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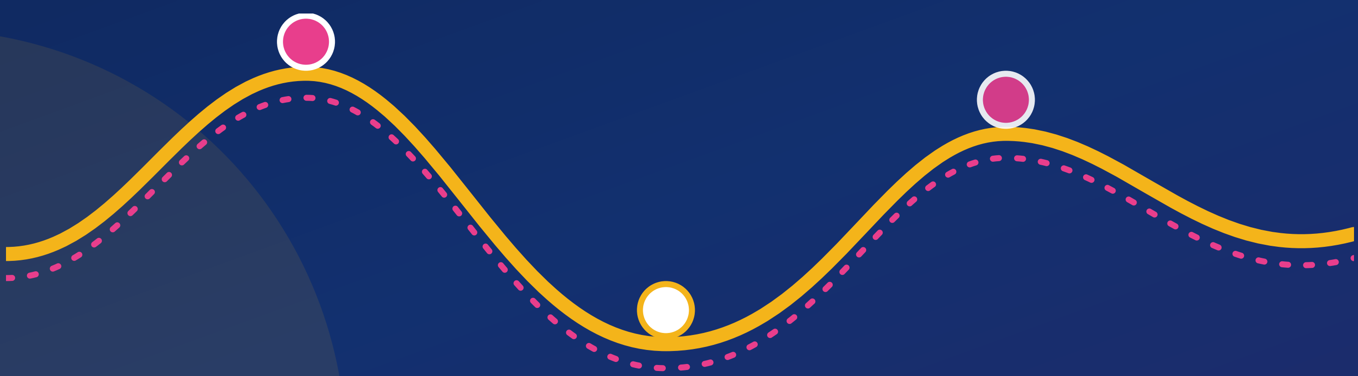
CLASS 9 · PHYSICS · CHAPTER 5

Work & Energy

Exercise — Completely Solved

- Every MCQ ticked, highlighted & explained
- All answers worked out step by step
- Diagrams, tables & block diagrams included



9 Multiple Choice	10 Short Answer	9 Constructed Response
5 Comprehensive	13 Numericals	

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Contents

Exercise of Chapter 5 · Work and Energy

Quick Formula Sheet

Everything you need for this exercise

Work

$W = F\,d\cos\theta$

θ = angle between force and displacement

Special cases

$\theta = 0^\circ \Rightarrow W = F\,d$

At 0° work is maximum; at 90° $W = 0$

Kinetic energy

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

Energy due to motion

Potential energy

$\mathrm{PE} = m\,g\,h$

Energy due to position

Conservation

$\mathrm{PE} + \mathrm{KE} = \text{constant}$

Energy only changes its form

Power

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

1 watt = 1 J s^{-1}

Efficiency

$$\frac{\text{output}}{\text{input}} \times 100\ \%$$

Useful output ÷ total input

Equations of motion

$v = u + a\,t$

$v^2 = u^2 + 2a\,s$

Units: 1 J = 1 N m = 1 kg m^2 s^{-2}. 1 W = 1 J s^{-1}.
Note: take $g = 10$ m s^{-2} in all calculations.

A Multiple Choice Questions

Tick (✓) the correct answer.

5.1 **Work done is maximum when the angle between the force F and the displacement d is:**

(a) $0°$ ✓
(b) $30°$
(c) $60°$
(d) $90°$

Explanation ✓ Correct answer: (a)

Work is given by $W = F\,d\cos\theta$. The factor $\cos\theta$ is largest when $\theta = 0°$, because $\cos 0° = 1$.

So work is maximum when force and displacement point in the **same direction**. For $30°$, $60°$ and $90°$ the values of $\cos\theta$ are 0.87, 0.5 and 0, so less work is done (zero at $90°$).

5.2 **A joule can also be written as:**

(a) kg m s^{-2}
(b) kg m s^{-1}
(c) $\text{kg m}^2\text{s}^{-3}$
(d) $\text{kg m}^2\text{s}^{-2}$ ✓

Explanation ✓ Correct answer: (d)

1 joule = 1 newton × 1 metre, and 1 N = 1 kg m s^{-2}.

$$1\text{ J} = (\text{kg m s}^{-2}) \times \text{m} = \text{kg m}^2\text{ s}^{-2}$$

Option (a) is the newton, (b) is the unit of momentum and (c) is the watt.

5.3 **The SI unit of power is:**

(a) joule
(b) newton
(c) watt ✓
(d) second

Explanation ✓ Correct answer: (c)

Power is the rate of doing work, $P = \frac{W}{t}$, so its unit is joule per second ($J\ s^{-1}$). This unit is named the **watt (W)**.

Joule is the unit of work, newton of force and second of time.

