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CHAPTER NOTES

Work, Energy, and Simple Machines Class 9 Notes | CBSE Science Chapter 7

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**Ira**
Your teacher for Work, Energy, and ...



Hi, I am **Ira**. I teach this syllabus all day, so **Work, Energy, and Simple Machines** is very much my home ground.

Ask me anything from this chapter. A concept, a numerical, or that one doubt you did not want to raise in class. Pick one to start:

Explain Work, Energy, and Simple Machines simply

What can the board exam ask?

Most important formulas

Quiz me on this chapter

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Work, Energy, and Simple Machines Class 9 Notes | CBSE Science Chapter 7

Work, Energy, and Simple Machines is Chapter 7 of CBSE Class 9 Science (Exploration, 2026-27). It gives you a second way to analyse motion. In place of tracking forces and accelerations step by step, you track work and energy. The chapter defines work done by a constant force, states the work-energy theorem, derives kinetic energy ($\frac{1}{2}mv^2$) and gravitational potential energy (mgh), and shows that mechanical energy is conserved when only gravity acts. It ends with power and with three simple machines: the pulley, the inclined plane and the lever.

The chapter is numerical and full of exam-ready relations. Expect questions on the sign of work (positive, negative or zero), kinetic and potential energy calculations, speed at the bottom of a slide from $v = \sqrt{2gh}$, power in watt, and mechanical advantage of a ramp or a lever. The energy method you learn here is used again and again in Class 10 and in all later physics, so it pays to get the units and the signs right now.

Quick Answer - Work, Energy, and

Work done by a constant force is $W = F \cdot s$ where F is the force. It is measured in joule ($1 \text{ J} = 1 \text{ N} \cdot \text{m}$). Energy is the capacity to do work, and the work done on an object equals the change in its energy. For an object near the Earth is $U = mgh$, and their sum stays constant. Power is W/t in watt. Simple machines give mechanical advantage for the total work.



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All Key Formulas at a Glance

Quantity	Formula	SI Unit
Work done by a constant force	$W = F \times s$ (s in the direction of the force)	joule (J) = N m
Joule in base units	$1 \text{ J} = 1 \text{ N} \times 1 \text{ m} = 1 \text{ kg m}^2 \text{ s}^{-2}$	-
Work-energy theorem	work done on an object = change in its energy	joule (J)
Work by a constant force from u to v	$W = \frac{1}{2}m(v^2 - u^2)$	joule (J)
Kinetic energy	$K = \frac{1}{2}mv^2$	joule (J)
Gravitational potential energy (near the Earth)		
Mechanical energy		
Speed after falling or sliding through height h (no friction)		
Average power		
Mechanical advantage		
Inclined plane		
Lever (balanced)		



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Key Concepts

1. Work Done by a Constant Force

In science, "work" has one exact meaning. NCERT builds it from lifting 5 kg bags of wheat slowly through 1 m with an upward force equal to the weight, mg .

- Lift 3 bags together through 1 m: 3 times the force, 3 times the work. So **a larger force over the same distance does proportionally more work.**
- Lift one bag through 3 m: 3 times the distance, 3 times the work. So **the same force over a larger distance does proportionally more work.**

These observations give the scientific definition (Eq. 7.1):

Work done on an object by a constant force = force applied $\times$ displacement in the direction of the force

$$W = F \times s \quad (\text{Eq. 7.2})$$

The rule works in any direction, as long as the **force (or agency) doing the work** and

The joule

The SI unit of work is the **joule (J)**. Since **1 joule is the work done on an object when a constant force of 1 newton acts on it through a displacement of 1 m in the direction of the force.** Because $1 \text{ N} = 1 \text{ kg}$

Force and displacement both have magnitudes described by a number with a positive or negative sign.

Work as the area under a force-displacement graph

For a constant 10 N force over 1 m, the force-displacement graph is a rectangle under it has area $10 \text{ N} \times 1 \text{ m} = 10 \text{ J}$. **When a constant force acts on an object, the work done equals the area under the force-displacement graph between the initial and final positions.**

When is work done equal to zero?



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Condition	Why $W = 0$	Example
No force, $F = 0$	$F \times s = 0 \times s = 0$	No force acts on the object at all
No displacement, $s = 0$	$F \times 0 = 0$, however large the force	Pushing a rigid wall; a weightlifter holding a barbell steady
Force perpendicular to displacement	No displacement in the direction of the force	A girl carrying a box while walking: her upward force balances its weight, the box moves horizontally

You feel tired pushing a wall because your muscles repeatedly expand and contract and use up your body's internal energy, yet you do no work on the wall.

