power out put?
A. 80/3 W **B**. 800/15 W **C**. 400 W **D**. 5 kW

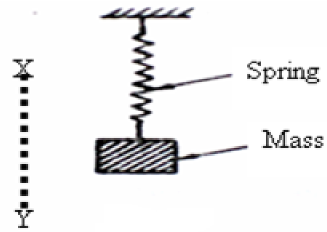
15. In which action(s) below is there a work done?
I. Pushing a wall without moving it.
II. Taking a book from a table to a higher shelf.
III. Walking on a bridge for 50 m
A. I only B. II only C. III only D. II and III only

16. A bullet of mass 5g is fired at a speed of 400ms^{-1}. How much energy does it have?
A. ½ x 5 x 10^2 x 400J B. ½ x 5 x 10^3 x 400J
C. ½ x 5 x 10^{-3} x 400 x 400J D. ½ x 5 x 10^2 x 400 x 400J

17. Which of the following forms mechanical energy?
A. Electrical energy and kinetic energy B. Potential energy and nuclear energy
C. Nuclear energy and kinetic energy D. Potential energy and kinetic energy

18. An object, of mass 2kg, dropped from the top of a building hits the ground with kinetic energy of 900J. The height of the building is
A. 30m B. 45m C.90m D. 180m

19. A mass attached to the end of a string moves up and down to maximum and minimum points X and Y as shown in figure 7.1 below. When the mass is at X the



A. kinetic energy is maximum, potential energy is minimum
B. kinetic energy is zero, potential is maximum
C. kinetic energy is equal to potential energy
D. kinetic energy and potential energy are both zero

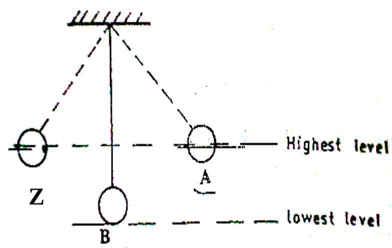
20. An electric motor of power 500 watts lifts an object of 100 kg. How high can the object be raised in 20 sec?

A. 40m **B.** 30m **C.** 20m **D.** 10m

21. A motor can pull a 400 kg box up to a height of 10m in 4 sec. What is the power of the motor in kW?

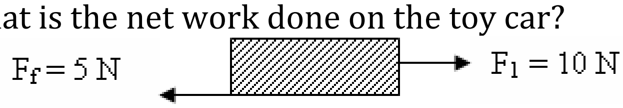
A. 10 **B.** 20 **C.** 30 **D.** 40

22. The diagram in the figure below shows an oscillation pendulum lob. Which of the following statements is true about its motion?



A. the K.E at B is equal to the K.E at A
B. the K.E at B is less than the P.E at A
C. the K.E at B is equal to the P.E at A.
D. the K.E at B is greater than the P.E at Z.

23. A toy car is pulled with a force of 10 N for 5m. If the friction force between the block and the surface is 5N, what is the net work done on the toy car?



A. 50 J B. 100 J C. 200 J D. 25 J

24. The energy changes that take place when a stone falls freely from rest to the ground can be orderly arranged as:

A. Kinetic energy → Potential energy → Sound energy → Heat.
B. Sound energy → Potential energy → Kinetic energy → Heat.
C. Potential energy → Sound energy → Kinetic energy → Heat.
D. Potential energy → Kinetic energy → Heat energy → Sound.

25. Ali and Veli move identical boxes equal distances in a horizontal direction. Since Ali is a weak child, the time needed for him to carry his box is two times longer than for Veli. Which of the following is true for Ali and Veli.

A. Ali does less work than Veli
B. Veli does less work than Ali.
C. Each does the same work.
D. Neither Ali nor Veli do any work

SECTION B

26. (a) Define the following terms.
  (i) Work.
  (ii) Power.
(b) State and define the SI units of the terms you have defined above.
(c) A crane lifts a load of 3500 N through a vertical height of 5 m in 5 second. Calculate:
  (i) the work done.
  (ii) the power developed by the crane.

27. (a) Define the term energy and state the SI unit for measuring it.
(b) Distinguish between potential energy and kinetic energy.
(c) A block of mass 2 kg falls freely from rest through a distance of 3m. Find the kinetic energy of the block.

28. (a) Define a joule.
(b) Describe briefly how you can measure your power.
(c) A boy of mass 45 kg runs up a flight of 60 steps in 5 seconds. If each step is 12 cm. Calculate:
  (i) the work done against gravity by the boy.
  (ii) the power developed by the boy.

29. (a) (i) State the types of heat engines you know.
  (ii) Describe the mechanism of operation of a four stroke petrol engine.
(b) (i) What are the factors that affect the efficiency of an engine?
  (ii) State how the factors you have stated in (c) above are minimized in a heat engine.

Test Yourself

1. The work done to move a body through a distance of 6 m is 30 J. Find the force that acts on the body.
2. A bullet of mass 12g strikes a solid surface at a speed of 200 ms^{-1}. If the bullet penetrates to a depth of 3cm, calculate the average net force acting on the bullet while it is being brought to rest.
3. A machine lifts 4 boxes per minute through height 8 m. If each box weighs 100 N, find the power that is expended.
4. A pump rated at 500 W is used to raise water to a height of 60 m. What mass of water can it deliver in one hour?
5. A ball is dropped from rest at a height of 20 m above the ground. If the ball bounces on hitting the ground and lost 20% of its original energy, calculate the maximum height it reaches again.

END.