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SOLUTIONS BOOK

CLASS 9

Science · Exploration

CHAPTER 7

Work, Energy, and Simple Machines

Complete Questions and Activities Solutions

In-text Questions | Activities | Worked Examples | Revise, Reflect, Refine

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Every question is followed by its answer. Question numbers above are clickable and the PDF bookmarks panel lets you jump to any exercise set or question. Figures are reproduced from the NCERT textbook (© NCERT) for educational use.

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7.1

CLASS 9 SCIENCE · CHAPTER 7

In-text Questions

Solutions · 17 questions

Directions (Questions 1–17): These are the questions that appear inside the chapter (Think It Over, Pause and Ponder and What If), numbered in the order in which they appear. Model answers based on the chapter are given.

QUESTION 1

Think It Over · p. 116

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



Chapter-opening illustration: children on playground slides

ANSWER

The child slides down under gravity alone (friction neglected), so the gravitational potential energy at the top is converted into kinetic energy at the bottom. The speed depends only on the vertical height h through which the child descends.

a Using conservation of mechanical energy

- At the top (starting from rest): potential energy = mgh, kinetic energy = 0.
- At the bottom: potential energy = 0, kinetic energy = $\frac{1}{2}mv^2$.
- Mechanical energy is conserved, so $\frac{1}{2}mv^2 = mgh$, which gives $v = \sqrt{(2gh)}$.

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b Reading the answer

The chapter gives no numerical height for the blue slide, so the speed is expressed in terms of h (the same working as Example 7.8). For illustration only: if h were 2 m and g = 10 m s^{-2}, then $v = \sqrt{(2 \times 10 \times 2)} = \sqrt{40} \approx 6.3$ m s^{-1}.

Therefore, the speed at the bottom of the blue slide is $v = \sqrt{(2gh)}$, where h is the vertical height of the slide.

QUESTION 2 *Think It Over · p. 116*

Will two children of different masses reach the bottom of the same slide with the same velocity?

ANSWER

Yes. Neglecting friction, both children reach the bottom with the same speed, because the mass cancels out of the energy equation.

a Why the mass does not matter

Child	Energy equation	Speed at bottom
Mass m_1	$\frac{1}{2}m_1v^2 = m_1gh$	$v = \sqrt{(2gh)}$
Mass m_2	$\frac{1}{2}m_2v^2 = m_2gh$	$v = \sqrt{(2gh)}$

The heavier child has more kinetic energy at the bottom, but not more speed: the extra kinetic energy comes from an equally larger potential energy mgh at the top.

Therefore, the velocity at the bottom depends only on the height h of the slide, not on the mass of the child.

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QUESTION 3 *Think It Over · p. 116*

Which of the slides will result in the largest magnitude of velocity for the child at its bottom?

ANSWER

Since $v = \sqrt{(2gh)}$, the slide with the greatest vertical drop gives the largest speed. The length, shape or steepness of a slide does not matter.

a Comparing the slides

- Compare the vertical height from the starting point of each slide to its exit point.
- Slides with equal vertical drops give equal speeds, however different their shapes (spiral, straight or curved).
- In the illustration, the blue and red slides appear to start from the same raised platform, while the purple slide appears to start from a lower tower. If they end at the same level, the blue and red slides give the larger (and equal) speeds.

Therefore, the slide whose top is highest above its bottom gives the largest speed at the bottom.

QUESTION 4 *Pause and Ponder 1 · p. 119*

In the previous chapter, a weightlifter is shown holding a barbell steady in her hands (Fig. 6.8). Is she doing any work on the barbell while holding it steady?

ANSWER

No. In the scientific sense, no work is done on the barbell while it is held steady.

a Reasoning

- Work done by a force is $W = F \times s$, where s is the displacement in the direction of the force.
- While the barbell is held steady it does not move, so $s = 0$ and $W = F \times 0 = 0$, however large the force.

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- She feels tired because her muscles repeatedly expand and contract and use up the internal energy of her body, but this is not work done on the barbell.

Therefore, holding the barbell steady means zero displacement, so zero work is done on it.