5.4 **The power of a water pump is 2 kW. The amount of water it can raise in one minute to a height of 5 metres is:**

(a) 1000 litres
(b) 1200 litres
(c) 2000 litres
(d) 2400 litres ✓

Explanation ✓ Correct answer: (d)

Work done by the pump in one minute ($g = 10\ m\ s^{-2}$):

$$W = P \times t = 2000 \times 60 = 120\,000\ J$$

$$W = mgh \Rightarrow m = \frac{W}{gh} = \frac{120\,000}{10 \times 5} = 2400\ kg$$

1 kg of water = 1 litre, so the pump raises **2400 litres**.

5.5 **A bullet of mass 0.05 kg has a speed of 300 m s^{-1}. Its kinetic energy will be:**

(a) **2250 J** ✓
(b) 4500 J
(c) 1500 J
(d) 1125 J

Explanation **✓ Correct answer: (a)**

$$KE = \tfrac{1}{2}\, m\, v^2 = \tfrac{1}{2} \times 0.05 \times (300)^2$$
$$KE = \tfrac{1}{2} \times 0.05 \times 90\,000 = 2250\ \text{J}$$

5.6 **If a car doubles its speed, its kinetic energy will be:**

(a) the same
(b) doubled
(c) increased to three times
(d) **increased to four times** ✓

Explanation **✓ Correct answer: (d)**

$KE = \tfrac{1}{2}\, m\, v^2$, so KE is proportional to v^2. If the speed becomes $2v$:

$$KE' = \tfrac{1}{2}\, m\, (2v)^2 = 4 \times (\tfrac{1}{2}\, m\, v^2) = 4 \times KE$$

5.7 **The energy possessed by a body by virtue of its position is:**

(a) kinetic energy
(b) **potential energy** ✓
(c) chemical energy
(d) solar energy

Explanation **✓ Correct answer: (b)**

Energy stored in a body because of its position (or state) is **potential energy**, e.g. water stored in a dam. Kinetic energy, on the other hand, is due to *motion*.

5.8 **The magnitude of momentum of an object is doubled, the kinetic energy of the object will:**

(a) double
(b) **increase to four times** ✓
(c) reduce to one-half
(d) remain the same

Explanation **✓ Correct answer: (b)**

Write KE in terms of momentum $p = m\,v$:

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

If p becomes $2p$ (mass fixed), $\mathrm{KE}' = \dfrac{(2p)^2}{2m} = 4 \times \dfrac{p^2}{2m} = 4 \times$ KE.

5.9 **Which of the following is not renewable energy source?**

(a) Hydroelectric energy

(b) **Fossil fuels** ✓

(c) Wind energy

(d) Solar energy

Explanation **✓ Correct answer: (b)**

Fossil fuels (coal, oil, natural gas) took millions of years to form. Once used, they cannot be replaced in a human lifetime, so they are **non-renewable**. Water, wind and sunlight are continually replenished by nature.

B Short Answer Questions

Clear, exam-ready short answers

5.1 What is the work done on an object that remains at rest when a force is applied on it?

Answer

The work done is **zero**.

$W = F\,d\cos\theta$, and the displacement $d = 0$

$\Rightarrow W = F \times 0 \times \cos\theta = 0$

Applying a force does not mean work is done — the object must actually move.

5.2 A slow-moving car may have more kinetic energy than a fast-moving motorcycle. How is this possible?

Answer

$KE = \frac{1}{2} m v^2$ depends on **both mass and speed**. A car is much heavier than a motorcycle, so a large mass can make up for a smaller speed.

Example

Car: $m = 1000$ kg, $v = 10$ m s^{-1}

$KE = \frac{1}{2} \times 1000 \times 10^2 = 50\,000$ J

Motorcycle: $m = 200$ kg, $v = 20$ m s^{-1}

$KE = \frac{1}{2} \times 200 \times 20^2 = 40\,000$ J

The car has more KE even though it moves at half the speed.

5.3 **A force F_1 does 5 J of work in 10 s. Another force F_2 does 3 J of work in 5 s. Which force delivers greater power?**

Answer

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

$$P_1 = \frac{5\ \text{J}}{10\ \text{s}} = 0.5\ \text{W}$$

$$P_2 = \frac{3\ \text{J}}{5\ \text{s}} = 0.6\ \text{W}$$

Since 0.6 W > 0.5 W, force F_2 delivers greater power.

5.4 **A woman runs up a flight of stairs. The gain in her gravitational potential energy is 4500 J. If she runs up the same stairs with twice the speed, what will be her gain in potential energy?**

Answer

Her gain in potential energy will still be **4500 J**.

$$\text{PE} = m\,g\,h$$

Potential energy depends only on mass, g and height. The stairs (height h) and the woman (mass m) are unchanged. Running faster only changes the *time* taken, so the *power* doubles, but the energy gained stays the same.

