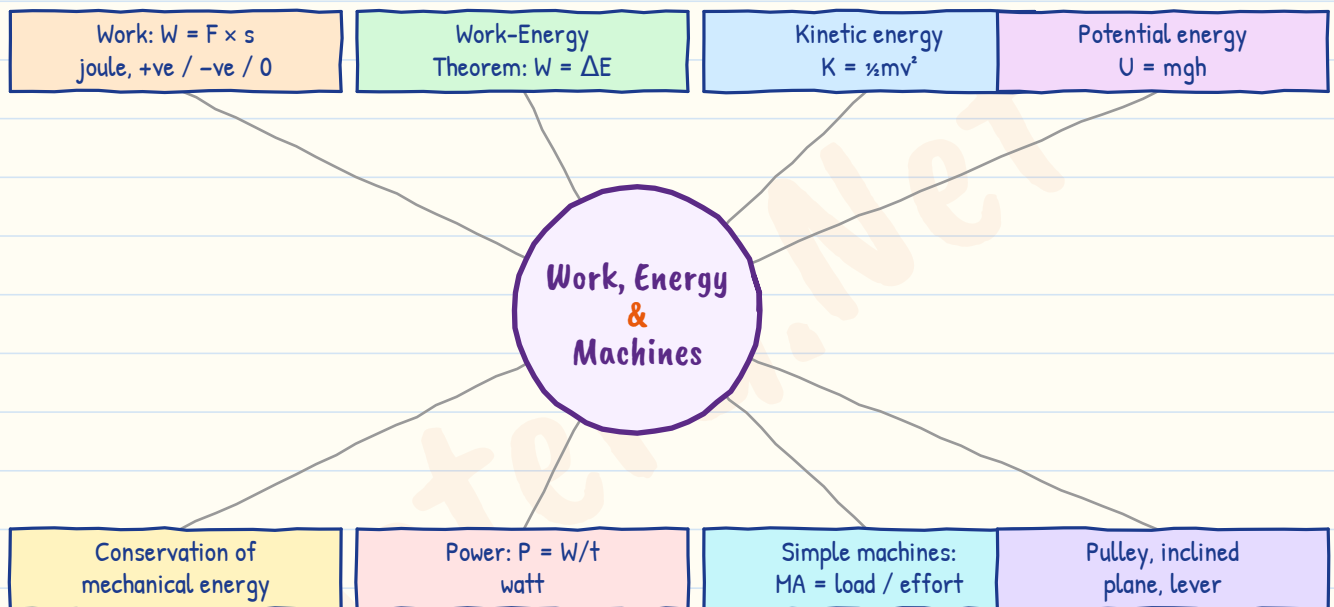


MasterG.Net CBSE Coaching Classes

Work, Energy, and Simple Machines

Class 9 Science (Exploration) | NCERT Chapter 7

Handwritten Notes + In-between Q&As + Derivations + Numericals + Most Important Questions



Roadmap of the chapter: one look and you know the whole journey!

How to read these notes

[Textbook] = straight from NCERT [Extra] = beyond the book, builds understanding [★

Most Imp] = exam favourite, revise twice!

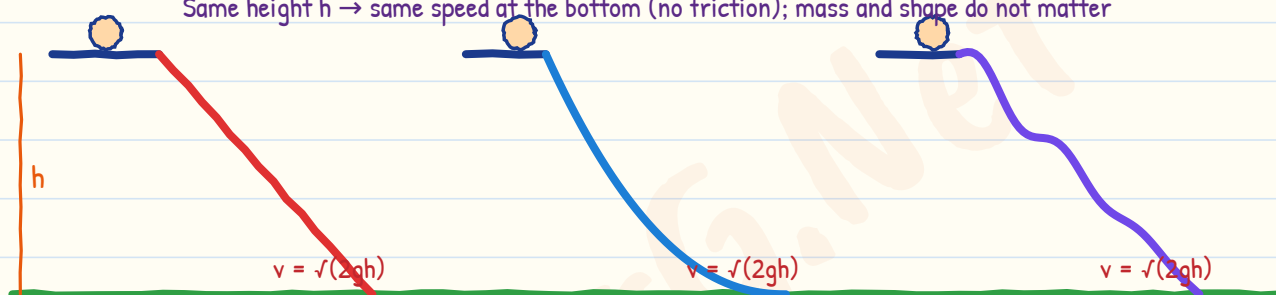
Red highlighted words = **key terms**. Green words = **answers / results**. Blue = normal ink.

Every numerical is solved in 4 steps: Given → Formula → Substitute → Answer with unit.

7.0 Why This Chapter?

- ✦ In Chapters 4 and 6 we used kinematic equations and Newton's laws. But when forces change with time or act in complicated ways, these become difficult.
- ✦ A simpler, more powerful way: the ideas of **work, energy and power**. Energy is the **capacity to do work**; it sits behind almost every activity (food → walking, electricity → fan, fuel → car).
- ✦ We also study **simple machines** which let us do tasks with less effort or more convenience.
- ✦ In science, work, energy and power have **precise meanings**, different from everyday talk.

Same height h → same speed at the bottom (no friction); mass and shape do not matter



Think It Over (slides): all three children start at the same height h

Think It Over: Dekhe Kya Seekha Tumne? (answers at the end of the journey)

Q1. What will be the magnitude of velocity of the child at the bottom of the blue slide?

[Textbook]

Ans. Using conservation of energy: $mgh = \frac{1}{2}mv^2 \rightarrow v = \sqrt{2gh}$, where h = height of the slide (friction ignored).

Q2. Will two children of different masses reach the bottom of the same slide with the same velocity? [Textbook]

Ans. Yes. Mass cancels out in $mgh = \frac{1}{2}mv^2$, so $v = \sqrt{2gh}$ does not depend on mass.

Q3. Which slide gives the largest velocity at the bottom? [Textbook]

Ans. The one with the **greatest height h** . The shape or length of the slide does not matter (ignoring friction).

7.1 Work Done by a Constant Force

► Building the idea: lifting wheat bags (Fig. 7.2)

- ✦ Lift a 5 kg bag slowly to 1 m: you apply an upward force $F = mg$ and the bag moves 1 m in the direction of force → you did some work (call it W).
- ✦ Lift 3 bags one after another to 1 m → $3W$ (more fuel needed if a machine does it).
- ✦ Lift all 3 bags together to 1 m: force is 3 times ($3F$) over the same distance → work is also $3W$.
- ✦ Lift 1 bag to 3 m: same force over 3 times the distance → $3W$.
- ✦ So work $\propto$ force and work $\propto$ displacement: a bigger force, or a longer displacement, means more work.

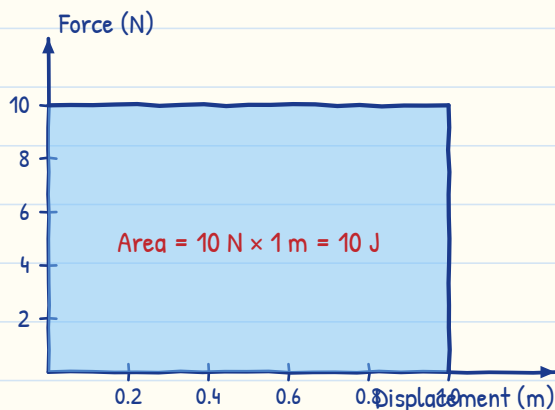
Definition + formula ★

- ✦ Work done on an object by a constant force = **force $\times$ displacement in the direction of the force**
- ✦ $W = F \times s$ (Eq. 7.2) SI unit: **joule (J)**
- ✦ **1 J** = work done when a force of 1 N displaces an object by 1 m in the direction of the force: $1 \text{ J} = 1 \text{ N} \times 1 \text{ m} = 1 \text{ kg m}^2 \text{ s}^{-2}$.
- ✦ Work has **magnitude and sign (+ or -) but no direction**, i.e. it is a scalar. Force and displacement are vectors.

Note from the book

- ✦ While describing work, always say **which force (agency)** does the work and **on which object**. Example: "work done by the girl on the dumbbell".

► Force-displacement graph (Fig. 7.4)



Area under the F - s graph

= WORK DONE

(works even if force is not constant)

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

Fig. 7.4: Work = area under the force-displacement graph

Even when the force is **not constant**, work can be found as the area under the F - s graph between the initial and final positions.

► When is work done equal to zero? (7.1.1)

Situation	Why work = 0	Example
Force is zero ($F = 0$)	$W = 0 \times s = 0$	Object sliding on a frictionless surface at constant velocity (no horizontal force)
No displacement ($s = 0$)	$W = F \times 0 = 0$	Pushing a rigid wall; weightlifter holding a barbell steady
Force $\perp$ displacement	No displacement in the direction of force	Girl carrying a box while walking: her upward force does zero work on the box

- ♦ Why do we feel tired when pushing a wall? Muscles repeatedly expand and contract and use up **internal (chemical) energy** of the body, but no work is done **on the wall** in the scientific sense.
- ♦ Next Level Up: if force makes an angle θ with displacement, $W = F s \cos\theta$ (higher grades; at $\theta = 90^\circ$ this gives zero).