QUESTION 5 *Pause and Ponder 2 · p. 119*

Is the work done by friction on the stack of coins that travels on a rough surface (Fig. 6.13c) — positive, negative or zero?

ANSWER

The work done by friction on the moving coins is negative.

a Reasoning

- Friction acts opposite to the direction of motion of the coins, so the force and the displacement are in opposite directions.
- When the displacement is opposite to the force, the work done by the force is negative: $W = F \times (-s)$.
- By the work-energy theorem, this negative work decreases the kinetic energy of the coins, so they slow down and stop.

Therefore, the work done by friction on the coins is negative.

QUESTION 6 *Pause and Ponder 3 · p. 121*

When you pedal a bicycle on a flat road, your muscles supply energy. In what forms does this muscular energy appear as you ride?

ANSWER

The chemical energy of the food we eat is converted by the muscles into mechanical energy, which then appears in several forms while we ride.

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a Forms of the muscular energy

Form of energy	Where it appears
Kinetic energy	In the moving bicycle and rider, when the speed increases or is maintained
Thermal energy (heat)	In the chain, bearings and tyres (friction), in the air (air resistance) and in the warming body
Sound energy	In the small noises of the chain, tyres and moving parts

On a flat road the height does not change, so no potential energy is gained. At a steady speed, the muscular energy mostly goes into doing work against friction and air resistance, which appears as heat.

Therefore, muscular energy appears mainly as kinetic energy, thermal energy and a little sound energy.

QUESTION 7 *Pause and Ponder 4 · p. 123*

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?

ANSWER

Equal kinetic energies with different masses mean the lighter object moves faster. Equate $\frac{1}{2}mv^2$ for both.

a Given

Object	Mass	Kinetic energy
A	m	K
B	$4m$	K (same)

b Solution

Step	Working	Result
1	$\frac{1}{2}mv_A^2 = \frac{1}{2}(4m)v_B^2$	Equal energies
2	Cancel $\frac{1}{2}m$ on both sides	$v_A^2 = 4v_B^2$
3	Take the square root of the magnitudes	$v_A = 2v_B$
4	Ratio	$\mathbf{v_A : v_B = 2 : 1}$

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Therefore, the ratio of the magnitudes of velocities of A and B is 2 : 1.

QUESTION 8 *Pause and Ponder 5 · p. 123*

Does the kinetic energy of an object which moves with constant velocity change with its position?

ANSWER

No. The kinetic energy of an object moving with constant velocity does not change with its position.

a **Reasoning**

- Kinetic energy is $K = \frac{1}{2}mv^2$; it depends only on the mass and the speed, not on where the object is.
- With constant velocity, m and v do not change, so K stays constant.
- Equivalently, the net force is zero, so no net work is done and (work-energy theorem) there is no change in energy.

Therefore, the kinetic energy stays the same at every position.

QUESTION 9 *Pause and Ponder 6 · p. 126*

Does the potential energy of an object near the surface of the Earth change if it moves with constant velocity in the horizontal direction? What if the object is gradually raised in the vertical direction?

ANSWER

Near the Earth's surface the potential energy is $U = mgh$, so it changes only when the height h changes.

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a The two cases

Motion	Height *h*	Potential energy *mgh*
Horizontal, constant velocity	Does not change	No change
Gradually raised vertically	Increases	Increases (by *mg* times the rise in height)

Therefore, horizontal motion leaves the potential energy unchanged, while raising the object increases it.

QUESTION 10 *Pause and Ponder 7 · p. 129*

For the situation depicted in Fig. 7.19, calculate the mechanical energy of the ball just before it hits the ground and show that even at this position, it is *mgh*.

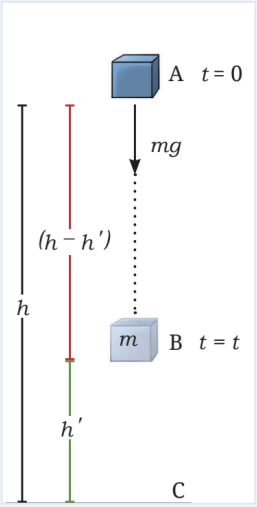


Fig. 7.19. An object falling freely due to gravity

ANSWER

The ball is dropped from height h with $u = 0$. Just before it hits the ground its height is zero. Find its speed and add the two energies.