Positive and negative work

- **Positive work:** the displacement is in the forward: you do positive work on it.
- **Negative work:** the displacement is opposite to the direction of the force. For example, a goalkeeper pushes against its motion: she does negative work. Displacement as negative.

The ball and goalkeeper push on each other. The ball does positive work on the goalkeeper, the goalkeeper does negative work on the ball. The ball acts against its motion, so it does negative work.

Example 7.1 (NCERT): a girl lifts a dumbbell (the displacement is along the displacement of its weight, upward) is along the displacement. She does positive work to hold it, but it moves down: negative work.

2. Energy and the Work-Energy Theorem

A thrown cricket ball knocks over the wicket. Each has a **capacity to do work**. All objects **possess energy**. The ball got its energy from the work done in raising it. Positive work on an object can be done by another object, as the ball does to the wicket.

Work-energy theorem: work done on an object is equal to the change in its kinetic energy.



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- It also holds for a **system of objects** and when the forces are **not constant**.
- Positive work increases the energy; negative work decreases it.
- The SI unit of energy is the **joule**, named after James Prescott Joule, who studied how mechanical and thermal energy convert into each other.

Carrom (Example 7.3): the striker hits the white coin, which hits the black coin. The striker does positive work on the white coin (its energy rises); by Newton’s third law the white coin does negative work on the striker (its energy falls). Likewise the white coin does positive work on the black coin and the black coin negative work on the white coin.

Forms of energy

Energy exists in many forms, and it can change from one form to another.

Form	What it is (NCERT Fig. 7.10)
Mechanical energy	Energy due to mo
Thermal energy	Energy that make
Light energy	Energy that allow
Sound energy	Energy of vibratio
Electrical energy	Energy related to
Nuclear energy	Energy stored in t
Chemical energy	Energy stored in t between atoms

Conversions: bulb, electrical to light; water mechanical in muscles; ringing bell, mech. energy into kinetic energy, and friction and

3. Kinetic Energy

Mechanical energy is the energy an object are kinetic energy and potential energy.



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Kinetic energy is the energy possessed by an object due to its motion. A moving bicycle and a rolling ball have it. An object at rest is defined to have zero kinetic energy.

Deriving the expression

Take an object of mass m moving with initial velocity u . A constant force F acts on it along its motion, so its acceleration a is constant, and after a displacement s its velocity is v .

- 1. Kinematic equation: $v^2 = u^2 + 2as$, so $s = (v^2 - u^2) / (2a)$ (Eq. 7.4)
- 2. Work done: $W = F \times s$, and Newton's second law gives $F = ma$, so $W = ma \times s$.
- 3. Substitute s : $W = ma \times (v^2 - u^2) / (2a)$
- 4. The a cancels: **$W = \frac{1}{2}m(v^2 - u^2)$** (Eq. 7.5)

By the work-energy theorem, this work is the change in the object's energy. If the object starts from rest ($u = 0$), the whole change is its final kinetic energy:

$K = \frac{1}{2}mv^2$ (Eq. 7.6)

- SI unit: joule. Kinetic energy has no direction.
- Positive work on the object: velocity and kinetic energy increase.
- Negative work: velocity and kinetic energy decrease.
- No work ($W = 0$) and no change of velocity: an object moving with constant velocity has the same kinetic energy.

How K depends on mass and speed

Change	
Mass doubled, same speed	K doubles
Speed doubled, same mass	K becomes four times

4. Potential Energy

Release a stretched slingshot (gulel) band. It has kinetic energy it did not have. That energy was stored in the band. We say the band does work **due to its shape**: the work done to stretch it is stored in it.



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spring stores energy the same way and, on release, returns to its shape and hands the energy to the object in contact as kinetic energy.

Energy stored by relative position

- **Magnets:** unlike poles pulled apart and released rush together with kinetic energy (strong magnets can crush a pea between them).
- **Electric charges:** separated charges also store energy that can do work when released.
- **Earth and ball:** lifting the ball needs work against gravity; released, ball and Earth rush together and gain kinetic energy.

Definition: the energy stored by an object as a result of its deformation, or in a system of objects due to their relative positions, is called **potential energy**.

Gravitational potential energy

The Earth hardly moves towards a ball, so the **gravitational potential energy of the ball**. In this case, the **gravitational potential energy**.

