CLASS 9 SCIENCE

Chapter 7 Notes

Work, Energy and Simple Machines

Chapter focus

This chapter develops the scientific ideas of work, energy and power, relates work to changes in energy, explains kinetic and potential energy and conservation of mechanical energy and introduces simple machines such as pulleys, inclined planes and levers.

1. Work Done by a Constant Force

- Work is done by a force on an object when the force produces displacement in the direction of the force.
- For a constant force acting along the displacement: $W = F \times s$.
- A larger force acting through the same distance does proportionally more work.
- The same force acting through a larger distance also does proportionally more work.
- While describing work, specify the force or agency doing the work and the object on which the work is done.
- The SI unit of work is joule (J).
- $1\ J = 1\ N \times 1\ m = 1\ kg\ m^2\ s^{-2}$.
- For a force-displacement graph, work done is represented by the area under the graph.

2. When is Work Zero?

Situation	Work done
Force on the object is zero	Zero
Object has no displacement	Zero
Force is perpendicular to displacement	Zero

- Pushing a rigid wall does no mechanical work on the wall because the wall does not move.
- A person carrying a box horizontally applies an upward force while displacement is horizontal; the force and displacement are perpendicular, so this force does zero work on the box.

Important

You may feel tired even when mechanical work on an object is zero because your body uses internal energy while muscles act.

3. Positive and Negative Work

Type	Direction of force and displacement	Example
Positive work	Same direction	Pushing a wheelchair forward
Negative work	Opposite directions	Goalkeeper stopping a moving ball
Zero work	No displacement or perpendicular directions	Holding a load steady / carrying it horizontally

- When positive work is done on an object, its energy can increase.
- When a force opposes motion, its work can be negative.

4. Work-Energy Theorem

Statement
Work done on an object = change in its energy.

- An object having the capacity to do work is said to possess energy.
- Positive work can transfer energy to an object.
- An object can later transfer its energy by doing work on another object.
- The work-energy theorem can also be applied to a system of objects and to situations where forces are not constant.
- The SI unit of energy is joule (J), the same as the unit of work.
- Mechanical work is one way of transferring energy; energy can also be transferred through heat, radiation, electric circuits, sound waves and other processes.

5. Forms of Energy

Form	Basic idea / example
Mechanical energy	Energy due to motion or position.
Thermal energy	Energy associated with warming or heating.
Light energy	Energy that enables us to see.
Sound energy	Energy associated with vibrations.
Electrical energy	Energy related to position or motion of charges.
Chemical energy	Energy stored in chemical bonds, such as in food and fuels.
Nuclear energy	Energy stored in atomic nuclei.

- Energy can change from one form to another.
- A bulb converts electrical energy into light energy.
- An electric water heater converts electrical energy into thermal energy.
- Food provides chemical energy that can be converted into mechanical energy by muscles.
- A ringing bell converts mechanical energy into sound energy.

6. Mechanical Energy

- Mechanical energy is the energy an object possesses due to its motion or position.
- Mechanical energy = kinetic energy + potential energy.

7. Kinetic Energy

Definition
The energy possessed by an object due to its motion is called kinetic energy.

- All moving objects possess kinetic energy.
- For an object of mass m moving with velocity v: $K = \frac{1}{2}mv^2$.
- The SI unit of kinetic energy is joule (J).
- Kinetic energy has no direction.
- If velocity doubles while mass remains the same, kinetic energy becomes four times.
- Positive work that increases speed increases kinetic energy; negative work that reduces speed decreases kinetic energy.
- If velocity remains unchanged, kinetic energy remains constant.

8. Potential Energy

Definition
Energy stored because of deformation of an object or because of the relative positions of objects in an interacting system, is called potential energy.

- A stretched rubber band, bent bow and compressed or stretched spring can store potential energy.
- Systems involving gravitational, electric or magnetic interactions can store energy because of relative positions.
- Work done against some internal forces can increase the potential energy of a system.
- Work done against friction does not result in stored potential energy.