► Positive and negative work (7.1.2)

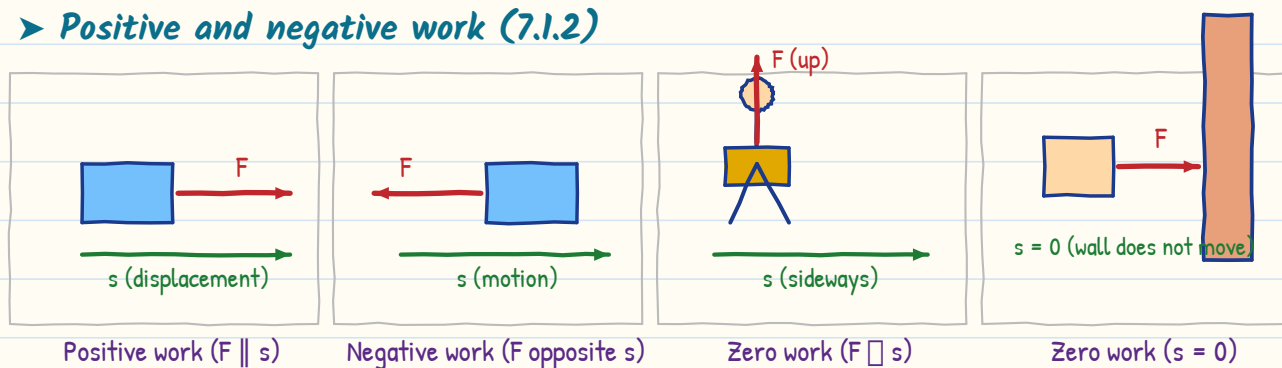


Fig. 7.6 / 7.7: Positive, negative and zero work

- ♦ Displacement in the **same direction** as the force $\rightarrow$ work is **positive** (pushing a wheelchair).

- ✦ Displacement in the **opposite direction** to the force $\rightarrow$ work is **negative** (goalkeeper stopping a ball; friction on a sliding object).
- ✦ Book note: the ball and goalkeeper apply equal and opposite forces on each other: the ball does positive work on the goalkeeper, the goalkeeper does negative work on the ball.

Example 7.1 + 7.2 (solved)

- ✦ **Ex 7.1** Girl lifting a dumbbell and lowering it: while lifting, force (upward) and displacement (upward) are in the same direction $\rightarrow$ **positive work**. While lowering slowly, her force (upward, holding it) is opposite to displacement (down) $\rightarrow$ **negative work**.
- ✦ **Ex 7.2** Given: $F = 200 \text{ N}$ (on the ball, opposite to its motion); displacement of the ball taken as -0.15 m .
- ✦ Formula: $W = F \times s \rightarrow W = 200 \text{ N} \times (-0.15 \text{ m}) = -30 \text{ J}$ (negative because the force opposes the displacement).

Galtiyan Mat Karna! (Common mistakes) ★

- ✦ "I pushed hard for 10 minutes, so I did a lot of work": wrong if the object did not move. **No displacement $\rightarrow$ no work**.
- ✦ Carrying a bag while walking on level ground does **zero work by the lifting force** (force up, motion sideways).
- ✦ Work can be **negative**; energy transferred out of the object. Negative work does NOT mean "no work".
- ✦ Do not forget the sign when displacement is opposite to force; and always convert $\text{cm} \rightarrow \text{m}$, $\text{g} \rightarrow \text{kg}$, $\text{km h}^{-1} \rightarrow \text{m s}^{-1}$ (divide by 3.6).

Pause and Ponder + Extras: Chalo, Dimaag Lagayein!

Q1. A weightlifter holds a barbell steady in her hands (Fig. 6.8). Is she doing any work on the barbell? [Textbook]

Ans. No. The barbell does not move ($s = 0$), so $W = F \times 0 = 0$, even though she feels tired (muscles use internal energy).

Q2. Is the work done by friction on a stack of coins moving on a rough surface positive, negative or zero? [Textbook]

Ans. **Negative**. Friction acts opposite to the direction of motion (displacement).

Q3. Define 1 joule of work. [Extra ★ Most Imp]

Ans. 1 J is the work done when a force of 1 N moves an object by 1 m in the direction of the force.

Q4. A force of 40 N moves a trolley 5 m in the direction of the force. Find the work done.

[Extra ★ Most Imp]

Ans. Given $F = 40 \text{ N}$, $s = 5 \text{ m}$. $W = F \times s = 40 \times 5 = 200 \text{ J}$.

Q5. A cyclist applies brakes; the braking force is 50 N and the cycle moves 4 m before stopping. Work done by the brakes? [Extra ★ Most Imp]

Ans. Force opposes motion: $W = 50 \times (-4) = -200 \text{ J}$.

Q6. A man carries a 20 kg load on his head and walks 100 m on level ground. Work done by him on the load? [Extra]

Ans. Zero: the force he applies (up, equal to the weight) is perpendicular to the horizontal displacement.

Q7. Why is work a scalar although force and displacement are vectors? [Extra ★ Most Imp]

Ans. Work depends on the product of the magnitude of force and displacement along the force; it has only magnitude and a sign (+/-), no direction.

7.2 The Work-Energy Theorem

- ✦ A fielder's thrown ball hits the wickets and makes them fall; a flowerpot raised to a height can damage an object below when it falls. Both have a **capacity to do work** → they possess **energy**.
- ✦ The ball got its energy from the work done by the fielder; the pot got its energy from the work done in raising it.
- ✦ When positive work is done on an object, it **gains energy**; it can use that energy to apply a force on another object (energy is **transferred**).

Work-Energy Theorem ★

- ✦ **Work done on an object = change in its energy** (Eq. 7.3) → $W = E_{\text{final}} - E_{\text{initial}}$
- ✦ Holds for a system of objects and also when forces are not constant. SI unit of energy = **joule (J)**, same as work.
- ✦ Positive work → energy increases. Negative work → energy decreases. Zero work → energy unchanged.

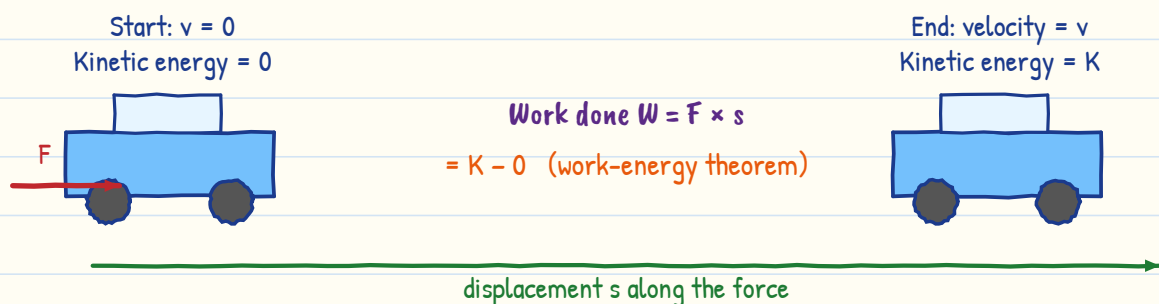


Fig. 7.11: Work done by force = kinetic energy gained from rest

Example 7.3: the carrom shot (solved)

- ✦ Striker hits the white coin: the striker does **positive work** on the white coin (its energy increases). By Newton's third law the white coin does **negative work** on the striker (striker's energy decreases).
- ✦ White coin hits black coin: white does positive work on black (black gains energy); black does negative work on white (white loses energy).
- ✦ So energy is **transferred** striker $\rightarrow$ white coin $\rightarrow$ black coin.

Ready to Go Beyond: other ways to transfer energy (Extra)

- ✦ Mechanical work is only **one way**. Energy is also transferred as **heat** (hot $\rightarrow$ cold), by **radiation** (Sun $\rightarrow$ Earth, no contact), through electric circuits, sound waves and even nuclear reactions in the Sun.
- ✦ Meet a Scientist: the joule is named after **James Prescott Joule**, who showed how mechanical and thermal energy are related and interconvertible.

Kuch Mazedaar Questions

Q1. State the work-energy theorem. [Textbook ★ Most Imp]

Ans. Work done on an object (or system) equals the change in its energy.

Q2. When you pedal a bicycle on a flat road, in what forms does your muscular energy appear?

[Textbook]

Ans. Mostly as **kinetic energy** of the bicycle + rider, and as **heat** (friction in the chain/tyres, air resistance, and body heat), plus a little sound. (On a slope, some becomes gravitational potential energy.)

Q3. Does a ball thrown by a fielder gain energy? From where? [Extra ★ Most Imp]

Ans. Yes. The fielder does positive work on the ball; by the work-energy theorem this work appears as the ball's kinetic energy.

Q4. If the work done on an object is negative, what happens to its energy? [Extra]

Ans. It decreases (the object loses/transfers energy), e.g. a ball stopped by a goalkeeper.

7.3 Forms of Energy

Energy is the capacity to do work. It exists in many forms and can change from one form to another.

Mechanical motion / position	Thermal makes things hot	Light lets us see	Sound vibrations of air
Electrical charges: position/motion	Nuclear stored in nuclei	Chemical fuel and food (bonds)	Energy changes form to form!

Fig. 7.10: Different forms of energy

Device / process	Energy conversion
Electric bulb	Electrical → light + heat
Electric water heater	Electrical → thermal
Food in our body	Chemical → mechanical (muscles) + heat
Ringling bell / speaking	Mechanical → sound
Photosynthesis	Light → chemical
Solar panel	Light → electrical
Microphone	Sound → electrical
Water falling from a dam	Gravitational PE → kinetic → (turbine) electrical
Burning matchstick	Chemical → heat + light
Fire cracker	Chemical → sound + light + heat + kinetic
Unwinding a watch spring	Elastic PE → kinetic
Truck moving uphill	Chemical (fuel) → kinetic + gravitational PE (+ heat)

Energy transformations: Revise Reflect Refine Q4 answers are included here

Law of conservation of energy (Extra)

- ✦ Energy can **neither be created nor destroyed**; it only changes from one form to another.
The total energy of an isolated system (no external forces) stays constant.

7.4 Mechanical Energy

Mechanical energy is the energy an object has due to its **motion or position**. It is of two kinds: **kinetic** and **potential**.

7.4.1 Kinetic Energy

- Energy possessed by an object due to its **motion**: a moving bicycle, a rolling ball.
- An object at rest is taken to have zero kinetic energy. Start from rest and apply force F ; by the work-energy theorem, work done = kinetic energy gained.