Activity 7.1: a heavy ball dropped into loose soil reaches the deepest depression from the greatest height. **greater the height above the Earth's surface**

Deriving $U = mgh$: take the potential energy zero. To raise it gradually to height h , apply a force $F = mg$. Displacement = $mg \times h = mgh$ (Eq. 7.7). By this work, potential energy:

$U = mgh$ (Eq. 7.8), unit joule.

- $U = mgh$ is valid only near the Earth's surface.
- Moving horizontally at constant velocity does not change potential energy.
- The gain in potential energy depends on the height (e.g., climbing stairs) is taken.
- Enrichment: work against gravitational, elastic, and electric forces. Work done against friction is not potential energy.



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5. Conservation of Mechanical Energy

Mechanical energy = kinetic energy + potential energy. Follow an object of mass m dropped from rest at point A, height h (NCERT Fig. 7.19).

Point	Potential energy	Kinetic energy	Mechanical energy
A (height h , $t = 0$, $u = 0$)	mgh	0	mgh
B (after time t , height h')	$mgh' = mgh - \frac{1}{2}mg^2t^2$	$\frac{1}{2}mv^2 = \frac{1}{2}mg^2t^2$	mgh
Just before the ground	0	mgh	mgh

Working for point B: with acceleration g , $v^2 = u^2 + 2gh' = 0 + 2g(h - \frac{1}{2}gt^2)$. Then $U = mgh' = mgh - \frac{1}{2}mg^2t^2$. Their sum is mgh (Eq. 7.10c).

The kinetic energy gained, $\frac{1}{2}mg^2t^2$, equals the loss in potential energy. **the gravitational force, its mechanical energy is conserved. This is the conservation of mechanical energy.**

The pendulum (Activity 7.2)

Draw a horizontal line on paper behind a scale and release it.

- **At P** (extreme): no kinetic energy, only potential energy
- **At Q** (lowest point): potential energy zero, kinetic energy maximum
- **At R** (other extreme): kinetic energy zero, potential energy maximum

The bob rises almost to the line, so mechanical energy is conserved. energy loss due to friction at the support and air resistance is negligible.

Why the energy method is powerful

Energy conservation gives final speeds without needing time. A child on a frictionless slide of height h , $mgh = \frac{1}{2}mv^2$, so $v = \sqrt{2gh}$. The speed at the bottom is $\sqrt{2gh}$.



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depends only on the height: the shape of the slide and the mass of the child do not matter. Two children of different masses on the same slide reach the bottom with the same speed, and the tallest slide gives the largest speed.

When friction or air resistance acts, mechanical energy decreases, and the work-energy theorem handles it: work done by the resistive force = change in $(K + U)$. This is how the escape-ramp problem (Example 7.9) is solved.

6. Power

Running up the stairs with your bag in one minute and walking up in five minutes need the same work. The difference is **power**.

Power is the rate at which work is done. Average power:

$$P = W / t \quad (\text{Eq. 7.11})$$

- SI unit: **watt (W)**; $1 \text{ W} = 1 \text{ J s}^{-1}$, one joule per second. James Watt, the inventor of an efficient steam engine.
- More work in the same time needs more power.
- **Horsepower (hp)**: another unit, used for engines.
- Do not confuse the symbol W for work with w for weight.

Lifting the same mass twice as high in twice the time needs twice the power. Raising a flag twice as fast halves the time. Changing the speed changes the power and leaves the work the same. The work depends on the flag's mass, g and the height.

7. Simple Machines, Mechanical Advantage

The total work needed for a task cannot be reduced by using simple machines. Changing the magnitude or direction of the force is what simple machines do.

- **Effort**: the force we apply to a machine.
- **Load**: the force that needs to be overcome.



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- **Mechanical advantage = load / effort** (Eq. 7.12). It has no unit. MA greater than 1 lets a small effort move a large load.

Pulley

A pulley is a wheel with a groove that guides a rope. With a **fixed pulley** on a flagpole, you pull down and the flag goes up. Effort equals load, so **MA of a fixed pulley = 1**. It helps by changing the direction of the effort, since pulling down is easier than lifting up.

Enrichment: in a **movable pulley** system the load hangs from a moving pulley, one rope end is fixed and effort is applied at the other. Such systems can have MA greater than 1, and are used in elevators and cranes.

Inclined plane

Activity 7.3: a spring balance shows the cart's full weight when it is lifted straight up to a stool about 0.5 m high, and a smaller reading when it is pulled up a smooth plank. A less steep plank needs even less force, over a larger distance.