9. Gravitational Potential Energy

- Near Earth's surface, raising an object requires work against gravitational force.
- For mass m raised through height h: $W = mgh$.
- Taking the ground configuration as zero potential energy, gravitational potential energy at height h is $U = mgh$.
- Greater mass or greater height gives greater gravitational potential energy, for the same value of g.
- The SI unit of potential energy is joule (J).

Note
The expression $U = mgh$ is used near Earth's surface, where g can be treated as approximately constant.

10. Conservation of Mechanical Energy

- The sum of kinetic energy and potential energy is called mechanical energy.
- As a freely falling object moves downward, its potential energy decreases while its kinetic energy increases.
- The decrease in potential energy is converted into an equal increase in kinetic energy when no other external forces remove mechanical energy.
- Thus, mechanical energy remains constant for motion under gravity when other external forces are absent.
- For a pendulum, energy changes between potential and kinetic energy as the bob moves.
- In real situations, friction and air resistance gradually reduce mechanical energy by transferring it to other forms.

Conservation principle
When only the relevant conservative interaction is involved, $K + U$ remains constant. This can often provide a simpler way to solve motion problems.

11. Power

Definition
Power is the rate at which work is done.

- Average power: $P = W/t$.
- Doing more work in the same time requires more power.
- Doing the same work in less time also requires more power.
- The SI unit of power is watt (W).
- $1\ W = 1\ J\ s^{-1}$.
- Another unit sometimes used for engines is horsepower; $1\ hp = 746\ W$.

12. Simple Machines

- Simple machines make tasks easier by changing the magnitude or direction of the force that must be applied.
- They do not reduce the total work required in the ideal case.
- The force applied to a machine is called effort.
- The force that must be overcome is called load.
- Mechanical advantage (MA) = load/effort.
- The three simple machines: pulley, inclined plane and lever.

13. Pulley

- A pulley is a grooved wheel that guides a rope.
- A fixed pulley changes the direction of effort but does not reduce its magnitude in the ideal case.
- For an ideal fixed pulley, effort = load and mechanical advantage = 1.
- A movable pulley or a system of pulleys can have mechanical advantage greater than 1.
- Pulley systems are used in applications such as elevators and cranes.

14. Inclined Plane

- An inclined plane allows a heavy load to be moved to a higher or lower level using a smaller force over a larger distance.
- As the plane becomes longer and less steep for the same height, the required effort decreases.
- Ignoring friction, effort × length of plane = load × vertical height.
- Mechanical advantage of an ideal inclined plane: $MA = L/h$, where L is the length of the plane and h is its vertical height.
- Since $L > h$, an ideal inclined plane has mechanical advantage greater than 1.

Trade-off
A simple machine can reduce the force required, but the effort generally has to act through a greater distance. Ideally, total work remains the same.

15. Lever

- A lever is a rigid bar that can rotate about a fixed point called the fulcrum.
- The distance from the fulcrum to the point where effort acts is the effort arm.
- The distance from the fulcrum to the load is the load arm.
- For balance: effort × effort arm = load × load arm.
- Mechanical advantage of a lever = load/effort = effort arm/load arm.
- Increasing the effort arm can reduce the effort needed to move a given load.

16. Classes of Levers

Class	Relative position	Examples
Class I	Fulcrum between effort and load	Scissors, crowbar, pliers, balance scale, seesaw
Class II	Load between fulcrum and effort	Lemon squeezer, wheelbarrow, bottle opener
Class III	Effort between fulcrum and load	Tongs/tweezers, broom, hammer, oar

- Many everyday machines combine two or more simple machines.
- Machines do not create energy; they help us use energy more conveniently and effectively.