Derivation of $K = \frac{1}{2}mv^2$ ★ (Most Important)

- Mass m , initial velocity u , final velocity v , constant force F , displacement s , acceleration $a = F/m$.
- Step 1 (kinematics): $v^2 = u^2 + 2as \rightarrow s = (v^2 - u^2)/(2a)$ (7.4)
- Step 2 (definition): $W = F \times s$ and Newton's 2nd law $F = ma \rightarrow W = ma \times s$
- Step 3 (substitute s): $W = ma \times (v^2 - u^2)/(2a) = \frac{1}{2} m (v^2 - u^2)$ (7.5)
- Step 4 (work-energy theorem): this is the change in energy. For $u = 0$, change = final KE:
- $K = \frac{1}{2} m v^2$ (7.6) SI unit: joule (J). KE is a scalar (no direction).
- Positive work $\rightarrow$ velocity increases $\rightarrow$ KE increases. Negative work $\rightarrow$ velocity decreases $\rightarrow$ KE decreases. $W = 0$ and velocity constant $\rightarrow$ KE constant.
- $K \propto m$ (double the mass $\rightarrow$ double KE) and $K \propto v^2$ (double the speed $\rightarrow$ 4 times KE; triple $\rightarrow$ 9 times). This is why high-speed crashes are so dangerous.

Example 7.4: velocity of a vehicle doubles. KE?

- Initial KE = $\frac{1}{2}mv^2$. New KE = $\frac{1}{2}m(2v)^2 = \frac{1}{2}m \times 4v^2 = 4 \times (\frac{1}{2}mv^2) \rightarrow$ **4 times** the original.

Example 7.5: cricket ball, $m = 0.2$ kg, $v = 154.8$ km/h

- Given: $m = 0.2$ kg, $v = 154.8 \text{ km h}^{-1} = 154.8 \div 3.6 = 43 \text{ m s}^{-1}$.
- Formula: $K = \frac{1}{2}mv^2$. Substitute: $K = \frac{1}{2} \times 0.2 \times 43^2 = 0.1 \times 1849 =$ **184.9 J**.

Example 7.6: jet aircraft stopped by a wire ($m = 15000$ kg, $F = 367500$ N, $s = 100$ m)

- Final KE = 0; initial KE = $\frac{1}{2} \times 15000 \times v^2$. Change in KE = $-\frac{1}{2} \times 15000 \times v^2$.

- ✦ Wire force opposes displacement $\rightarrow$ work by wire $W = F \times s = 367500 \times (-100) \text{ J}$.
- ✦ Work-energy theorem: $-\frac{1}{2} \times 15000 \times v^2 = -367500 \times 100 \rightarrow v^2 = (2 \times 367500 \times 100)/15000 = 4900 \text{ m}^2 \text{ s}^{-2}$.
- ✦ $v = 70 \text{ m s}^{-1} = 252 \text{ km h}^{-1}$

Pause and Ponder: Quick Check — Ho Jaye?

Q1. Two objects A and B of mass m and $4m$ have the same kinetic energy. Ratio of their velocities? [Textbook ★ Most Imp]

Ans. $\frac{1}{2} m v_A^2 = \frac{1}{2} (4m) v_B^2 \rightarrow v_A^2 = 4 v_B^2 \rightarrow v_A = 2 v_B$.

➤ Ratio $v_A : v_B = 2 : 1$ (lighter object moves twice as fast).

Q2. Does the KE of an object moving with constant velocity change with its position? [Textbook]

Ans. No. $KE = \frac{1}{2}mv^2$ depends only on mass and speed; both are constant, so KE is constant wherever the object is.

Q3. Find the KE of a 1000 kg car at 36 km/h and at 72 km/h. Compare. [Extra ★ Most Imp]

Ans. 36 km/h = 10 m/s: $K = \frac{1}{2} \times 1000 \times 100 = 50000 \text{ J}$. 72 km/h = 20 m/s: $K = \frac{1}{2} \times 1000 \times 400 = 200000 \text{ J}$.

➤ Doubling the speed $\rightarrow$ **4 times** KE.

Q4. A body of mass 4 kg has 50 J of kinetic energy. Find its speed. [Extra ★ Most Imp]

Ans. $K = \frac{1}{2}mv^2 \rightarrow v^2 = 2K/m = 100/4 = 25 \rightarrow v = 5 \text{ m s}^{-1}$.

Q5. Can kinetic energy ever be negative? Why? [Extra]

Ans. No. m is positive and v^2 is positive, so $K \geq 0$. (Work can be negative; KE cannot.)

7.4.2 Potential Energy

- ✦ Slingshot, bow and arrow, stretched rubber band, spring: when released they apply a force on the object and give it **kinetic energy**; the stretched/bent object returns to its shape.
- ✦ So the work done earlier in deforming them was **stored** in the band/bow/spring (it can do work due to its **shape or configuration**).
- ✦ Energy can also be stored by changing the **arrangement (relative positions)** of objects in a system: separated unlike magnets, separated electric charges, the Earth-ball system when the ball is lifted.

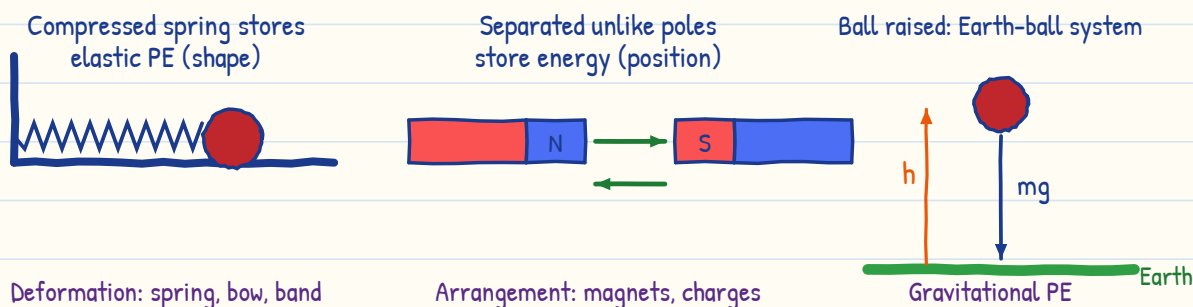


Fig. 7.14 – 7.16: Energy stored by deformation and by relative position

Definition ★

- ✦ **Potential energy** = energy stored in an object because of its **deformation**, or in a system of objects because of their **relative positions** (gravitational, electric or magnetic forces).
- ✦ **Ready to Go Beyond:** an external force is needed to overcome the internal forces and deform an object; when it is removed, the internal forces undo the deformation and can do work. **Next Level Up:** work done against **friction** is NOT stored as potential energy.

➤ Gravitational potential energy (GPE)

- ✦ Earth is far more massive than the ball, so it hardly moves; the energy of the Earth-ball system is simply called the **gravitational potential energy of the ball**. In this chapter "potential energy" means GPE.
- ✦ **Activity 7.1:** drop a heavy ball from 1 m and 2 m onto loose sand. The depression from the greater height is **deeper** → greater height means more potential energy (more work was done raising it).

Derivation of $U = mgh$ ★ (Most Important)

- ✦ Object of mass m on the ground; define $PE = 0$ there. Raise it **gradually** (slowly) to height h .
- ✦ Applied force = weight = mg (equal and opposite to gravity). Displacement = h .
- ✦ Work done $W = \text{force} \times \text{displacement} = mg \times h = mgh$ (7.7)
- ✦ By the work-energy theorem this work appears as potential energy: **$U = mgh$** (7.8) unit: joule (J).
- ✦ Valid near the Earth's surface only (g is constant). Far away, g decreases (higher grades).

Example 7.7: ball of 200 g at 10 m ($g = 10 \text{ m s}^{-2}$)

- ✦ Given: $m = 200 \text{ g} = 0.2 \text{ kg}$, $h = 10 \text{ m}$, $g = 10$. Formula: $U = mgh$.
- ✦ $U = 0.2 \times 10 \times 10 = \mathbf{20 \text{ J}}$.

Pause and Ponder: Yeh Zaroor Aayega!

Q1. Does the PE of an object near the Earth's surface change if it moves with constant velocity in the horizontal direction? What if it is gradually raised vertically? [Textbook ★ Most Imp]

Ans. Horizontal motion at constant height: h does not change $\rightarrow$ PE **does not change**.

➤ Raised vertically: h increases $\rightarrow$ PE **increases** ($U = mgh$).

Q2. Distinguish between kinetic energy and potential energy. [Extra ★ Most Imp]

Ans. KE: due to motion, $K = \frac{1}{2}mv^2$, zero for a body at rest; example: moving car. PE: due to position/deformation, $U = mgh$ (gravity), zero at the reference level; example: raised ball, stretched spring.

Q3. A 2 kg stone is lifted to a height of 5 m ($g = 10$). Find its PE. [Extra ★ Most Imp]

Ans. $U = mgh = 2 \times 10 \times 5 = 100 \text{ J}$.

Q4. Why is the PE of a spring said to be due to its "configuration"? [Extra]

Ans. Because the energy is stored by changing its shape (stretch/compression), not by motion.

Q5. Is gravitational PE of the ball or of the ball-Earth system? Why do we say "PE of the ball"? [Extra ★ Most Imp]

Ans. It belongs to the ball-Earth system (due to their separation). Since Earth is so massive that it hardly moves, we loosely call it the PE of the ball.

7.4.3 Conservation of Mechanical Energy

Mechanical energy = **kinetic energy + potential energy**. Let us follow an object of mass m dropped from rest from height h (free fall; only gravity acts).