5.5 Define work and its SI unit.

Work

Work is done when a force acts on a body and moves it in the direction of the force. It is the product of the force and the displacement in the direction of the force.

$W = F\,d\cos\theta$ (θ = angle between F and d)

If $\theta = 0°$: $W = F\,d$

SI unit

The SI unit of work is the **joule (J)**. One joule is the work done when a force of 1 newton moves a body through 1 metre in the direction of the force: 1 J = 1 N × 1 m.

5.6 What is the potential energy of a body of mass *m* when it is raised through a height *h*?

Answer

To raise the body at constant speed we must apply an upward force equal to its weight, $F = m\,g$.

Work done $= F \times h = m\,g \times h$

This work is stored in the body as gravitational potential energy:

$\mathrm{PE} = m\,g\,h$

(m in kg, $g = 10\ \mathrm{m\ s^{-2}}$, h in m, PE in joules.)

5.7 Find an expression for the kinetic energy of a moving body.

Derivation

Let a body of mass m be at rest ($u = 0$). A constant force F gives it acceleration a over a distance s until its speed is v.

1. Work done: $W = F\,s$
2. Newton's second law $F = m\,a$, so $W = m\,a\,s$
3. Third equation of motion ($u = 0$): $v^2 = 2a\,s \Rightarrow a\,s = \dfrac{v^2}{2}$
4. Substitute: $W = m \times \dfrac{v^2}{2} = \frac{1}{2}\,m\,v^2$

This work is stored in the body as kinetic energy:

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

5.8 Define efficiency of a working system. Why a system cannot have 100% efficiency?

Efficiency

Efficiency is the ratio of the useful energy (work) output to the total energy input, usually written as a percentage.

$$\text{Efficiency} = \frac{\text{useful energy output}}{\text{total energy input}} \times 100\ \%$$

Why never 100 %?

In every real system some input energy is wasted as heat (friction between moving parts), sound and air resistance. This wasted energy cannot be turned back into useful work, so output is always less than input. Hence efficiency is **always below 100 %.**

5.9 What is power? Define the unit used for it.

Power

Power is the **rate of doing work** (or the rate of transferring energy).

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

Unit

The SI unit of power is the **watt (W)**. One watt is the power of a source that does 1 joule of work in 1 second: 1 W = 1 J s^{-1}.

Bigger units: 1 kW = 1000 W and 1 MW = 10^6 W.

5.10 Differentiate between renewable and non-renewable energy sources.

Point	Renewable	Non-renewable
Meaning	Naturally replenished again and again	Exist in limited amounts; cannot be replaced quickly
Time to renew	Short	Millions of years
Supply	Practically unlimited	Will run out one day
Pollution	Little or none	Burning gives smoke and gases
Examples	Sun, wind, water	Coal, oil, natural gas

C Constructed Response Questions

Reason it out — with diagrams & examples

5.1 Can the kinetic energy of a body ever be negative?

Answer

No. Kinetic energy can never be negative.

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

Mass m is always positive and v^2 is a square, so it can never be negative. KE is either zero (body at rest) or positive. A negative velocity only shows the *direction* of motion; squaring removes the sign.

$$v = -4 \text{ m s}^{-1} \Rightarrow KE = \tfrac{1}{2} \times 2 \times (-4)^2 = 16 \text{ J}$$

5.2 Which one has the greater kinetic energy: an object travelling with a velocity *v* or an object twice as heavy travelling with a velocity of ½ *v*?

Solution

Object 1: mass m, velocity $v \Rightarrow KE_1 = \tfrac{1}{2} m v^2$

Object 2: mass $2m$, velocity $\tfrac{1}{2}v \Rightarrow KE_2 = \tfrac{1}{2} (2m) \left(\frac{v}{2}\right)^2$

$$KE_2 = \tfrac{1}{2} \times 2m \times \frac{v^2}{4} = \frac{m v^2}{4}$$

$$\frac{KE_1}{KE_2} = \frac{\tfrac{1}{2} m v^2}{\tfrac{1}{4} m v^2} = 2$$

So the object of mass m moving with velocity v has **twice** the kinetic energy. Halving the velocity cuts KE to a quarter, while doubling the mass only doubles it.

5.3 **A car is moving along a curved road at constant speed. Does its kinetic energy change?**

Answer

No, its kinetic energy stays the same.

- $KE = \frac{1}{2} m v^2$ depends only on the **speed**, not on the direction of motion.
- On a curve the direction of the velocity changes, but the speed is constant, so KE is constant.
- The sideways force that turns the car is perpendicular to its motion, so it does no work: $W = F\,d \cos 90° = 0$.