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a Solution

Step	Working	Result
1	Height after time t: $h' = h - \frac{1}{2}gt^2$. At the ground $h' = 0$	$t^2 = 2h/g$
2	Velocity at the ground: $v = gt$, so $v^2 = g^2t^2 = g^2(2h/g)$	$v^2 = 2gh$
3	Potential energy = $mgh' = mg(0)$	0
4	Kinetic energy = $\frac{1}{2}mv^2 = \frac{1}{2}m(2gh)$	mgh
5	Mechanical energy = potential + kinetic = 0 + mgh	***mgh***

Therefore, just before hitting the ground the mechanical energy is *mgh*, the same as at the start: it is conserved.

QUESTION 11 *Pause and Ponder 8 · p. 129*

You may have seen an exhibit like that in Fig. 7.22 in a science park, where a ball is released from the highest point. Describe how the kinetic energy and potential energy change at points A, B and C. Why do subsequent points, such as C, D and E, usually have lower heights compared to the previous ones? Could it have anything to do with the energy lost due to friction?

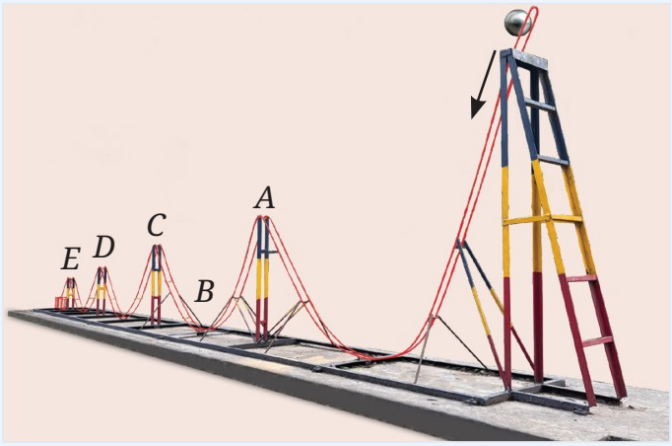


Fig. 7.22. Ball roller coaster in a science park

ANSWER

The ball starts at the highest point with only potential energy. As it moves along the track, potential and kinetic energy keep changing into each other, and a little mechanical energy is lost at every stage.

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a Changes in kinetic and potential energy

Stage	Potential energy	Kinetic energy
Release (highest point)	Maximum	Zero
Going down into a valley	Decreases	Increases (maximum at the lowest point)
Climbing to a crest (A, then B, then C)	Increases	Decreases, but the ball is still moving at the crest
From crest A to B to C	Smaller at each crest, since the crests get lower	Total of the two is slightly less at each crest

b Why are C, D and E lower than the points before them?

- Yes, it is due to the energy lost to friction (between the ball and the track) and to air resistance.
- These forces do negative work, converting part of the mechanical energy into thermal energy (heat) and sound.
- With less mechanical energy left at each stage, the ball cannot climb as high as before. Without friction, it would rise to the same height each time.

Therefore, potential and kinetic energy interchange along the track, and the lost energy makes each later crest lower.

QUESTION 12 *Pause and Ponder 9 · p. 132*

Explain why roads on hills are built to wind around in gentle slopes rather than going straight up (Fig. 4.26)?

ANSWER

A hill road is an inclined plane. For the same gain in height, a gentler slope makes the road longer and reduces the force needed.

a Using the inclined plane

- Effort needed: $F' = mgh/L$ (Eq. 7.13), where h is the height gained and L is the length of the road.
- A road going straight up is short (small L), so a large force is needed.

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- A winding road is much longer (large L), so the mechanical advantage L/h is larger and a smaller force is needed.
- The work done against gravity (mgh) is the same; it is simply spread over a longer distance.

Therefore, winding roads on gentle slopes need less effort from vehicles to climb the same height.

QUESTION 13 *Pause and Ponder 10 · p. 132*

To reach a higher floor, we find climbing an inclined ladder easier in comparison to climbing a vertical ladder (Fig. 7.30). Explain why.