Let the load be the weight mg , the effort F' at constant speed, ignoring friction:

- Work done by you = $F' \times L$
- Potential energy gained = mgh
- Work-energy theorem: $F' \times L = mgh$, so

MA of an inclined plane = load / effort = L/h

Since L is larger than h , the effort F' is less. An inclined plane reduces the effort further. Force $\times$ distance is conserved. Wind in gentle slopes and an inclined ladder.

8. The Lever

Activity 7.4: a 30 cm scale resting on a pencil acts as a lever.

A **lever** is a rigid bar that can rotate about a fixed point.

- **Fulcrum:** the fixed point about which the lever rotates.



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- **Load:** the force to be overcome.
- **Effort:** the force applied.

The distance of the load from the fulcrum is the **load arm**; the distance of the effort from the fulcrum is the **effort arm**.

Why a small force can lift a large load

The small force F_1 moves a large distance d_1 ; the other end applies a large force F_2 through a small distance d_2 . The work done at one end is transferred to the other:

$$F_1 \times d_1 = F_2 \times d_2 \quad (\text{Eq. 7.14})$$

A lever reduces the force needed. It does not reduce the total work done.

Beam balance (Activity 7.5) and the law of the lever

A scale hung at its midpoint (the fulcrum) with coins in the right pan, that pan must move down when $n_1 \times L_1 = n_2 \times L_2$:

$$\text{effort} \times \text{effort arm} = \text{load} \times \text{load arm} \quad (\text{Eq. 7.15})$$

$$\text{MA of a lever} = \text{load} / \text{effort} = \text{effort arm} / \text{load arm}$$

A longer effort arm means a smaller effort is needed to lift the same load. The effort arm stays the same.

Everyday uses: a spoon used to prise open a lid, a nutcracker, a pair of scissors. When you cut something hard with scissors, you push the handles together, the blades become shorter, so the same effort produces a larger load.

Classes of levers (enrichment, Table 7.1)



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Class	What lies in between	Examples in NCERT
Class I	Fulcrum between effort and load	Tongs (scissor-type, pivot in the middle), scissors, crowbar, pliers, balance scale, seesaw
Class II	Load between fulcrum and effort	Lemon squeezer, wheel barrow, bottle opener
Class III	Effort between fulcrum and load	Tongs (hinged at one end), tweezers, broom, hammer, oar

NCERT lists tongs under both Class I and Class III. Decide from where the pivot is: at the middle it is Class I, at the end it is Class III.

Many machines are made of two or more simple machines. In all of them, ignoring friction, the work put in equals the useful work done on the load. This means that simple machines **use energy more effectively**. So no perpetual motion machine is possible. In reality, due to friction and air resistance and, with no energy input, the machine will stop.

Science and society: the Himalayan glaciers melt, the kinetic energy in a pipe, which drives a wheel, the energy of stored water in the same way to generate electricity.



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Formula and Reaction Sheet

Quantity / Law	Formula	Unit
Work by a constant force	$W = F \times s$	J
Work from a graph	$W = \text{area under force-displacement graph}$	J
Work-energy theorem	work done on object = change in its energy	J
Work by constant force, u to v	$W = \frac{1}{2}m(v^2 - u^2)$	J
Kinetic energy	$K = \frac{1}{2}mv^2$	J
Potential energy	$U = mgh$	J
Mechanical energy	$E = K + U$	
Speed at the bottom of height h	$v = \sqrt{2gh}$	
Average power	$P = W / t$	
Mechanical advantage	$MA = \text{load} / \text{effort}$	
Inclined plane	$F' \times L = m \times g \times h$	
Lever	$F_1 \times d_1 = F_2 \times d_2$	



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Important Definitions

- **Work done by a constant force:** the product of the force and the displacement of the object in the direction of the force.
- **One joule:** the work done on an object when it is displaced by 1 metre in the direction of the force.

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- **Energy:** the capacity to do work. An object having the capacity to do work is said to possess energy.
- **Work-energy theorem:** the work done on an object (or a system) is equal to the change in its energy.
- **Mechanical energy:** the energy an object possesses due to its motion or position; the sum of its kinetic energy and potential energy.
- **Kinetic energy:** the energy possessed by an object due to its motion, $K = \frac{1}{2}mv^2$.
- **Potential energy:** the energy stored by an object as a result of its deformation, or in a system of objects due to their relative positions.
- **Conservation of mechanical energy:** the mechanical energy of an object moving under the gravitational force stays constant if no other external force acts on it.
- **Power:** the rate at which work is done, $P = W/t$.
- **Simple machine:** a device that makes a task easier by changing the magnitude or direction of the force that needs to be applied, without changing the amount of work done.
- **Effort:** the force applied to a machine. $E = F \times d$.
- **Mechanical advantage:** the ratio of the load to the effort. $MA = \frac{L}{E}$.
- **Lever:** a rigid bar that can rotate about a fixed point called the fulcrum.
- **Load arm / effort arm:** the distance of the load/effort from the fulcrum.