5.4 **Comment on the statement, "An object has one joule of potential energy."**

Comment

The statement is **incomplete**. Potential energy is always measured *relative to a reference level* (usually the ground), and that level is not mentioned.

- $PE = m\,g\,h$, so 1 J can be a mass of 0.1 kg (100 g) held 1 m above the ground: $0.1 \times 10 \times 1 = 1$ J. A small apple lifted 1 m has about this much PE.
- The same object has a different PE if measured from the floor, a table or the ground.
- One joule is a very small amount of energy.

5.5 **While driving on a motorway, the tyre of a vehicle sometimes bursts. What may be its cause?**

Cause

1. At high speed the tyre rubs on the road and its rubber flexes again and again. **Kinetic energy is converted into heat** by friction.
2. The tyre and the air inside become hot, so the **pressure of the air rises** (at constant volume, pressure increases with temperature).
3. When the pressure becomes more than the tyre wall can bear — especially if the tyre is worn, overloaded or over-inflated — the tyre **bursts**.

Precaution: keep tyres at the recommended pressure and check them before long, fast journeys.

5.6 **While playing cricket on a street, the ball smashes a window pane. Describe the energy changes in this event.**

Energy changes

Chemical energy → Bat KE → Ball KE → Sound + heat

1. Muscles use **chemical energy** to swing the bat, which gains **kinetic energy**.
2. The bat does work on the ball and gives it **kinetic energy** (in flight the ball also exchanges KE and PE).
3. The ball hits the glass: part of its KE breaks the glass, part becomes **sound** (the crash) and **heat**, and part becomes KE of the flying glass pieces. The ball slows down.

5.7 **A man rowing a boat upstream is at rest with respect to the shore. Is he doing work?**

Answer

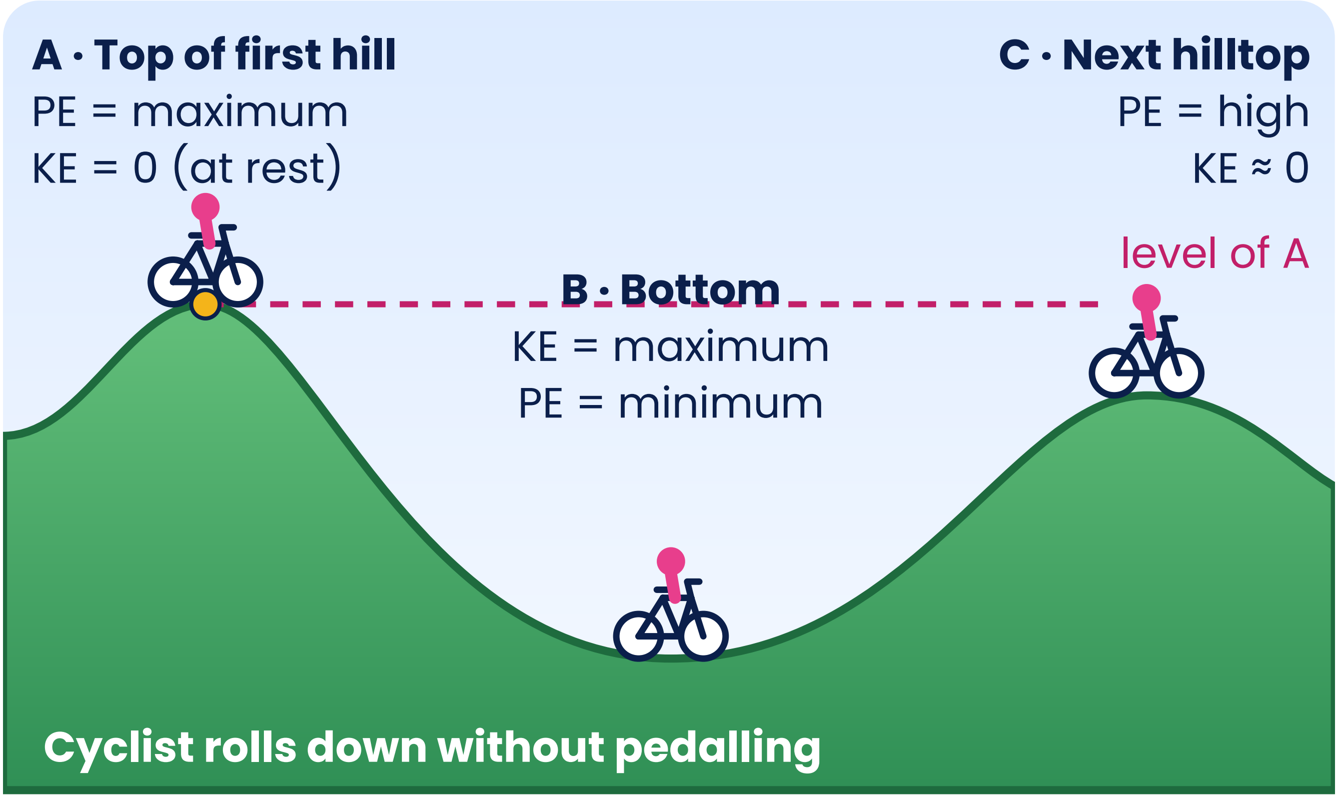
No — not in the scientific sense, with respect to the shore.