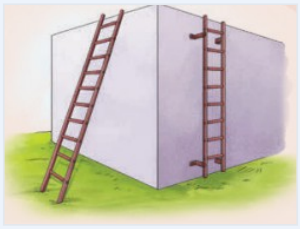


Fig. 7.30. Climbing ladders

ANSWER

An inclined ladder works like an inclined plane: we cover a longer distance along it, but need a smaller force.

a Comparison

Point	Vertical ladder	Inclined ladder
Distance climbed for the same height h	$L = h$	$L > h$
Mechanical advantage L/h	1	Greater than 1
Force needed along the path	Equal to the whole weight mg	mgh/L, less than mg
Work against gravity	mgh	mgh (same)

Therefore, the inclined ladder is easier because the same work is done over a longer distance with a smaller force.

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QUESTION 14 *Pause and Ponder 11 · p. 135*

Why is it easier to open the lid of a can by using a spoon as shown in Fig. 7.35?



Fig. 7.35. Opening the lid by using a spoon

ANSWER

The spoon acts as a lever. A small effort applied far from the pivot produces a large force on the lid near the pivot.

a Parts of the lever

Part	In this case
Fulcrum	The rim of the can on which the spoon rests
Load	The resistance of the lid, acting close to the fulcrum (short load arm)
Effort	The force of the hand at the far end of the handle (long effort arm)

Mechanical advantage = effort arm / load arm, which is greater than 1 here. From effort × effort arm = load × load arm, a small effort balances and overcomes the large load.

Therefore, the spoon’s long handle (long effort arm) lets a small effort open the lid easily.

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QUESTION 15 *Pause and Ponder 12 · p. 135*

Why do you push an object closer to scissors fulcrum when you want to cut an object which is hard?

ANSWER

The scissors is a lever with its fulcrum at the pivot. The object to be cut is the load, and the fingers apply the effort.

a Reasoning

- Moving the object towards the fulcrum makes the load arm shorter, while the effort arm stays the same.
- From effort × effort arm = load × load arm, the force applied on the object = effort × (effort arm / load arm), which increases when the load arm decreases.
- So the mechanical advantage (effort arm / load arm) increases, and the same effort cuts a harder object.

Therefore, a shorter load arm gives a larger cutting force for the same effort.

QUESTION 16 *Pause and Ponder 13 · p. 135*

Throughout history, many designs of perpetual machines (using wheels, weights or magnets) have been proposed but none actually work. Why do all real machines eventually slow down and stop? Explain in terms of work and energy.

ANSWER

Real machines lose mechanical energy continuously, and nothing replaces it. So they must slow down and stop.

a Energy losses

- Friction at the bearings and air resistance do negative work on the moving parts.
- This work converts mechanical energy into thermal energy (heat) and sound, which spread into the surroundings and cannot be fully brought back.

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b No source of energy

- Machines do not create energy; they only help us use it more effectively.
- Doing useful work transfers energy to the load. Without fuel or electricity to supply more, the energy runs out and the machine stops.

Therefore, real machines stop because friction and air resistance keep removing mechanical energy that is never replaced.

QUESTION 17 *What If ... · p. 135*

What if it were possible to build a perpetual motion machine, which once started, could continue doing useful work forever, without any fuel or electricity?

ANSWER

This is a thought experiment. Such a machine would have to deliver energy continuously without taking any in.

a What it would mean

- Doing useful work transfers energy out of the machine, so the energy would have to be created from nothing.
- That would contradict the principle that the total energy of a system not acted upon by external forces stays constant.
- It would also need to have no friction or air resistance at all, which is impossible for real machines.
- We would have a free and unlimited source of energy and no need for fuel or electricity, but since no such machine has ever worked, scientists conclude it cannot exist.

Therefore, a perpetual motion machine is impossible, because machines can only use energy more effectively, never create it.

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7.2

CLASS 9 SCIENCE · CHAPTER 7

Activities

Solutions · 8 questions

Directions (Questions 1–8): These are the activities in the chapter (Activities 7.1 to 7.5) and The Journey Beyond tasks. Observation-based answers and model results are given; your own measurements may differ slightly.