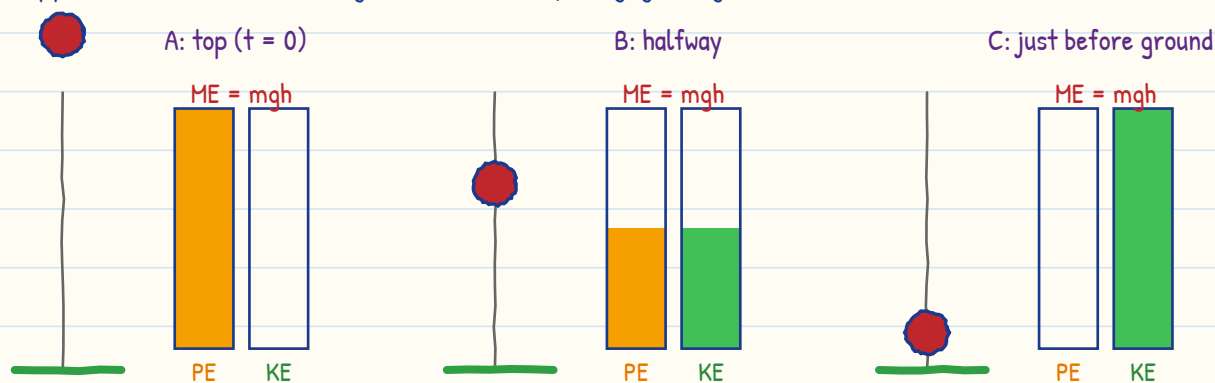


Fig. 7.19: PE changes into KE during free fall; the total stays mgh

Free-fall proof ★

➤ At A ($t = 0$, $u = 0$): $PE = mgh$; $KE = 0$; $ME = mgh$. (7.9)

➤ After time t at B: $v = u + gt = gt$ and fallen distance = $\frac{1}{2}gt^2$, so height $h' = h - \frac{1}{2}gt^2$.

- ✦ PE at B = $mgh' = mgh - \frac{1}{2}mg^2t^2$; KE at B = $\frac{1}{2}mv^2 = \frac{1}{2}mg^2t^2$ (7.10a, b)
- ✦ ME at B = $(mgh - \frac{1}{2}mg^2t^2) + \frac{1}{2}mg^2t^2 = mgh$ (same as at A!)
- ✦ The decrease in PE ($\frac{1}{2}mg^2t^2$) is exactly equal to the increase in KE ($\frac{1}{2}mg^2t^2$). Hence mechanical energy is **conserved** when no external force (like friction/air resistance) acts.

Statement

- ✦ If only gravitational (internal) forces act, the **mechanical energy remains constant**: PE + KE = constant. Loss in PE = gain in KE.

► Activity 7.2: the pendulum

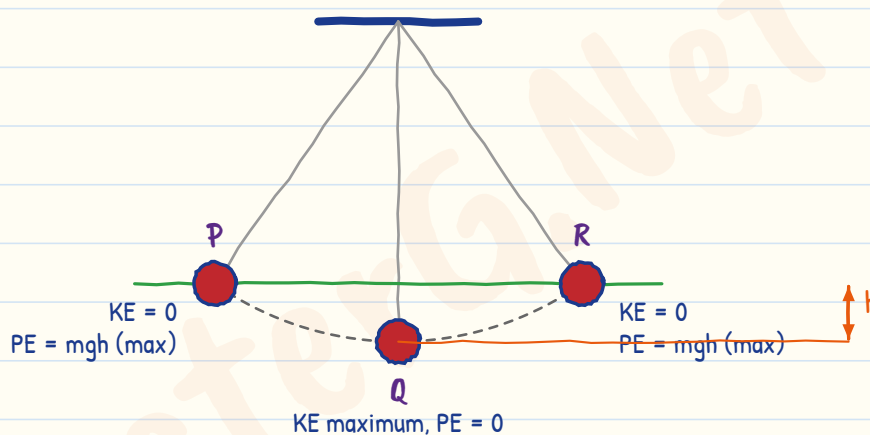


Fig. 7.20: Energy changes in a swinging pendulum

- ✦ Release the bob at P (level of the horizontal line). At P: KE = 0, PE = mgh (h from the lowest point). At Q (bottom): PE = 0, KE maximum. At R (other end): KE = 0 again and PE = mgh .
- ✦ The bob reaches **almost the same height** → mechanical energy stays (nearly) constant. In real life the pendulum slowly stops: energy is lost as **heat and sound** due to friction at the support and **air resistance**.
- ✦ Ready to Go Beyond: mechanical energy is one part of a bigger picture; the **total energy** (all forms) of an isolated system stays constant.

Threads of Curiosity

- ✦ Solving problems directly with Newton's laws can be cumbersome. Tracking total mechanical energy often gives the final speed or position **without working through the details of the motion**.

Example 7.8: speed of a child at the bottom of a slide of height h

- ★ PE at top = mgh ; KE at bottom = $\frac{1}{2}mv^2$; friction neglected $\rightarrow$ PE is entirely converted into KE.
- ★ $\frac{1}{2}mv^2 = mgh \rightarrow v^2 = 2gh \rightarrow v = \sqrt{2gh}$
- ★ v depends only on h , **not on the child's mass or the slide's shape**. (Same result for a freely falling body.)

Example 7.9: escape ramp ($m = 10000$ kg, $v = 72$ km/h, 30° ramp, sand force 50000 N, $g = 10$)

- ★ Given: $v = 72 \div 3.6 = 20$ m s $^{-1}$. On a 30° incline the truck rises 1 m for every 2 m along the ramp $\rightarrow$ height gained = $d/2$.
- ★ Initial energy = KE = $\frac{1}{2} \times 10000 \times 20^2 = 2000000$ J (PE = 0). Final energy = PE only = $mg \times d/2 = 10000 \times 10 \times d/2 = 50000 d$.
- ★ Work by sand = $-50000 d$ (force opposes motion). Work-energy theorem: $-50000 d = 50000 d - 2000000$.
- ★ $100000 d = 2000000 \rightarrow d = 20$ m (minimum length of ramp).

Pause and Ponder: Thoda Practice Ho Jaye

Q1. For Fig. 7.19, calculate the mechanical energy of the ball just before it hits the ground and show that it is mgh . [Textbook ★ Most Imp]

Ans. At the ground $h' = 0$ so PE = 0. Fall time from $h = \frac{1}{2}gt^2$ gives $t^2 = 2h/g$.

- Speed $v = gt \rightarrow v^2 = g^2t^2 = 2gh$. KE = $\frac{1}{2}mv^2 = \frac{1}{2}m \times 2gh = mgh$.
- ME = PE + KE = $0 + mgh = mgh$ (equal to the ME at the top).

Q2. Ball roller coaster (Fig. 7.22): how do KE and PE change at A, B, C? Why do later points C, D, E have lower heights? Is friction involved? [Textbook ★ Most Imp]

Ans. At a crest the PE is high and KE is lower; going down PE $\rightarrow$ KE (KE maximum at the lowest point); climbing the next crest KE $\rightarrow$ PE.

- Each next crest is lower because some mechanical energy is lost as **heat and sound** due to **friction and air resistance**. Yes, friction is responsible.

Q3. A ball is thrown vertically upward at 10 m/s ($g = 10$). Find the maximum height using energy. [Extra ★ Most Imp]

Ans. At the top KE = 0: $\frac{1}{2}mv^2 = mgh \rightarrow h = v^2/2g = 100/20 = 5$ m.

Q4. A stone is dropped from 20 m. Find its speed just before hitting the ground ($g = 10$).

[Extra ★ Most Imp]

Ans. $v = \sqrt{2gh} = \sqrt{2 \times 10 \times 20} = \sqrt{400} = 20 \text{ m s}^{-1}$.

Q5. A 0.1 kg pendulum bob is released from 0.2 m above its lowest point. Speed at the bottom? [Extra ★ Most Imp]

Ans. $v = \sqrt{2gh} = \sqrt{2 \times 10 \times 0.2} = \sqrt{4} = 2 \text{ m s}^{-1}$.

Q6. Is mechanical energy conserved if the ball falls through air with air resistance? Why?

[Extra]

Ans. No. Air resistance is an external force that converts some mechanical energy into heat, so ME decreases.

Q7. Why do heavy and light stones dropped from the same height reach the ground together (ignoring air resistance)? [Extra ★ Most Imp]

Ans. Because $v = \sqrt{2gh}$ is independent of mass (and $a = g$ is the same for all).

7.5 Power

- Running up the stairs in 1 minute feels very different from walking up in 5 minutes though the **same work** is done. The difference is **power**.
- Power** = rate at which work is done (or energy is transferred).

Formula ★

- $P = W / t$ (Eq. 7.11) (average power)
- SI unit: **watt (W)**; $1 \text{ W} = 1 \text{ J s}^{-1}$. Bigger units: $1 \text{ kW} = 1000 \text{ W}$, $1 \text{ MW} = 10^6 \text{ W}$.
- More work in the same time, or the same work in less time → **more power**. Doubling speed of doing a job halves the time → doubles power.
- Horsepower (hp): $1 \text{ hp} = 746 \text{ W}$ (James Watt compared steam engines with horses; the unit watt honours Watt, inventor of an efficient steam engine).

Quantity	Meaning	Formula	SI unit	Scalar/Vector
Work	Force × displacement	$W = F s$	joule (J)	Scalar
Energy	Capacity to do work	$K = \frac{1}{2}mv^2$, $U = mgh$	joule (J)	Scalar
Power	Rate of doing work	$P = W/t$	watt (W)	Scalar

Extra: kilowatt-hour (kWh): the unit on your electricity bill

- $1 \text{ kWh} = 1 \text{ kW} \times 1 \text{ h} = 1000 \text{ W} \times 3600 \text{ s} = 3.6 \times 10^6 \text{ J}$. It is a unit of **energy** (not power).

- ♦ Example: a 60 W bulb running for 5 h uses $60 \times 5 = 300 \text{ Wh} = 0.3 \text{ kWh}$ (1 "unit" = 1 kWh).