17. Important Formulae

Concept	Formula
Work by constant force along displacement	W = F × s
Work-energy theorem	W = change in energy
Kinetic energy	$K = ½mv^2$
Gravitational potential energy	U = mgh
Mechanical energy	E = K + U
Power	P = W/t
Mechanical advantage	MA = load/effort
Inclined plane	MA = L/h
Lever balance	effort × effort arm = load × load arm
Lever mechanical advantage	MA = effort arm/load arm

18. Common Conceptual Points

- Applying a force alone does not guarantee that mechanical work is done; displacement in the direction of force is required.
- Work and energy have the same SI unit, joule.
- Work can be positive, negative or zero; energy itself is not assigned a direction.
- Kinetic energy depends on the square of velocity.
- Gravitational potential energy near Earth's surface depends on mass, g and vertical height, not on the path taken.
- A machine may reduce effort, but ideally it cannot reduce the total work needed for the task.
- A fixed pulley mainly provides convenience by changing the direction of effort.
- A longer, gentler inclined plane requires less force but greater displacement.
- In a lever, a longer effort arm can provide greater mechanical advantage.
- Real machines eventually lose useful mechanical energy because of effects such as friction.

19. Quick Numerical Examples

Example 1: Work
A 200 N force acts opposite to a displacement of 0.15 m. Work = 200 × (−0.15) = −30 J.

Example 2: Kinetic energy
For m = 2 kg and v = 4 m s^{-1}: K = ½ × 2 × 4^2 = 16 J.

Example 3: Potential energy
For m = 0.2 kg, h = 10 m and g = 10 m s^{-2}: U = mgh = 20 J.

Example 4: Power
If 1500 J of work is done in 5 s: P = 1500/5 = 300 W.

Example 5: Inclined plane
For an ideal ramp of length 50 cm and height 30 cm: MA = 50/30 ≈ 1.67.

20. Key Terms

Term	Meaning
Work	Energy transfer associated with a force producing displacement.
Energy	Capacity to do work.
Kinetic energy	Energy due to motion.
Potential energy	Stored energy due to deformation or relative position.
Mechanical energy	Sum of kinetic and potential energy.
Power	Rate of doing work.
Effort	Force applied to a machine.
Load	Force that the machine must overcome.
Mechanical advantage	Ratio of load to effort.
Pulley	Grooved wheel used with a rope.
Inclined plane	Sloping surface used to move a load between levels.
Lever	Rigid bar that rotates about a fulcrum.
Fulcrum	Fixed point about which a lever rotates.

21. Exam-Oriented Self-Check Questions

1. Define work done by a constant force and write its SI unit.
2. Under what conditions is work done equal to zero?
3. Differentiate between positive, negative and zero work with one example each.
4. State the work-energy theorem.
5. Define energy. Name the forms of energy.
6. Define kinetic energy and derive/write its expression.
7. How does kinetic energy change if velocity is doubled?
8. What is potential energy? Give examples of energy stored due to deformation.
9. Write the expression for gravitational potential energy near Earth's surface.
10. Explain the conservation of mechanical energy for a freely falling object.
11. How do kinetic and potential energies change during the motion of a simple pendulum?
12. Define power and write its SI unit.
13. What is meant by effort, load and mechanical advantage?
14. How does a fixed pulley make work more convenient?
15. Why can a movable pulley require less effort than lifting a load directly?
16. Explain why a longer inclined plane requires less effort for the same height.
17. Write the mechanical advantage of an ideal inclined plane.
18. State the law/condition of balance for a lever.
19. Differentiate among Class I, Class II and Class III levers.
20. Why can no real machine do useful work forever without an energy source?

One-Minute Chapter Summary

Quick revision

Work by a constant force along displacement is W = Fs and is measured in joules. Work changes the energy of an object or system. Kinetic energy is $K = \frac{1}{2}mv^2$ and gravitational potential energy near Earth's surface is U = mgh. Their sum is mechanical energy, which remains conserved in ideal motion under gravity when other external forces do not remove mechanical energy. Power is the rate of doing work, P = W/t. Simple machines such as pulleys, inclined planes and levers change the magnitude or direction of effort; they provide convenience or mechanical advantage but do not create energy or reduce the ideal total work.

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