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Solved Examples (NCERT)

Example 1: Negative work by a goalkeeper

Question: While saving a goal, a goalkeeper stops a ball moving with a velocity of 10 m/s while applying a force of 200 N. How much work does he do?

Solution: The force is opposite to the ball's motion, so the work done is negative: $s = -15 \text{ cm} = -0.15 \text{ m}$.

$W = F \times s = 200 \text{ N} \times (-0.15 \text{ m}) = -30 \text{ J}$. The goalkeeper removes 30 J of kinetic energy from the ball.

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Example 2: Kinetic energy of a fast delivery (NCERT Example 7.5)

Question: In one of their fastest deliveries, an Indian cricketer bowled a cricket ball with an approximate mass of 0.2 kg at a velocity of about 154.8 km h^{-1} . Calculate the kinetic energy of the ball at the time of its delivery.

Solution: $v = 154.8 \div 3.6 = 43 \text{ m s}^{-1}$.

$$K = \frac{1}{2}mv^2 = \frac{1}{2} \times 0.2 \text{ kg} \times (43 \text{ m s}^{-1})^2 = 0.1 \times 1849 = \mathbf{184.9 \text{ J}}.$$

Example 3: Stopping a jet on an aircraft carrier (NCERT Example 7.6)

Question: A jet aircraft of mass 15000 kg lands on the deck of an aircraft carrier. To stop the aircraft within the short length of the deck a hook on the aircraft's tail is caught in a wire stretched across the deck. The wire exerts an approximately constant backward force of 367500 N and stops the jet within 100 m. What was the velocity of the aircraft just before the wire caught the hook?

Solution: Let the speed be v .

- Initial $K = \frac{1}{2} \times 15000 \times v^2$; final $K = 0$. C
- The wire's force is opposite to the displ
(-100 m) = -36750000 J .
- Work-energy theorem: $-\frac{1}{2} \times 15000 \times v^2$
- $v^2 = 4900 \text{ m}^2 \text{ s}^{-2}$, $v = \mathbf{70 \text{ m s}^{-1}} = 70 \times 3$

Example 4: Truck on an escape ramp

Question: Escape ramps are inclined planes where trucks can stop if their brakes fail on a highway. A truck of mass 15000 kg fails to stop and its brakes fail. The driver steers it onto an escape ramp where the sand exerts a force of 50000 N opposite to the direction of motion. How long must the ramp be to be able to stop such a truck? Take $g = 10 \text{ m s}^{-2}$. For every 2 m it travels along the ramp, it rises 1 m vertically.

Solution:

- $v = 72 \text{ km h}^{-1} = 20 \text{ m s}^{-1}$. Initial $K = \frac{1}{2} \times 15000 \times 20^2 = 3000000 \text{ J}$.



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2. Let the truck travel d along the ramp. Height gained $= d/2$. Final $K = 0$; final $U = 10000 \times 10 \times d/2 = 50000 \text{ N} \times d$.
3. Change in energy $= 50000d - 2000000$.
4. Work by the sand $= -50000 \text{ N} \times d$ (force opposite to motion).
5. Work-energy theorem: $-50000d = 50000d - 2000000$, so $100000d = 2000000$, $d = \mathbf{20 \text{ m}}$.

Example 5: Power of a weightlifter (NCERT Example 7.10)

Question: A weightlifter lifts a 75 kg mass by 2 m in 5 seconds . How much power would she require for this task?

Solution: $W = mgh = 75 \text{ kg} \times 10 \text{ m s}^{-2} \times 2 \text{ m} = 1500 \text{ J}$. $P = W/t = 1500 \text{ J} / 5 \text{ s} = \mathbf{300 \text{ W}}$.

Example 6: Power of a car engine (NCERT Example 7.11)

Question: A car of mass 1000 kg starts from rest and reaches a speed of 72 km h^{-1} in 10 seconds . Calculate the power of the engine.

Solution: $v = 72000 \text{ m} / 3600 \text{ s} = 20 \text{ m s}^{-1}$

Work done by the engine $=$ change in $K =$

$P = 200000 \text{ J} / 10 \text{ s} = \mathbf{20000 \text{ W}}$ (20 kW).