Example 7.10: weightlifter lifts 75 kg by 2 m in 5 s ($g = 10$)

- ♦ $\text{Work} = mgh = 75 \times 10 \times 2 = 1500 \text{ J}$. $\text{Power} = W/t = 1500/5 = 300 \text{ W}$.

Example 7.11: car of 1000 kg from rest to 72 km/h in 10 s

- ♦ $v = 72000/3600 = 20 \text{ m s}^{-1}$, $u = 0$.
- ♦ $\text{Work by engine} = \Delta KE = \frac{1}{2} \times 1000 \times 20^2 - 0 = 200000 \text{ J}$. $\text{Power} = 200000/10 = 20000 \text{ W}$ (20 kW).

Kuch Mazedaar Questions

Q1. Define power. What is its SI unit? [Textbook ★ Most Imp]

Ans. Rate of doing work; watt (W) = 1 J s^{-1} .

Q2. Two girls climb the same stairs; A takes 10 s and B takes 20 s. Who develops more power? Why? [Extra ★ Most Imp]

Ans. Work done is the same (mgh) but A takes less time, so A's power = W/t is **double** B's.

Q3. A pump lifts 500 kg of water to a height of 20 m in 100 s ($g = 10$). Find its power. [Extra ★ Most Imp]

Ans. $W = mgh = 500 \times 10 \times 20 = 100000 \text{ J}$; $P = W/t = 100000/100 = 1000 \text{ W} = 1 \text{ kW}$.

Q4. A 60 W bulb is used for 5 hours. Energy consumed in kWh and joules? [Extra ★ Most Imp]

Ans. $60 \text{ W} \times 5 \text{ h} = 300 \text{ Wh} = 0.3 \text{ kWh} = 0.3 \times 3.6 \times 10^6 = 1.08 \times 10^6 \text{ J}$.

Q5. Does a machine of higher power always do more work? [Extra]

Ans. Not necessarily; work = power $\times$ time. A high-power machine running for a very short time can do less work.

7.6 Simple Machines

- ✦ The total work needed for a task **cannot be reduced**; but it can be made easier by changing the **magnitude or direction of the force** applied. Devices that do this are **simple machines**: pulley, inclined plane, lever.
- ✦ **Effort** = force we apply to the machine. **Load** = force to be overcome (e.g. weight).

Mechanical advantage ★

- ✦ **MA = load / effort** (Eq. 7.12)
- ✦ $MA > 1$: a small effort moves a large load (but the effort moves through a larger distance). MA has **no unit** (a ratio of two forces).

7.6.1 Pulley

- ✦ A **pulley** is a wheel with a groove that guides a rope.
- ✦ A **fixed pulley** does not reduce the force; it only **changes the direction** of effort (pull down instead of lifting up, e.g. a flag). $\text{Effort} = \text{load} \rightarrow \mathbf{MA = 1}$.
- ✦ Ready to Go Beyond: a **movable pulley or a system of pulleys** has $MA > 1$. The load hangs on the movable pulley; one rope end is fixed and the other end is free for effort. Used in elevators and cranes.

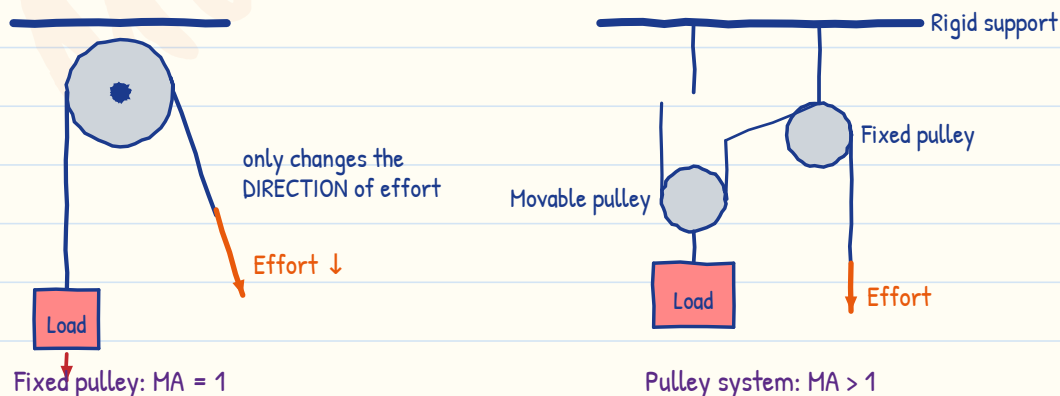
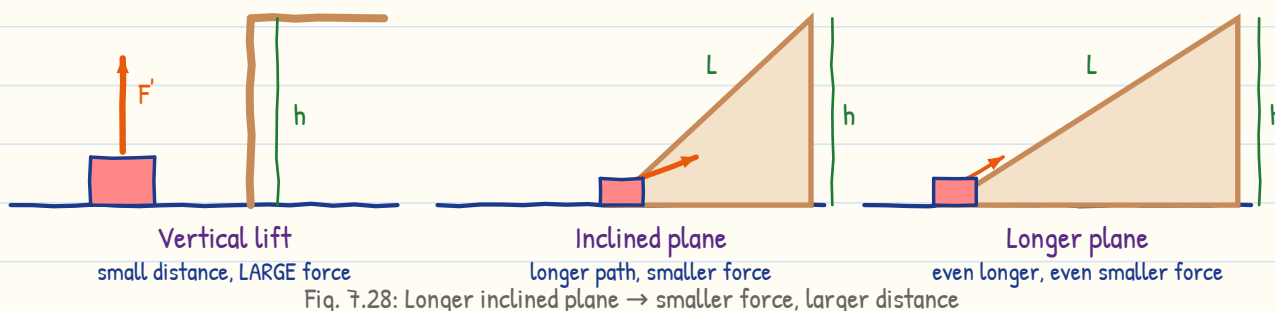


Fig. 7.24 / 7.25: Fixed pulley and a system of pulleys

7.6.2 Inclined Plane

- ✦ A ramp/slope lets us raise a heavy load to a height h by pushing it along a longer path L with a smaller force.
- ✦ **Activity 7.3**: pull a cart up a plank with a spring balance. The balance reading (effort) is **smaller on the plank** than when lifting vertically, and gets smaller as the plank becomes

less steep, but you pull over a **longer distance**.



Derivation of MA of an inclined plane ★

- Load = weight mg ; effort = F ; plane length L , height h . Move the object at constant speed (ignore friction).
- Work done by you = $F \times L$. PE gained by the object = mgh . Work-energy theorem: $F L = mgh \rightarrow mg/F = L/h$.
- MA = load/effort = $mg/F = L/h$ (7.13).** Since $L > h$, $MA > 1$. A longer, shallower plane (bigger L) gives a bigger MA.
- Note from the book: the **work done is the same** in all cases; if the force decreases, the displacement increases.

Example 7.12: ramp over a 30 cm step; ramp width 40 cm

- AB (height) = 30 cm, BC (width) = 40 cm. Length of ramp AC = $\sqrt{(30^2 + 40^2)} = \sqrt{2500} = 50$ cm (right-angled triangle).
- $MA = L/h = 50/30 = 1.67$.

7.6.3 Lever

- Activity 7.4:** a ruler over a pencil lets 1–2 light erasers lift a heavier stapler. A **lever** is a rigid bar that can rotate about a fixed point.
- Three parts: **fulcrum** (fixed pivot), **load** (force to be overcome) and **effort** (force applied). Distance of the load from the fulcrum = **load arm**; of the effort = **effort arm**.
- The end where small force F_1 is applied moves a larger distance d_1 ; the end applying the larger force F_2 moves a smaller distance d_2 .

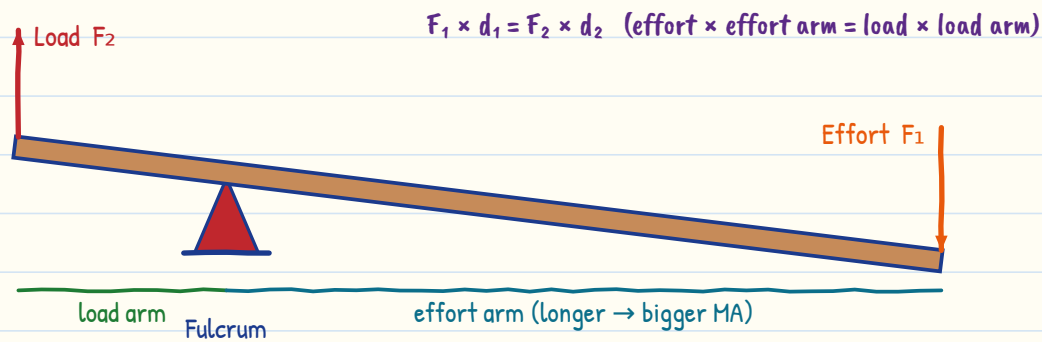


Fig. 7.32: A lever lifting a heavy rock

Principle of the lever ★

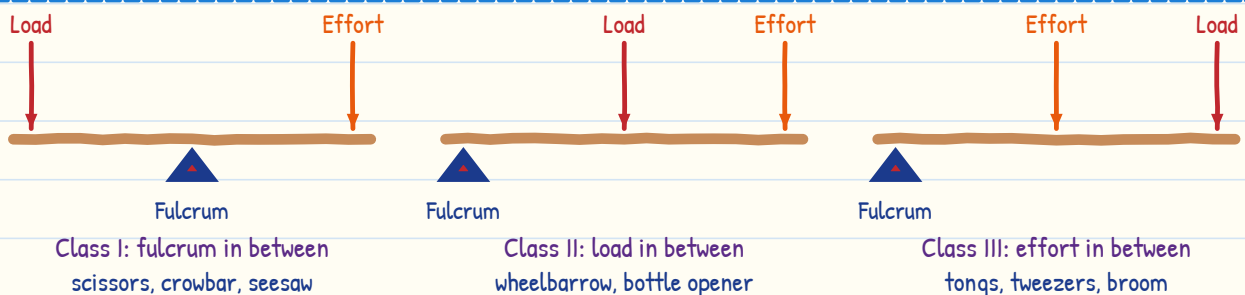
- Work is transferred from one end to the other: $F_1 \times d_1 = F_2 \times d_2$ (7.14)
- Balance condition (Activity 7.5, beam balance): **effort $\times$ effort arm = load $\times$ load arm** or $n_1 L_1 = n_2 L_2$ (7.15)
- MA = load/effort = **effort arm / load arm = L_1/L_2** (7.16)
- A lever reduces the force required but **not the total work done**.