QUESTION 1

Activity 7.1 · p. 125

Activity 7.1: Let us investigate. 1. Take a heavy ball and a large container filled with loose sand. 2. Raise the ball over the sand bed to a height of about 1 m and drop it (Fig. 7.17). Is a depression created in the sand? Why does the ball create a depression? 3. Now, raise the ball to the height of 2 m and release it at a slightly different position over the sand bed such that the depressions do not overlap. Repeat this step one more time. Compare the depths of the depressions. Is there any difference? In which case is the depression deepest and in which case the shallowest?



Fig. 7.17. Depressions created by a ball in sand dropped from different heights

ANSWER

Yes, a depression is created each time, and its depth depends on the height from which the ball is dropped: the greater the height, the deeper the depression.

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a Observations

Drop	Observation
From about 1 m	A depression is formed in the sand
From greater heights (2 m and above)	Deeper depressions than from 1 m
Deepest depression	Drop from the greatest height
Shallowest depression	Drop from the smallest height

b Explanation

- Raising the ball to a height requires work, which is stored as potential energy *mgh*; a greater height needs more work, so more energy is stored.
- While falling, this potential energy changes into kinetic energy. On reaching the sand the ball pushes the sand aside, doing work on it until it stops.
- More energy at release means more work on the sand, and hence a deeper depression.

Therefore, the greater the height of the ball above the ground, the greater its potential energy and the deeper the depression.

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QUESTION 2 *Activity 7.2 · p. 127*

Activity 7.2: Let us experiment. 1. Set up a simple pendulum as you have learnt in Grade 7. 2. Paste a white sheet of paper on a wall behind the pendulum. Draw a horizontal line above the position of the bob when it is not oscillating (Fig. 7.20). 3. Take the bob to one side to a point P, which is at the level of the horizontal line and let it go. Observe it at the extreme points of the first couple of oscillations. Does the bob almost reach the level of the horizontal line?

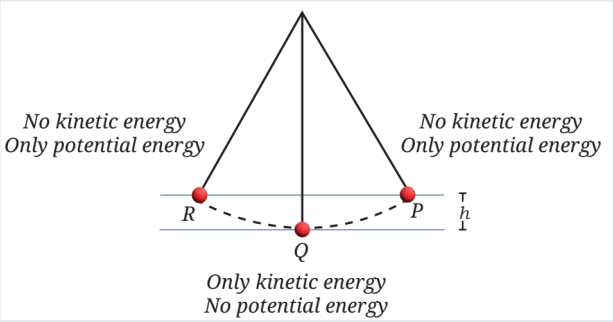


Fig. 7.20. A pendulum

ANSWER

Yes. The bob almost reaches the level of the horizontal line on the other side, and comes back to almost the same level again.

a Energy at the three positions

Position	Kinetic energy	Potential energy
P (extreme, at the line)	Zero	Maximum, *mgh*
Q (lowest point)	Maximum	Zero
R (other extreme)	Zero	Regained, almost *mgh*

The bob reaches almost the same height it started from, which shows that its mechanical energy stays almost constant. It is a little below the line because some energy is lost to friction at the support and to air resistance; for the same reason a real pendulum slowly stops.

Therefore, the bob almost reaches the line, demonstrating the conservation of mechanical energy.

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QUESTION 3 *Activity 7.3 · p. 131*

Activity 7.3: Let us experiment. 1. Take a smooth plank (say a cardboard piece) about 1.5 m long, a toy car (or the cart that you used in Activity 6.3) and a spring balance. Attach the spring balance to the cart. Arrange an elevated surface, such as the top of a low stool or a pile of books, at about 0.5 m height from the floor. 2. First, lift the cart vertically, slowly and steadily, from the floor to the top of the pile of books or stool, and note the reading of the spring balance scale. This reading indicates the force required to lift the cart vertically which is equal to the weight of the cart. 3. Next, place the plank against the top of the pile of books or stool as shown in Fig. 7.27a. Pull the cart along the plank slowly and steadily. Is the reading of the spring balance (the force required) smaller than that of step 2? 4. Now, reduce the angle between the plank and the base as shown in Fig. 7.27b, and repeat the step 3. Observe how the force required changes as the plank becomes less steep.