Example 7: Mechanical advantage

Question: A person uses an inclined ramp to lift a box. The ramp has a width of 40 cm . What is the mechanical advantage to achieve the task?

Solution: Height (30 cm) and horizontal width (40 cm) form a right-angled triangle; the ramp is the hypotenuse.

$MA = L / h = 50 \text{ cm} / 30 \text{ cm} = \mathbf{1.67}$.

Example 8: Balancing a seesaw (NCERT Example 7.12)

Question: For a seesaw having four seats, each at a distance of 1 m from the pivot, on which seats should children of masses 30 kg and 20 kg sit to balance the seesaw?



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Solution: A and B lie on one side of the fulcrum C, D and E on the other. Put the 15 kg child on A (2 m from C) and the other child at distance L on the other side. Using effort $\times$ effort arm = load $\times$ load arm: $15 \text{ kg} \times 2 \text{ m} = 30 \text{ kg} \times L$, so $L = 1 \text{ m}$. The 30 kg child sits on **seat D**. (Equally, 15 kg on E and 30 kg on B.) The heavier child sits closer to the fulcrum.

Example 9: Ball thrown up against air resistance (NCERT exercise 10)

Question: A ball of mass 2 kg is thrown up with a velocity of 20 m s^{-1} . (i) Identify the sign of the work done by gravity on the ball during its upward motion and its downward motion. (ii) If the ball reaches a height of 19.4 m, how much work was done by air resistance (assume $g = 10 \text{ m s}^{-2}$).

Solution: (i) Gravity acts downward. Going up, displacement is upward: **negative work**. Coming down, displacement is downward: **positive work**.

(ii) Initial energy: $K = \frac{1}{2} \times 2 \times 20^2 = 400 \text{ J}$, $U = 0$. At the top: $K = 0$, $U = 2 \times 10 \times 19.4 = 388 \text{ J}$. Change in mechanical energy = $388 - 400 = -12 \text{ J}$. Work done by air resistance = **-12 J**.

Competency-Based Questions

1. Source-based: The gharat of the Himalayan region

In the Himalayan region, water flowing down the mountain turns a traditional gharat or panchakki. The traditional gharat or panchakki uses the water's energy. A wheel turns a grinding stone for grain.

(a) Name the energy changes from the top to the bottom.
kinetic energy of water $\rightarrow$ kinetic (rotation) + sound due to friction.

(b) 50 kg of water falls through a vertical height of 8 m. How much work is done?
lose? ($g = 10 \text{ m s}^{-2}$) $mgh = 50 \times 10 \times 8 = 4000 \text{ J}$

(c) With no losses, what would its speed be at the bottom?

2. Data-based: Beam balance reaction

In Activity 7.5, the left pan holds 1 coin at 2 g and the right pan as follows.



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Coins in right pan, n_2	1	2	4	8
Distance of right pan, L_2 (cm)	20	10	5	?

(a) What rule do the readings follow? $n_1 \times L_1 = n_2 \times L_2 = 20$ coin cm in every case.

(b) Find the missing value. $8 \times L_2 = 20$, $L_2 = 2.5$ cm.

(c) Treating the single coin as effort, what is the MA in the last case? $MA = \text{load/effort} = 8/1 = 8$
 $= \text{effort arm/load arm} = 20/2.5$.

3. Assertion-Reason

Assertion (A): A girl walking on a level road with a box in her hands does no work on the box through the upward force she applies. **Reason (R):** Work done by a force is zero when the force is perpendicular to the displacement.

Answer: (a) Both true, and R is the correct explanation of A.

4. Assertion-Reason

Assertion (A): When the speed of a car doubles, its kinetic energy is proportional to the square of the speed.

Answer: (d) A is false, R is true. Doubling the speed of a car doubles its kinetic energy.

5. Assertion-Reason

Assertion (A): A fixed pulley is useful even though it does not change the direction of the force applied. **Reason (R):** A fixed pulley changes the direction of the force applied.

Answer: (a) Both true, and R is the correct explanation of A.

6. Assertion-Reason

Assertion (A): On a frictionless slide, a heavier object reaches the bottom with the same speed. **Reason (R):** Both the potential energy at the top and the kinetic energy at the bottom are proportional to the mass.



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Answer: (a) Both true, and R is the correct explanation of A. m cancels in $mgh = \frac{1}{2}mv^2$, leaving $v = \sqrt{2gh}$.

7. Case-based: Roads on hills

A mountain road climbs 100 m of height over 2 km of road length. A 10000 kg truck moves up it at a steady speed. Ignore friction; $g = 10 \text{ m s}^{-2}$.