Example 7.13: seesaw (AC = EC = 2 m; BC = DC = 1 m); children of 15 kg and 30 kg

- Put the 15 kg child at A (2 m). The other child at distance L: $15 \times 2 = 30 \times L \rightarrow L = 1$ m.
- So the 30 kg child must sit at **seat D** (the seat 1 m from the fulcrum on the other side).

Ready to Go Beyond: classes of levers (Table 7.2)

- Class I:** fulcrum in between load and effort: tongs (some), scissors, crowbar, pliers, balance scale, seesaw.
- Class II:** load in between fulcrum and effort: lemon squeezer, wheelbarrow, bottle opener.
- Class III:** effort in between fulcrum and load: tweezers, broom, hammer, oar, tongs.



Three classes of levers

Simple machine	What it changes	Mechanical advantage	Work done
Fixed pulley	Direction of effort	1	Same (no gain)
Pulley system	Magnitude of effort	> 1	Same

Simple machine	What it changes	Mechanical advantage	Work done
Inclined plane	Magnitude of effort (longer path)	L / h	Same (ignoring friction)
Lever	Magnitude (and sometimes direction)	effort arm / load arm	Same

Machines do not create energy ★

- ✦ In all cases conservation of energy holds: the work we put in = useful work on the load (ignoring friction). Machines only help us use energy **more conveniently**; they never create energy.
- ✦ What if a perpetual motion machine existed? It would work forever without fuel: **impossible** because friction/air resistance convert mechanical energy to heat, and energy cannot be created.
- ✦ Extra: $\text{efficiency} = (\text{useful work output} / \text{work input}) \times 100\%$. For real machines it is always **less than 100%**.

Pause and Ponder: Chalo Likhein

Q1. Why are roads on hills built to wind around in gentle slopes instead of going straight up?

[Textbook ★ Most Imp]

Ans. A gentle, longer road is an inclined plane with large $L/h \rightarrow$ **large MA**: vehicles (and walkers) need a much smaller force (less engine power) and braking is safer. The work against gravity is the same; only the distance increases.

Q2. Why is climbing an inclined ladder easier than a vertical ladder? [Textbook ★ Most Imp]

Ans. The inclined ladder is a longer path to the same height ($MA = L/h > 1$), so less force per step is needed, though you climb a longer distance.

Q3. Why is it easier to open a can lid using a spoon? [Textbook ★ Most Imp]

Ans. The spoon acts as a **lever**: the handle gives a long effort arm and the part under the lid a short load arm, so $MA = \text{effort arm}/\text{load arm} > 1$ and a small effort overcomes the strong lid.

Q4. Why do you push a hard object closer to the fulcrum of scissors? [Textbook ★ Most Imp]

Ans. It shortens the load arm, so $MA = \text{effort arm}/\text{load arm}$ increases and the scissors apply a bigger force on the object.

Q5. Why do all real machines eventually slow down and stop? (perpetual motion) [Textbook ★ Most Imp]

Ans. Friction and air resistance convert part of the mechanical energy into heat and sound every cycle. Energy is not created, so without fuel/energy input the machine loses energy and stops.

Q6. Effort arm of a lever = 1.2 m and load arm = 0.3 m. Find MA and the effort needed to lift 200 N. [Extra ★ Most Imp]

Ans. $MA = 1.2/0.3 = 4$. Effort = load/MA = $200/4 = 50$ N.

Q7. An inclined plane is 5 m long and 1 m high. Find MA and effort to raise a 500 N load (no friction). [Extra ★ Most Imp]

Ans. $MA = L/h = 5$. Effort = $500/5 = 100$ N.

Q8. A 20 kg child sits 3 m from the fulcrum of a seesaw. Where must a 30 kg child sit to balance? [Extra ★ Most Imp]

Ans. $20 \times 3 = 30 \times L \rightarrow L = 2$ m on the other side.

Q9. Can a machine give $MA > 1$ and also reduce the work done? Explain. [Extra ★ Most Imp]

Ans. No. It can reduce the effort by increasing the distance over which the effort acts; work (force $\times$ distance) stays the same.

Bridging Science and Society: the gharat / panchakki (watermill)

- ✦ In the Himalayan region, water flowing downhill converts **potential energy** $\rightarrow$ **kinetic energy**. The water coming down the pipe drives a wheel (B) into rotation, which turns the grinding stone (C) to grind grain.
- ✦ In modern times, the PE of water stored in dams is converted into KE to generate electricity (hydroelectric power).

7.7 At a Glance + Formula Sheet

At a Glance

- ✦ Work is done by a force on an object when the force displaces it in the direction of the force. Energy is the capacity to do work.
- ✦ Work-energy theorem: work done on an object or system = change in its energy.
- ✦ **Kinetic energy**: due to motion. **Potential energy**: due to deformation or relative positions.
Power = rate of doing work.
- ✦ Simple machines make work easier by changing the magnitude or direction of the force; they do not reduce the total work.

Quantity	Formula	Unit
Work	$W = F \times s$	joule (J)
Work-energy theorem	$W = E_f - E_i$	J
Kinetic energy	$K = \frac{1}{2} m v^2$	J
Potential energy (gravitational)	$U = m g h$	J
Mechanical energy	$ME = K + U$ (constant if only gravity acts)	J
Speed after falling h	$v = \sqrt{2gh}$	$m s^{-1}$
Power	$P = W / t$	watt (W)
Mechanical advantage	$MA = \text{load} / \text{effort}$	no unit
Inclined plane	$MA = L / h$	no unit
Lever	$F_1 d_1 = F_2 d_2$; $MA = \text{effort arm} / \text{load arm}$	no unit
Conversions	$1 \text{ km h}^{-1} = 1/3.6 \text{ m s}^{-1}$; $1 \text{ kWh} = 3.6 \times 10^6 \text{ J}$; $1 \text{ hp} = 746 \text{ W}$	

7.8 Revise, Reflect, Refine: Solved

Textbook Exercise Solutions (Part 1)

Q1. True or False: (i) Work is done when a force is applied even if the object does not move. (ii) Lifting a bucket vertically upward is positive work on the bucket. (iii) SI unit of work and energy is joule. (iv) A motionless stretched rubber band has kinetic energy. (v) Energy can change from one form to another. [Textbook ★ Most Imp]

Ans. (i) **False**: no displacement $\rightarrow$ no work.

- (ii) **True**: force and displacement are both upward.
- (iii) **True**.
- (iv) **False**: it is at rest (no KE) but has elastic **potential** energy.
- (v) **True**.

Q2. Fill in the blanks. [Textbook ★ Most Imp]

Ans. (i) Work done = **force** $\times$ **displacement** (in the direction of force).

- (ii) 1 joule is done when a force of **1** newton displaces an object by 1 metre.
- (iii) $KE = \frac{1}{2} m v^2$.
- (iv) $PE = m g h$.
- (v) Power is the **rate** at which work is done.

Q3. A ball thrown upward is at its highest point. Which statements are correct? (i) force is zero (ii) acceleration is zero (iii) KE is zero (iv) PE is maximum. [Textbook ★ Most Imp]

Ans. (iii) and (iv) are correct.

- (i) wrong: gravity (mg) still acts. (ii) wrong: acceleration = g downward, even at the top.
- (iii) right: $v = 0$ at the top. (iv) right: height is maximum.

Q4. Identify the energy transformation: (i) a truck moving uphill (ii) unwinding of a watch spring (iii) photosynthesis (iv) water flowing from a dam (v) burning of a matchstick (vi) explosion of a fire cracker (vii) speaking into a microphone (viii) a glowing bulb (ix) a solar panel. [Textbook ★ Most Imp]

Ans. (i) chemical (fuel) → kinetic + gravitational PE (+ heat)

- (ii) elastic PE → kinetic
- (iii) light → chemical
- (iv) gravitational PE → kinetic (→ electrical in turbines)
- (v) chemical → heat + light
- (vi) chemical → sound + heat + light + kinetic
- (vii) sound → electrical
- (viii) electrical → light + heat
- (ix) light → electrical

Textbook Exercise Solutions (Part 2): Numericals

Q5. A student ($m = 50 \text{ kg}$) is lifted slowly in an elevator to the top floor, $h = 72.5 \text{ m}$ ($g = 10$); later he climbs the stairs to the top. Find (i) gain in PE in the elevator (ii) on the stairs (iii) conclusion. [Textbook ★ Most Imp]

Ans. (i) $U = mgh = 50 \times 10 \times 72.5 = 36250 \text{ J}$.

- (ii) The same: $50 \times 10 \times 72.5 = 36250 \text{ J}$ (initial and final heights are the same).
- (iii) Gravitational PE depends only on the **initial and final heights**, not on the path taken.

Q6. A crane lifts mass m to the 10th floor in time t , then raises the same mass to the 20th floor in $2t$. How much more energy and power are needed? (equal floor heights) [Textbook ★ Most Imp]

Ans. Let one floor = H . Energy to 10th floor $E_1 = mg(10H)$; power $P_1 = E_1/t$.

- To the 20th floor (from the ground): $E_2 = mg(20H) = 2E_1$ → energy doubles. Power $P_2 = 2E_1/2t = P_1$ → power is unchanged.
- (If the crane raises it only from the 10th to the 20th floor: extra energy = E_1 (same as before), time $2t$ → power halves.)