$W = F\,d\cos\theta$, and displacement $d = 0 \Rightarrow W = 0$

- His rowing force upstream balances the push of the river downstream, so the net force is zero and the boat stays at the same place.
- The boat does not move relative to the shore, so no work is done on it.
- He still feels tired because his muscles use up chemical energy, which changes into heat in his body.

5.8 (i) **A cyclist goes downhill from the top of a steep hill without pedalling and takes it to the top of the next hill. (i) Draw a diagram of what happened.**

Diagram



The dashed line marks the height of A. Hill C is a little lower because some energy is lost as heat and sound.

5.8 (ii) **(ii) Analyse this event in terms of potential and kinetic energy. Label your diagram using these terms.**

Analysis

Position	PE	KE
A — top of hill 1	Maximum	Zero (at rest)
A → B (down)	Decreases	Increases
B — bottom	Minimum	Maximum
B → C (up)	Increases	Decreases
C — top of hill 2	High	Almost zero

- Going down, height falls, so **PE is converted into KE** and speed increases.
- Going up the next hill, **KE is converted back into PE** and the cyclist slows down.
- Total energy is conserved; a small part is lost as heat by friction and air resistance, so hill C must be lower than A.

5.9 **Is timber or wood a renewable source of heat energy? Comment.**

Answer

Yes — but only if forests are managed properly.

- Trees can be regrown in a few decades, so wood can be replaced. It is renewable when new trees are planted as fast as old ones are cut.
- If trees are cut faster than they grow (deforestation), wood behaves like a non-renewable source and harms the environment.
- Burning wood gives out heat, but also smoke and carbon dioxide.

D Comprehensive Questions

Detailed answers with derivations & block diagrams

5.1 What is meant by kinetic energy? State its unit. Describe how it is determined.

Meaning

The energy possessed by a body because of its **motion** is called kinetic energy (KE). Examples: a moving car, a flowing river, a flying bullet.

Unit

Its SI unit is the **joule (J)**, where 1 J = 1 kg m^2 s^{-2}.

How it is determined

KE equals the work done in bringing a body from rest to speed v. Let a force F act on a body of mass m (initially at rest) through a distance s, giving it acceleration a and final speed v.

1. Work done: $W = F\,s$
2. From $F = m\,a$: $W = m\,a\,s$
3. From $v^2 = u^2 + 2a\,s$ with $u = 0$: $a\,s = \dfrac{v^2}{2}$
4. So $W = m \times \dfrac{v^2}{2}$, and this work is stored as KE.

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

KE is proportional to m and to v^2: doubling the speed makes KE four times. Example: a 2 kg ball at 3 m s^{-1} has KE = ½ × 2 × 3^2 = 9 J.

5.2 **State the law of conservation of energy. Explain it with the help of an example of a body falling from certain height in terms of its potential energy and kinetic energy.**

Law

Energy can neither be created nor destroyed. It can only change from one form to another. The total energy of an isolated system always remains constant.

Example: a falling body

A body of mass m is released from rest at height h above the ground (air resistance ignored).

1. **At the top:** $v = 0$, so KE = 0 and PE = $m\,g\,h$. Total = $m\,g\,h$.
2. **After falling a distance x:** $v^2 = 2g\,x$. PE = $m\,g\,(h - x)$ and KE = $\frac{1}{2}\,m\,(2g\,x) = m\,g\,x$. Total = $m\,g\,h$.
3. **Just before the ground:** $x = h$, so PE = 0 and KE = $\frac{1}{2}\,m\,(2g\,h) = m\,g\,h$. Total = $m\,g\,h$.

At every point the PE lost equals the KE gained, so the total **mechanical energy stays $m\,g\,h$**.

5.3 **Differentiate between renewable and non-renewable sources of energy. Give three examples for each.**

Point	Renewable	Non-renewable
Definition	Sources that are naturally replaced in a short time	Sources with a fixed stock that cannot be replaced once used
Formation	Supplied continuously by the sun, wind and water cycle	Formed from buried plants and animals over millions of years
Supply	Practically inexhaustible	Limited; will finish one day
Environment	Clean, little or no pollution	Burning gives CO_2, smoke and pollutants
Cost	High set-up cost, low running cost	Cheaper to start, but fuel gets costly

Renewable — 3 examples

- Solar energy
- Wind energy
- Hydroelectric energy

Non-renewable — 3 examples

- Coal
- Petroleum (oil)
- Natural gas

5.4 Explain what is meant by efficiency of a machine. How is it calculated? Why there is a limit for the efficiency of a machine?