(a) Treat the road as an inclined plane. What is its MA? $MA = L/h = 2000/100 = 20$.

(b) What force along the road is needed? Effort = load/MA = $(10000 \times 10)/20 = 5000 \text{ N}$.

(c) Compare the work done with lifting the truck straight up 100 m. Along the road: $5000 \text{ N} \times 2000 \text{ m} = 10^7 \text{ J}$. Straight up: $mgh = 100000 \times 100 = 10^7 \text{ J}$. The same work; the gentle slope only lowers the force needed.

8. Case-based: Two students on the stairs

Riya (40 kg) runs up a 6 m high staircase in 4 s. Take $g = 10 \text{ m s}^{-2}$.

(a) Who does more work? Riya: $40 \times 10 \times 6 = 2400 \text{ J}$. Same work for both. More work.

(b) Who develops more power? Riya: $2400/4 = 600 \text{ W}$. Same power for both. More powerful.

(c) What does this show? Work depends on the height. Power depends on how quickly the work is done.



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Important Questions for

1-Mark Questions

1. **State whether True or False: Work is done if an object does not move.** False. With no displacement, no work is done.

2. **Fill in the blank: 1 joule of work is done when a force of 1 newton moves an object 1 metre in the direction of the force.** 1 (N m)

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3. **State whether True or False: A motionless stretched rubber band has kinetic energy.** False.
It has potential energy due to its deformed shape.
4. **What is the mechanical advantage of a fixed pulley?** 1, since effort equals load.
5. **Express 1 horsepower in watt.** 1 hp = 746 W.

2-Mark Questions

1. **When a ball thrown upwards reaches its highest point, tick which of the following statement(s) are correct? (i) The force acting on the ball is zero. (ii) The acceleration of the ball is zero. (iii) Its kinetic energy is zero. (iv) Its potential energy is maximum.** (iii) and (iv).
Gravity still acts, so force and acceleration (g, downward) are not zero; the ball is momentarily at rest at its greatest height.
2. **Two objects A and B of mass m and 4m have the same kinetic energy. What is the ratio of the magnitude of velocities of A and B?** $\frac{1}{2}mv_A^2 = \frac{1}{2}(4m)v_B^2$ gives $v_A = 2v_B$, so **2 : 1**.
3. **Explain why roads on hills are built to wind around in gentle slopes rather than going straight up.** A winding road is an inclined plane. The mechanical advantage $MA = L/h$ is larger, so vehicles need a smaller effort.



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3-Mark Questions

1. **A student is slowly lifted straight up in a building. Later, the same student climbs a ladder. The height of the building is $h = 72.5$ m, and the student's mass is $m = 50$ kg. (i) Find the work done in lifting the student straight up to the top. (ii) Find the gain in potential energy of the student on the stairs to the same top. (iii) What do you conclude about the work done? (i) and (ii) both are equal, as work done is only on the height gained, not on the path.**
2. **A crane lifts a mass m to the 10th floor of a building. To lift the same mass to the 20th floor of the same building, how much more power is required? Assume that the height of each floor is h from the ground and floor n is n floor-heights above the ground. First lift: energy $E = mgh$ in time t, power $P = E/t$. Second lift: energy E more. Power = $2E/2t = E/t$: t is the same. If the crane started from the 10th floor, it would need only half the power.**

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3. A man of mass 60 kg rides a scooter of mass 100 kg. He accelerates the scooter to a velocity v . The next day, his son with a mass of 40 kg joins him as a passenger. If the scooter reaches the same speed on both days in the same time interval, what is the ratio of the fuel of the tank used on the two days? Assume that the energy transfer to the scooter happens entirely due to fuel, and no other losses occur due to air resistance and friction. Fuel $\propto$ kinetic energy given $\propto$ total mass at the same v . Day 1: 160 kg; day 2: 200 kg. Ratio = $160 : 200 = 4 : 5$.