ANSWER

Yes. The reading is smaller on the plank than for the vertical lift, and it becomes smaller still as the plank becomes less steep. But the cart then has to be pulled over a longer distance.

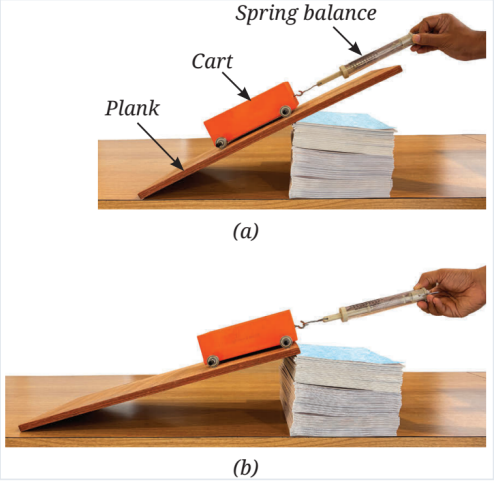


Fig. 7.27. Measuring the force required to pull up a cart along an inclined plank of (a) smaller length, and (b) larger length

a Observations

Set-up	Force (spring balance)	Distance moved
Vertical lift (step 2)	Equal to the weight of the cart	Height h
Steeper plank (step 3)	Less than the weight	Length L, larger than h
Less steep plank (step 4)	Even smaller	Larger L

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b Explanation

- Ignoring friction, $F' \times L = mgh$, so $F' = mg \times h/L$. The mechanical advantage is L/h.
- For the suggested size, $h = 0.5$ m and $L = 1.5$ m, the ideal force is one-third of the weight of the cart (mechanical advantage 3).
- The work done (force × distance) is the same in every case; if the force decreases, the displacement increases.

Therefore, the force needed decreases as the plank becomes less steep, but the work done remains the same.

QUESTION 4 *Activity 7.4 · p. 133*

Activity 7.4: Let us investigate. 1. Take a 30 cm long scale, a pencil, 2 – 3 erasers and a stapler (or a similar object). 2. Place the scale over the pencil such that the pencil is closer to one end of the scale as shown in Fig. 7.31. On the end of the scale closer to the pencil, place the stapler. 3. On the other end of the scale, place one eraser. Does the stapler lift up? If not, add one more eraser.

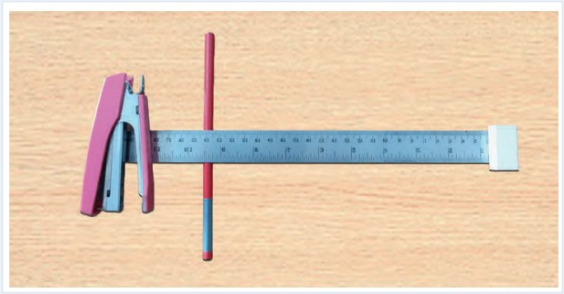


Fig. 7.31. Lifting a heavier object with lighter object

ANSWER

Yes. A much heavier object (the stapler) can be lifted by lighter erasers. If one eraser is not enough, adding one more eraser lifts it.

a The scale as a lever

Part	In this activity
Fulcrum	The pencil
Load	The stapler, near the fulcrum (short load arm)
Effort	The erasers, at the far end (long effort arm)

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The lever balances when effort × effort arm = load × load arm. Because the effort arm is much longer than the load arm, the mechanical advantage (effort arm / load arm) is greater than 1, so a small effort lifts a larger load.

Therefore, the scale works as a lever: a light eraser at the long arm can lift a heavy stapler at the short arm.

QUESTION 5 *Activity 7.5 · p. 133–134*

Activity 7.5: Let us experiment. Make a beam balance from a long scale (50 cm or larger) tied at its midpoint, with two paper cups as pans (Fig. 7.33). 4. Place 1 coin in the left pan (call it effort) and 1 identical coin in the right pan (call it load). Observe that the beam stays horizontal. 5. Add one more coin to the right pan, so that it contains 2 coins. The beam tilts. Move the heavier pan closer to the centre of the beam to balance the beam. Measure its distance from the centre. 6. Repeat step 5 with 4 coins and then 8 coins in the right pan. Each time, note its distance from the centre that balances the beam. 7. Record all observations and measurements, and complete the Table 7.1 by adding more rows.