Meaning

Efficiency tells us how much of the energy supplied to a machine is changed into **useful work**.

Calculation

$$\text{Efficiency} = \frac{\text{useful work (energy) output}}{\text{total work (energy) input}} \times 100\ \%$$

Example: a motor takes in 500 J and does 400 J of useful work.

$$\text{Efficiency} = \frac{400}{500} \times 100 = 80\ \%$$

Why is there a limit?

- Some input energy is always wasted as **heat** because of friction between moving parts.
- Energy is also lost as sound, vibrations and air resistance.
- This wasted energy cannot be recovered as useful work, so output < input.

Therefore the efficiency of every real machine is **less than 100 %**.

5.5 **Describe the process of electricity generation by drawing a block diagram of the process in the following cases. (i) Hydroelectric power generation**

(i) Hydroelectric power generation

Water stored in the dam
Potential energy

↓ PE → KE

Falling water in the penstock
Kinetic energy

↓ water strikes blades

Turbine
Rotational (mechanical) energy

↓ shaft turns generator

Generator
Electrical energy

↓ sent out

Transformer & transmission lines
Electricity sent to homes and industry

Water stored at height has PE. It rushes down the penstock and strikes the turbine blades, and the turbine turns the generator.

5.5 (ii)

(ii) Fossil fuels

(ii) Fossil fuel power plant

Fossil fuel (coal, oil or gas)
Chemical energy

↓ burning

Furnace & boiler
Heat energy — water becomes high-pressure steam

↓ steam jets spin turbine

Steam turbine
Kinetic (mechanical) energy

↓ shaft turns generator

Generator
Electrical energy

↓ sent out

Transformer & transmission lines
Electricity sent to homes and industry

The used steam is condensed and reused. Burning fossil fuels releases CO_2 and smoke.

E Numerical Problems

Given → Find → Solution → Answer ($g = 10\ m\ s^{-2}$)

5.1 **A force of 20 N acting at an angle of 60° to the horizontal is used to pull a box through a distance of 3 m across a floor. How much work is done?**

Given: $F = 20\ \mathrm{N}$ $\theta = 60°$ $d = 3\ \mathrm{m}$ **Find:** $W = ?$

Solution

$$W = F\, d\, \cos\theta$$

$$W = 20 \times 3 \times \cos 60° = 60 \times 0.5 = 30\ \mathrm{J}$$

Answer: 30 J

5.2 **A body moves a distance of 5 metres in a straight line under the action of a force of 8 newtons. If the work done is 20 joules, find the angle which the force makes with the direction of motion of the body.**

Given: $d = 5$ m | $F = 8$ N | $W = 20$ J **Find:** $\theta = ?$

Solution

$$W = F\,d\cos\theta \Rightarrow \cos\theta = \frac{W}{F\,d}$$

$$\cos\theta = \frac{20}{8 \times 5} = \frac{20}{40} = 0.5$$

$$\theta = \cos^{-1}(0.5) = 60°$$

Answer: 60°

5.3 **An engine raises 100 kg of water through a height of 80 m in 25 s. What is the power of the engine?**

Given: $m = 100$ kg | $h = 80$ m | $t = 25$ s | $g = 10$ m s^{-2}

Find: $P = ?$

Solution

1. Work done = gain in PE

$$W = m\,g\,h = 100 \times 10 \times 80 = 80\,000 \text{ J}$$

2. Power = work ÷ time

$$P = \frac{W}{t} = \frac{80\,000}{25} = 3200 \text{ W}$$

Answer: 3200 W (3.2 kW)

5.4 **A body of mass 20 kg is at rest. A 40 N force acts on it for 5 seconds. What is the kinetic energy of the body at the end of this time?**

Given: $m = 20$ kg | $u = 0$ | $F = 40$ N | $t = 5$ s **Find:** **KE = ?**

Solution

1. Acceleration

$$a = \frac{F}{m} = \frac{40}{20} = 2 \text{ m s}^{-2}$$

2. Final speed

$$v = u + a\,t = 0 + 2 \times 5 = 10 \text{ m s}^{-1}$$

3. Kinetic energy

$$\text{KE} = \tfrac{1}{2}\, m\, v^2 = \tfrac{1}{2} \times 20 \times 10^2 = 1000 \text{ J}$$

Answer: 1000 J

5.5 **A ball of mass 160 g is thrown vertically upward. The ball reaches a height of 20 m. Find the potential energy gained by the ball at this height.**

Given: $m = 160 \text{ g} = 0.16 \text{ kg}$ | $h = 20 \text{ m}$ | $g = 10 \text{ m s}^{-2}$

Find: $\text{PE} = ?$

Solution

$$\text{PE} = m\,g\,h$$

$$\text{PE} = 0.16 \times 10 \times 20 = 32 \text{ J}$$

Remember to convert grams to kilograms first: 160 g = 0.16 kg.