5-Mark Questions

- Derive $K = \frac{1}{2}mv^2$ using the work-energy theorem. How does K change if the velocity is doubled?** A constant force F acts on mass m , changing velocity from u to v over displacement s . From $v^2 = u^2 + 2as$, $s = (v^2 - u^2)/(2a)$. $W = F \times s = ma \times (v^2 - u^2)/(2a) = \frac{1}{2}m(v^2 - u^2)$. By the work-energy theorem this is the change in energy. Starting from rest ($u = 0$) it is the kinetic energy: $K = \frac{1}{2}mv^2$. Doubling v makes $K = \frac{1}{2}m(2v)^2 = 4 \times \frac{1}{2}mv^2$, four times the original.
- Show that the mechanical energy of a freely falling object remains constant.** Drop mass m from rest at height h . At the top: $U = mgh$, $K = 0$. At the bottom: $U = 0$, $K = mgh$. So $U + K = mgh$ is constant.
- A coconut of mass 1.5 kg falls from the top of a tree. The height of the tree is 10 m. On impact, it creates a depression in the sand. (i) Calculate the depth of the depression. (ii) Assume that the average resistive force of the sand is 3000 N. How much energy is used to create the depression?** (i) $U = mgh = 1.5 \times 10 \times 10 = 150 \text{ J}$. (ii) Kinetic energy $K = 150 \text{ J}$ is used to do work against the sand. $W = F \times d = 3000 \times d = 150$. So $d = 0.05 \text{ m}$. (iii) The tiny amount of energy (0.75 J) is ignored.



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Common Mistakes and Explanations

- Calling any effort "work".** Holding a heavy box is not work. Fix: check for displacement along the force.
- Using total distance when the force is not constant.** Upward force does no work. Fix: use only the distance over which the force acts.

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3. **Dropping the minus sign.** Braking, friction, a goalkeeper stopping a ball, gravity on a rising ball: all do negative work. Fix: take s negative when it is opposite to the force, and keep the sign through the work-energy equation.
4. **Squaring km h^{-1} .** Fix: convert to m s^{-1} first (divide by 3.6) and only then use $\frac{1}{2}mv^2$.
5. **Assuming K doubles when v doubles.** Fix: $K \propto v^2$, so double speed gives four times K .
6. **Grams in mgh .** Fix: 200 g is 0.2 kg; convert to SI before substituting.
7. **Thinking the stairs give more potential energy than the lift.** Fix: $U = mgh$ depends only on the height gained, never on the path.
8. **Saying force or acceleration is zero at the top of a throw.** Only the velocity (and so K) is zero; gravity still acts with acceleration g . Fix: separate velocity from acceleration.
9. **Believing a machine reduces work.** Fix: a machine reduces or redirects the force; the effort moves further, and the total work (ignoring friction) stays the same.
10. **Inverting mechanical advantage.** Fix: $MA = \text{load/effort} = L/h$ for a ramp = effort arm/load arm for a lever.



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Quick Revision Points

- Work by a constant force = force $\times$ displacement
- SI unit of work: joule; $1 \text{ J} = 1 \text{ N} \times 1 \text{ m} = 1 \text{ kg m}^2 \text{ s}^{-2}$
- Work has no direction; it is positive, negative or zero
- $W = 0$ when $F = 0$, when $s = 0$, or when $F \perp s$
- Work-energy theorem: work done on an object = change in its kinetic energy
- $K = \frac{1}{2}mv^2$; derived from $W = \frac{1}{2}m(v^2 - u^2)$
- Double speed: four times K . Same K , mass doubles
- Potential energy is stored by deformation (Earth-ball, magnets, charges).
- $U = mgh$ near the Earth's surface; it depends on height
- Only gravity acting: $K + U$ stays constant
- Frictionless slide or free fall through height h : $v = \sqrt{2gh}$
- Power = rate of doing work, $P = W/t$; $1 \text{ W} = 1 \text{ J/s}$
- Simple machines change the magnitude of force

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- $MA = \text{load} / \text{effort}$. Fixed pulley: $MA = 1$, changes direction only.
- Inclined plane: $F' \times L = mgh$; $MA = L/h > 1$; longer and gentler means less effort.
- Lever: $\text{effort} \times \text{effort arm} = \text{load} \times \text{load arm}$; $MA = \text{effort arm} / \text{load arm}$.

Weightage and Exam Pattern

Class 9 has no board exam. This chapter is assessed in school exams (periodic tests, half-yearly and annual papers), and the NCERT source gives no fixed mark allocation for it.

Question type	What this chapter typically supplies
MCQ, true/false, fill in the blanks	Units (joule, watt, horsepower), sign of work, K and U formulas, MA of a fixed pulley
Assertion-Reason	Zero work for $\vec{F} \perp \vec{d}$, $W = \sqrt{2gh}$, max
Short answer (2 to 3 marks)	One-step K, U path-independence
Long answer (5 marks)	Derivation of K energy, work-energy
Case-based and source-based	Escape ramps stair-climbing

This chapter is the foundation for Class 10 conservation return in every later numeric



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