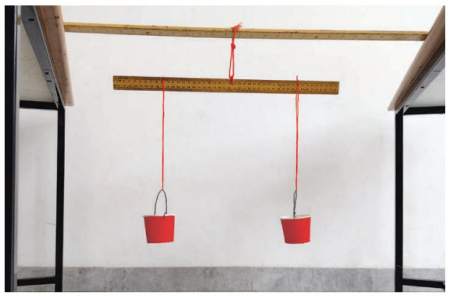


Fig. 7.33. Balancing cups hung on a scale

ANSWER

The beam balances when $n_1 \times L_1 = n_2 \times L_2$. Keeping the left pan at the end of a 50 cm scale (L_1 = 25 cm from the midpoint), the right-pan distance for each load is shown below.

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a Table 7.1 (model readings)

Number of coins in left pan, n_1 (Effort)	Distance of left pan from the fulcrum, L_1 (cm)	Number of coins in right pan, n_2 (Load)	Distance of right pan from the fulcrum, L_2 (cm)
1	25	1	25
1	25	2	12.5
1	25	4	6.25
1	25	8	3.125

b Checking the balance condition

$n_1 \times L_1$	$n_2 \times L_2$	Equal?	$L_2 = n_1L_1/n_2$
1 × 25 = 25	1 × 25 = 25	Yes	25 cm
1 × 25 = 25	2 × 12.5 = 25	Yes	12.5 cm
1 × 25 = 25	4 × 6.25 = 25	Yes	6.25 cm
1 × 25 = 25	8 × 3.125 = 25	Yes	3.125 cm

These are the expected values; your measured distances will be close to them, with small differences due to measurement error.

Therefore, the beam balances when effort × effort arm = load × load arm (Eq. 7.15): doubling the load halves its distance from the fulcrum.

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QUESTION 6 *The Journey Beyond · p. 139*

Remove both the ends from a pen so that the refill can slide freely through the barrel (Fig. 7.40). Fix the pen cap to the side of the barrel and attach a rubber band to the clip of the cap. Connect the free end of the rubber band to the refill using a safety pin. Stretch and release the rubber band. The refill shoots out, showing the conversion of elastic potential energy into kinetic energy. Repeat with different amounts of stretch, and observe how the distance travelled changes. Is there a relationship between the stretch and the distance travelled?

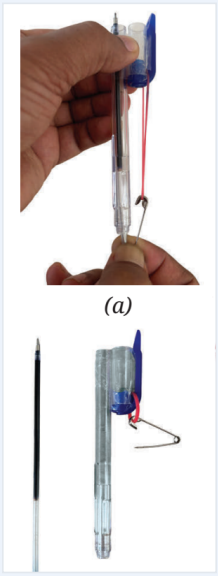


Fig. 7.40. Pen-refill launcher

ANSWER

Yes. The more the rubber band is stretched, the farther the refill travels.

a Record the observations

Stretch of the band	Energy stored	Distance travelled
Small	Small	Short (measure with a ruler)
Medium	Greater	Longer
Large	Greatest	Longest

b Explanation

- Work is done in stretching the band, and it is stored in the band as elastic potential energy.
- On release, the band pushes the refill and this energy becomes the kinetic energy of the refill.
- A larger stretch stores more energy, so the refill gains more kinetic energy and travels farther.

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Therefore, the distance travelled increases as the stretch increases.

QUESTION 7 *The Journey Beyond · p. 139*

Construct one or more simple machines, or a combination of them (lever, pulley, and inclined plane) using easily available materials, such as cardboard, wooden strips or rulers, pencils or bolts (to act as a fulcrum), thread or rope, small pulleys (or two bottle caps stuck together), and paper cups to hold small weights. Be imaginative in your design. Use your model to lift or move a small load, measure the effort and the load, and calculate the mechanical advantage.