Answer: 32 J

5.6 **A 0.14 kg ball is thrown vertically upward with an initial velocity of 35 m s^{-1}. Find the maximum height reached by the ball.**

Given: $m = 0.14$ kg | $u = 35$ m s^{-1} | $v = 0$ (at top) | $g = 10$ m s^{-2}

Find: $h = ?$

Solution

1. At the top the ball stops for a moment, so all its KE has become PE:

$$\tfrac{1}{2}\, m\, u^2 = m\, g\, h \Rightarrow h = \frac{u^2}{2g}$$

2. Put in the values

$$h = \frac{35^2}{2 \times 10} = \frac{1225}{20} = 61.25 \text{ m}$$

Check: KE = $\tfrac{1}{2} \times 0.14 \times 35^2 = 85.75$ J and PE = $0.14 \times 10 \times 61.25 = 85.75$ J ✔

Answer: 61.25 m

5.7 **A girl is swinging on a swing. At the lowest point of her swing, she is 1.2 m from the ground, and at the highest point she is 2.0 m from the ground. What is her maximum velocity and where?**

Given: Lowest point: 1.2 m | Highest point: 2.0 m | $g = 10\ \text{m s}^{-2}$ **Find:** **Maximum velocity and its position**

Solution

1 Height gained

$$h = 2.0 - 1.2 = 0.8\ \text{m}$$

2 At the highest point she stops (KE = 0). On coming down, all this PE becomes KE at the lowest point:

$$\tfrac{1}{2} m v^2 = m g h \Rightarrow v = \sqrt{2gh}$$

3 Calculate

$$v = \sqrt{2 \times 10 \times 0.8} = \sqrt{16} = 4\ \text{m s}^{-1}$$

Her mass cancels out. Speed is greatest at the lowest point because PE is minimum and KE is maximum there.

Answer: 4 m s⁻¹, at the lowest position

5.8 **A person pushes a lawn mower with a force of 50 N making an angle of 45° with the horizontal. If the mower is moved through a distance of 20 m, how much work is done?**

Given: $F = 50\ \text{N}$ $\theta = 45°$ $d = 20\ \text{m}$ **Find:** $W = ?$

Solution

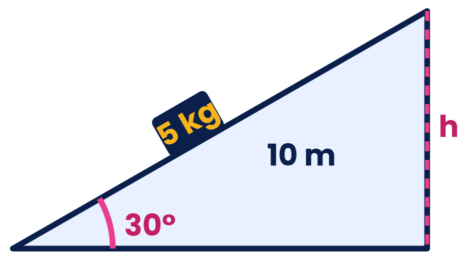
$$W = F\, d \cos\theta$$

$$W = 50 \times 20 \times \cos 45° = 1000 \times 0.707 = 707\ \text{J}$$

Answer: 707 J

5.9 (i) **Calculate the work done in (i) Pushing a 5 kg box up a frictionless inclined plane 10 m long that makes an angle of 30° with the horizontal.**

Given: $m = 5\ \text{kg}$ $s = 10\ \text{m}$ $\theta = 30°$ $g = 10\ \text{m s}^{-2}$ **Find:** $W = ?$



Solution

1. Force needed along the frictionless incline

$$F = m\, g \sin 30° = 5 \times 10 \times 0.5 = 25\ \text{N}$$

2. Work done

$$W = F \times s = 25 \times 10 = 250\ \text{J}$$

Answer: 250 J

5.9 (ii) **(ii) Lifting the box vertically up from the ground to the top of the inclined plane.**

Given: $m = 5\ \text{kg}$ $g = 10\ \text{m s}^{-2}$ **Find:** $W = ?$

Solution

1. Height of the incline

$$h = s \sin 30° = 10 \times 0.5 = 5\ \text{m}$$

2. Work done against gravity

$$W = m\,g\,h = 5 \times 10 \times 5 = 250\ \text{J}$$

Answer: 250 J

Conclusion: the work is the same (250 J) in both cases. Work done against gravity depends only on the vertical height, not on the path taken.