Q7. Flag raised on a pole with a pulley: which factors decide the energy? Does slow or quick raising change the work? If speed is doubled, how does power change? [Textbook ★ Most Imp]

Ans. Energy (work) = mgh depends on the **mass of the flag and the height of the pole** (and g).

- Slow or quick raising: **no change in the work done** (same mgh).
- Doubling the speed halves the time, so power = W/t becomes **double**.

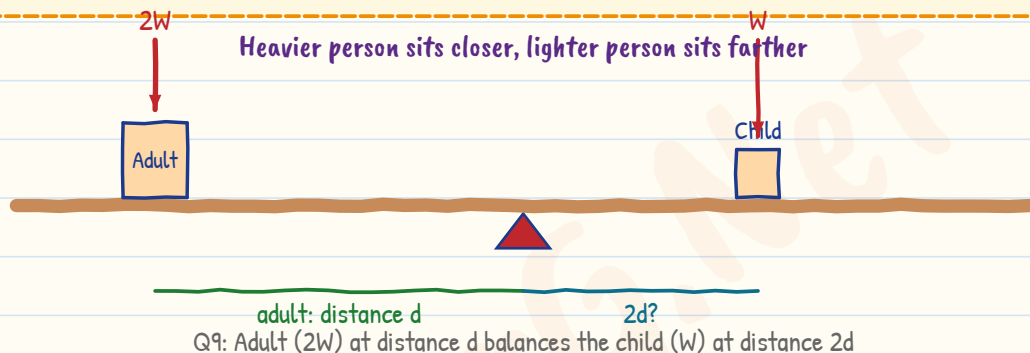
Q8. Man 60 kg on a 100 kg scooter reaches speed v ; next day with a 40 kg son also reaches speed v in the same time. Ratio of fuel used on the two days? (energy transfer to scooter due to fuel only) [Textbook ★ Most Imp]

Ans. Fuel energy = KE gained = $\frac{1}{2}Mv^2$. Day 1: $M = 160$ kg. Day 2: $M = 200$ kg.

➤ Ratio of fuel used = $160 : 200 = 4 : 5$.

Q9. Draw a seesaw balanced with a child on one side and an adult (twice the weight) on the other. [Textbook ★ Most Imp]

Ans. For balance, weight $\times$ distance must be equal: $2W \times d_{\text{adult}} = W \times d_{\text{child}} \rightarrow d_{\text{child}} = 2 d_{\text{adult}}$. The adult sits at distance d , the child at $2d$ (see the figure).



Textbook Exercise Solutions (Part 3)

Q10. Ball of 2 kg thrown up at 20 m/s. (i) Sign of work done by gravity on the way up and down. (ii) If it reaches 19.4 m, how much work was done by air resistance? ($g = 10$) [Textbook ★ Most Imp]

Ans. (i) Going up: gravity (down) is opposite to displacement (up) $\rightarrow$ work is **negative**. Coming down: same direction $\rightarrow$ work is **positive**.

➤ (ii) Initial KE = $\frac{1}{2} \times 2 \times 20^2 = 400$ J. At the top $v = 0$, PE gained = $mgh = 2 \times 10 \times 19.4 = 388$ J.

➤ Energy lost = $400 - 388 = 12$ J $\rightarrow$ work done by air resistance = **-12 J**.

Q11. Block of 10 kg, variable force (Fig. 7.37) from 0 m to 4 m; KE at 0 m is 180 J. Find speed at (i) 0 m (ii) 4 m. Any negative acceleration? [Textbook ★ Most Imp]

Ans. Work = area under the $F-s$ graph = $\frac{1}{2} \times (4 + 2) \times 50 = 150$ J (trapezoid, base 4 m and top 2 m, height 50 N).

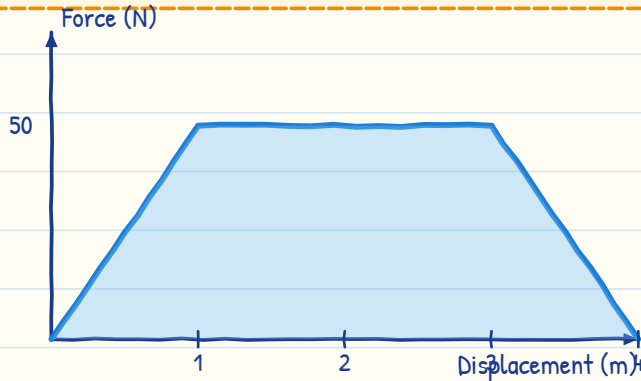
➤ (i) $\frac{1}{2} \times 10 \times v^2 = 180 \rightarrow v^2 = 36 \rightarrow v = 6 \text{ m s}^{-1}$.

➤ (ii) KE at 4 m = $180 + 150 = 330$ J $\rightarrow v^2 = 66 \rightarrow v \approx 8.1 \text{ m s}^{-1}$.

➤ Force is always along the motion (never negative), so the block **never has negative acceleration**. In 3–4 m the force decreases, so acceleration decreases but stays positive.

Q12. Moon's gravity is $1/6$ of Earth's. An astronaut throws a ball to 8 m on Earth; how high on the Moon with the same velocity? [Textbook ★ Most Imp]

Ans. $KE = \frac{1}{2}mv^2$ is the same; at the top it becomes mgh . So $g_E h_E = g_M h_M \rightarrow h_M = 6 \times 8 = 48 \text{ m}$.



Work = area of trapezoid
 $= \frac{1}{2} \times (4 + 2) \times 50 = 150 \text{ J}$

Force is never negative $\rightarrow$
 no negative acceleration

Fig. 7.37 (Q11): Work = area under the graph = 150 J

Textbook Exercise Solutions (Part 4)

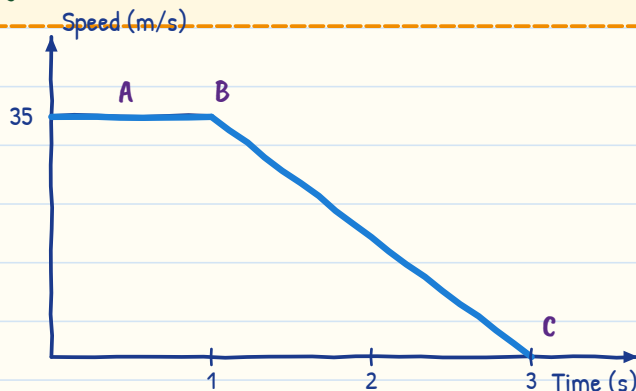
Q13. A 1000 kg car at constant speed; brakes applied after spotting an obstacle (Fig. 7.38: A-B at 35 m/s for 1 s, then speed falls to 0 at 3 s). (i) motion A to B (ii) KE at A (iii) work by brakes B to C (iv) KE transforms into? [Textbook ★ Most Imp]

Ans. (i) A to B: moves with **constant speed 35 m s^{-1}** (driver's reaction time, brakes not yet applied).

➤ (ii) KE at A = $\frac{1}{2} \times 1000 \times 35^2 = 612500 \text{ J}$.

➤ (iii) Work done by brakes = change in KE = $0 - 612500 = -612500 \text{ J}$ (negative: force opposes motion).

➤ (iv) KE is transformed into **heat (and some sound)** by friction between the brake pads, tyres and road.



A $\rightarrow$ B: constant speed 35 m/s
 (driver's reaction time, 1 s)

B $\rightarrow$ C: brakes applied, speed
 falls to zero (uniform retardation)

Fig. 7.38 (Q13): Speed-time graph of the braking car

Textbook Exercise Solutions (Part 5)

Q14. PE-displacement graph of a 0.5 kg ball on a frictionless track (Fig. 7.39): at O, $v = 0$ and $PE = 30$ J. Find velocity at P (20 J), Q (30 J), R (40 J). [Textbook ★ Most Imp]

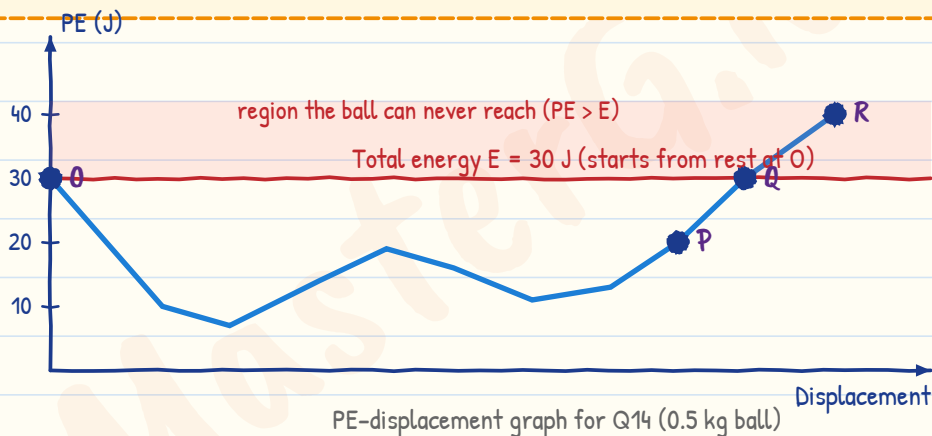
Ans. Total mechanical energy $E = KE + PE = 0 + 30 = 30$ J everywhere (frictionless).

- P: $KE = 30 - 20 = 10$ J $\rightarrow \frac{1}{2} \times 0.5 \times v^2 = 10 \rightarrow v^2 = 40 \rightarrow v \approx 6.3 \text{ m s}^{-1}$.
- Q: $KE = 30 - 30 = 0 \rightarrow v = 0$: the ball momentarily stops (a turning point).
- R: $PE = 40$ J is more than the total energy 30 J, so KE would be -10 J: impossible. **The ball can never reach R.**

Q15. Coconut of 1.5 kg falls 10 m onto wet sand. (i) velocity just before hitting (ii) depth of the depression if the average resistive force is 3000 N ($g = 10$). [Textbook ★ Most Imp]

Ans. (i) $v = \sqrt{2gh} = \sqrt{2 \times 10 \times 10} = \sqrt{200} \approx 14.1 \text{ m s}^{-1}$.