5.10 **A box of mass 10 kg is pushed up along a ramp 15 m long with a force of 80 N. If the box rises up a height of 5 m, what is the efficiency of the system?**

Given: $m = 10$ kg | $d = 15$ m | $F = 80$ N | $h = 5$ m **Find:** **Efficiency = ?**

Solution

1. Work input

$$\text{Input work} = F\,d = 80 \times 15 = 1200\ \text{J}$$

2. Useful work output (gain in PE)

$$\text{Output work} = m\,g\,h = 10 \times 10 \times 5 = 500\ \text{J}$$

3. Efficiency

$$\text{Efficiency} = \frac{500}{1200} \times 100 = 41.7\ \%$$

Answer: 41.7 %

5.11 **A force of 600 N acts on a box to push it 5 m in 15 s. Calculate the power.**

Given: $F = 600\ \text{N}$ $d = 5\ \text{m}$ $t = 15\ \text{s}$ **Find:** $P = ?$

Solution

1. Work done

$$W = F\,d = 600 \times 5 = 3000\ \text{J}$$

2. Power

$$P = \frac{W}{t} = \frac{3000}{15} = 200\ \text{W}$$

Answer: 200 W

5.12 **A 40 kg boy runs up-stair 10 m high in 8 s. What power he developed.**

Given: $m = 40\ \text{kg}$ $h = 10\ \text{m}$ $t = 8\ \text{s}$ $g = 10\ \text{m s}^{-2}$

Find: $P = ?$

Solution

1. Work done against gravity

$$W = m\,g\,h = 40 \times 10 \times 10 = 4000\ \text{J}$$

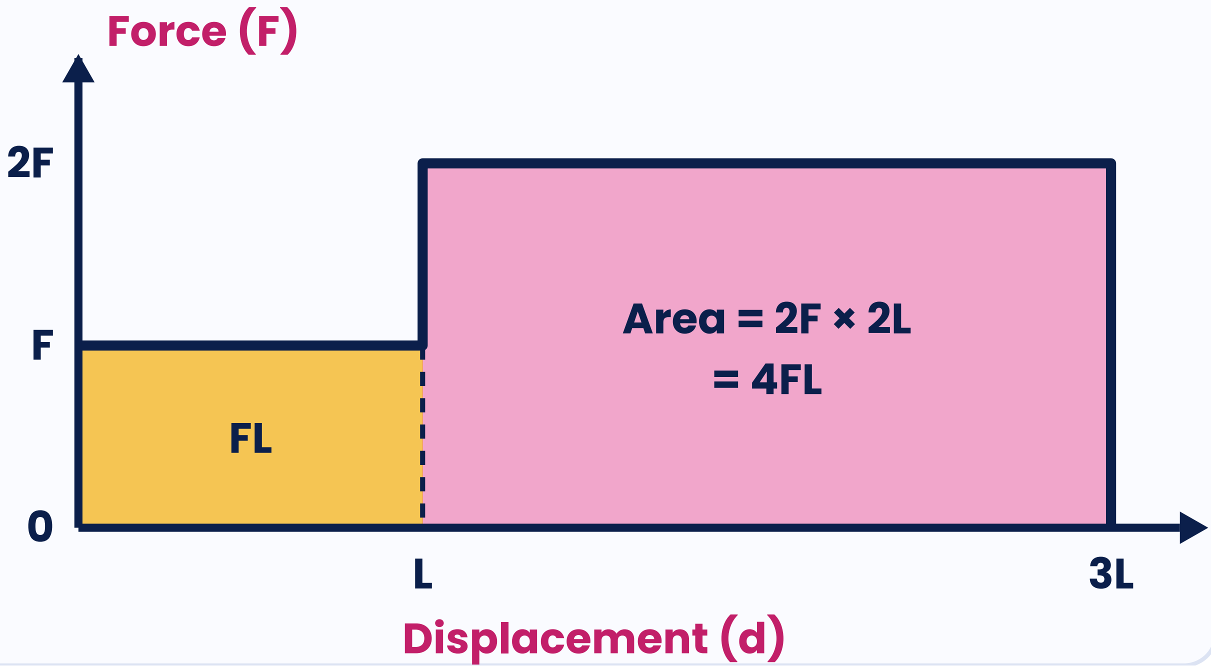
2. Power

$$P = \frac{W}{t} = \frac{4000}{8} = 500\ \text{W}$$

Answer: 500 W

5.13 **A force F acts through a distance L on a body. The force is then increased to $2F$ that further acts through $2L$. Sketch a force-displacement graph and calculate the total work done.**

Force–displacement graph



The second stage starts where the first ends, so the total displacement is $L + 2L = 3L$.

5.13 (contd.)

Solution

Work done = **area under the force–displacement graph**.

1. First stage (force F, distance L)

$$W_1 = F \times L = F\,L$$

2. Second stage (force $2F$, distance $2L$)

$$W_2 = 2F \times 2L = 4F\,L$$

3. Total work

$$W = W_1 + W_2 = F\,L + 4F\,L = 5F\,L$$

Answer: 5 FL (or 5 units if FL = 1 unit)