- (ii) Energy = $mgh = 1.5 \times 10 \times 10 = 150$ J = work by sand = $F \times d \rightarrow d = 150/3000 = 0.05$ m = 5 cm.



7.9 Most Important Extra Practice**Section A: MCQs (Quick Check — Ho Jaye?)**

1. SI unit of work is:
(a) watt (b) joule (c) newton (d) pascal
2. Work done is zero when:
(a) force $\perp$ displacement (b) displacement is zero (c) force is zero (d) all of these
3. A girl stands holding a 10 kg bag for 5 min. Work done on the bag:
(a) positive (b) negative (c) zero (d) 100 J
4. If the velocity of a body is tripled, its kinetic energy becomes:
(a) 3 times (b) 6 times (c) 9 times (d) 27 times
5. PE of a 2 kg stone at 5 m ($g = 10 \text{ m s}^{-2}$):
(a) 10 J (b) 100 J (c) 50 J (d) 20 J
6. A stretched rubber band at rest has:
(a) kinetic energy (b) elastic potential energy (c) sound energy (d) no energy
7. 1 watt is equal to:
(a) 1 J s^{-1} (b) 1 J s (c) 1 N m (d) 1 kg m
8. Mechanical advantage of a fixed pulley is:
(a) 0 (b) 1 (c) 2 (d) $1/2$
9. MA of an inclined plane 4 m long and 1 m high:
(a) $1/4$ (b) 4 (c) 3 (d) 5
10. Scissors is a lever of class:
(a) I (b) II (c) III (d) none
11. Simple machines make work easier by reducing the:
(a) work done (b) energy needed (c) effort (force) (d) all of these
12. A freely falling body's speed just before the ground depends on:
(a) mass and height (b) only height (c) only mass (d) time only
13. At the highest point of a ball thrown vertically upward:
(a) KE max, PE min (b) KE = 0, PE max (c) KE = PE (d) both zero
14. 1 horsepower equals:
(a) 100 W (b) 476 W (c) 746 W (d) 1000 W
15. An object moving in a circle at constant speed has kinetic energy that is:
(a) increasing (b) decreasing (c) constant (d) zero

Answer key: 1-b 2-d 3-c 4-c 5-b 6-b 7-a 8-b 9-b 10-a 11-c 12-b 13-b 14-c 15-c

Section B: Assertion-Reason (options: (i) both true, R explains A; (ii) both true, R does not explain A; (iii) A true, R false; (iv) A false, R true)

Q1. A: Pushing a rigid wall does no work. R: The wall has no displacement. [Extra ★ Most Imp]

Ans. Answer (i): both true, R explains A.

Q2. A: Negative work decreases the kinetic energy. R: In negative work the force acts opposite to the displacement. [Extra ★ Most Imp]

Ans. Answer (i).

Q3. A: A lever reduces the total work needed to lift a load. R: A lever reduces the effort needed. [Extra ★ Most Imp]

Ans. Answer (iv): A is false (work stays the same; only the effort reduces), R is true.

Q4. A: Heavy and light bodies dropped from the same height reach the ground with the same speed (no air resistance). R: $v = \sqrt{2gh}$ does not depend on mass. [Extra ★ Most Imp]

Ans. Answer (i).

Q5. A: A swinging pendulum finally stops. R: Part of its mechanical energy is converted into heat due to friction and air resistance. [Extra ★ Most Imp]

Ans. Answer (i).

Section C: Short and Long Answers (Yeh Zaroor Aayega!)

Q1. Define work and joule. When is work done zero, positive and negative? Give one example each. [Extra ★ Most Imp]

Ans. Work = force $\times$ displacement in the direction of force; joule = work when 1 N moves an object 1 m in its direction.

➤ Zero: pushing a wall / carrying a load horizontally. Positive: pushing a wheelchair. Negative: goalkeeper stopping a ball, friction.

Q2. State and prove the expression for kinetic energy ($K = \frac{1}{2}mv^2$). [Extra ★ Most Imp]

Ans. Use $v^2 = u^2 + 2as$, $W = F s = ma s = \frac{1}{2}m(v^2 - u^2)$; with $u = 0 \rightarrow K = \frac{1}{2}mv^2$ (see the derivation box in 7.4.1).

Q3. Derive $U = mgh$. Does the PE depend on the path taken to reach height h ? [Extra ★ Most Imp]

Ans. $W = mg \times h = mgh$ stored as PE; no, only on the initial and final heights (QS: elevator vs stairs).

Q4. State and verify the law of conservation of mechanical energy for a freely falling body.

[Extra ★ Most Imp]

Ans. At A: $ME = mgh$; at B: $PE = mgh - \frac{1}{2}mg^2t^2$, $KE = \frac{1}{2}mg^2t^2$, $sum = mgh$; ME is constant (see 7.4.3).

Q5. Differentiate between work, energy and power. [Extra ★ Most Imp]

Ans. See the comparison table in 7.5: work is force $\times$ displacement (J); energy is the capacity to do work (J); power is the rate of doing work (W).

Q6. Derive the mechanical advantage of an inclined plane. Why is a longer ramp easier? [Extra ★ Most Imp]

Ans. $FL = mgh \rightarrow MA = L/h$; longer $L \rightarrow$ smaller effort but longer distance, same work.

Q7. What are the three classes of levers? Give two examples of each. [Extra ★ Most Imp]

Ans. Class I (fulcrum between): scissors, seesaw; Class II (load between): wheelbarrow, bottle opener; Class III (effort between): tweezers, broom.

Q8. Why does a fixed pulley have $MA = 1$ yet is useful? [Extra ★ Most Imp]

Ans. Effort = load so $MA = 1$, but it changes the direction of the force: pulling down is easier than lifting up.

Q9. Why can no machine have an efficiency of more than 100%? [Extra ★ Most Imp]

Ans. A machine cannot create energy; some input energy is always lost as heat/sound due to friction.

Section D: Numericals (Numericals ka Mazaa)

Q1. A force of 5 N acts on a box that moves 2 m opposite to the force. Work done? [Extra ★ Most Imp]

Ans. $W = 5 \times (-2) = -10 \text{ J}$.

Q2. An object of 2 kg moves at 3 m/s. A force then increases its speed to 5 m/s. Work done? [Extra ★ Most Imp]

Ans. $W = \Delta KE = \frac{1}{2} \times 2 \times (25 - 9) = 16 \text{ J}$.

Q3. A car (1000 kg) moving at 20 m/s is stopped by brakes in 40 m. Find the braking force. [Extra ★ Most Imp]

Ans. $KE = \frac{1}{2} \times 1000 \times 400 = 200000 \text{ J} = F \times 40 \rightarrow F = 5000 \text{ N}$.

Q4. A 50 kg boy climbs a 4 m high staircase in 8 s ($g = 10$). Power? [Extra ★ Most Imp]

Ans. $W = mgh = 50 \times 10 \times 4 = 2000 \text{ J}$; $P = 2000/8 = 250 \text{ W}$.

Q5. A machine lifts 100 kg through 10 m using 12000 J of energy. Efficiency? [Extra ★ Most Imp]

Ans. Useful work = $100 \times 10 \times 10 = 10000$ J; efficiency = $10000/12000 \times 100 = 83.3\%$.

Q6. A bullet of 20 g at 300 m/s: KE? [Extra ★ Most Imp]

Ans. $m = 0.02$ kg; $K = \frac{1}{2} \times 0.02 \times 90000 = 900$ J.

Section E: HOTS / Case-based

Q1. Two children with masses 25 kg and 40 kg slide down the same 2 m high slide ($g = 10$).

Compare their speeds at the bottom. Compare their KE. [Extra ★ Most Imp]

Ans. Both: $v = \sqrt{2gh} = \sqrt{40} \approx 6.3$ m/s, **same speed**.

► $KE = mgh$: $25 \times 10 \times 2 = 500$ J and $40 \times 10 \times 2 = 800$ J → the heavier child has more KE.

Q2. A 0.2 kg ball is dropped from 5 m and rebounds to 3.2 m. How much energy was lost?

Where did it go? ($g = 10$) [Extra ★ Most Imp]

Ans. Loss = $mg(5 - 3.2) = 0.2 \times 10 \times 1.8 = 3.6$ J, converted into heat and sound during impact (and air resistance).

Q3. Why is it dangerous to drive faster than the speed limit? Give a reason using work and energy. [Extra ★ Most Imp]

Ans. $KE \propto v^2$: at double speed the KE is 4 times, so the brakes must do 4 times the work, and the stopping distance (for the same braking force) becomes 4 times.

Q4. You pull a heavy trunk up a ramp, then lift it straight up with a machine of the same MA.

In which case is the work done on the trunk larger? Explain. [Extra]

Ans. The work done on the trunk (mgh) is the **same**; the ramp only reduces the force while increasing the distance.

The Journey Beyond: activities from the book

- ✦ Pen refill launcher: stretch a rubber band attached to the refill and release; it shoots out (elastic PE → KE). Stretch more → travels farther.
- ✦ Build a lever / pulley / inclined plane from cardboard, rulers, thread; measure load and effort and calculate MA.
- ✦ Explore PhET simulations: Energy Skate Park, Energy Forms and Changes, Pendulum Lab, Masses and Springs.

The Quest Continues...

- ★ Scientists believe the expansion of the Universe is accelerating and have proposed a mysterious form of energy called **dark energy**, which cannot be exchanged with other forms of energy. Studying it may reveal the fate of the Universe billions of years from now.