ANSWER

This is a project. The steps and a model report are given; fill in your own measurements.

a Steps

- Build a lever (ruler on a pencil), an inclined plane (plank on books) or a pulley (thread over bottle caps).
- Put a known load in a paper cup and find the effort needed to lift or move it (for example with a spring balance or by adding weights).
- Calculate the mechanical advantage = load / effort (Eq. 7.12).

b Model report and expected ideal values

Machine	Measurements	Ideal mechanical advantage	Formula
Lever	Effort arm 20 cm, load arm 5 cm	4	Effort arm / load arm
Inclined plane	Length 50 cm, height 30 cm	1.67	L / h
Fixed pulley	Effort = load	1	Load / effort

Your measured mechanical advantage will be a little smaller than the ideal value because of friction. Remember that a machine reduces the effort but not the total work done.

Therefore, the mechanical advantage of your model is the load divided by the effort needed.

NCERT ARCHIVE

QUESTION 8 *The Journey Beyond · p. 139*

Computer simulations can help in visualising physical quantities that are difficult to observe directly. The PhET simulations (https://phet.colorado.edu) provide interactive models, such as Energy Skate Park, Energy Forms and Changes, Pendulum Lab, and Masses and Springs. Use these to explore how different forms of energy change as parameters, such as mass, height, and friction are varied.

ANSWER

This is a simulation activity. The results below follow from the chapter and are what you should observe.

a What to expect

Parameter changed	What you observe	Reason
Height increased	Larger speed at the bottom; more potential energy at the top	$U = mgh$ and $v = \sqrt{(2gh)}$
Mass increased	Energies become larger but the speed at the bottom is the same (no friction)	Mass cancels from $\frac{1}{2}mv^2 = mgh$
Friction added	The skater or bob does not return to the same height; thermal energy appears; total energy stays constant	Friction turns mechanical energy into heat
Spring stretched or compressed (Masses and Springs)	Energy is stored in the spring and released as motion	Elastic potential energy

Therefore, the simulations show energy changing form (potential, kinetic, thermal) with the total energy conserved.

NCERT ARCHIVE

7.3

CLASS 9 SCIENCE · CHAPTER 7

Worked Examples

Solutions · 13 questions

Directions (Questions 1–13): These are the worked examples in the chapter (Examples 7.1 to 7.13). Each one is re-solved step by step with every calculation checked.

QUESTION 1 *Example 7.1 · p. 119*

While exercising, a girl lifts a dumbbell and slowly lowers it down. Identify when the girl does positive work on the dumbbell and when she does negative work on it.

ANSWER

The sign of the work depends on whether the force and the displacement are in the same or in opposite directions.

Motion	Force applied by the girl	Displacement	Work
Lifting it up	Upward, equal to the weight	Upward (same direction as force)	**Positive**
Lowering it down	Upward, to hold it	Downward (opposite to force)	**Negative**

Therefore, the girl does positive work while lifting the dumbbell and negative work while lowering it.

NCERT ARCHIVE

QUESTION 2 *Example 7.2 · p. 119*

While saving a goal (Fig. 7.7b), a goalkeeper's hand moved back by 15 cm as she stopped a ball while applying a force of 200 N. How much work did the goalkeeper do on the ball in stopping it?

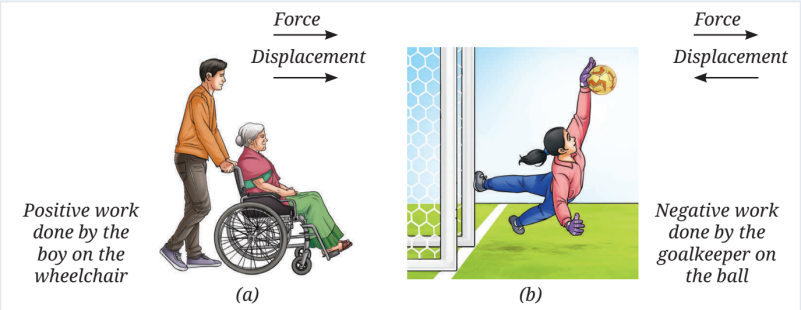


Fig. 7.7. Examples of (a) positive, and (b) negative work done on object

ANSWER

The force on the ball is opposite to the ball's displacement, so the work is negative.

a Given

Quantity	Value
Force applied, F	200 N
Displacement of ball (opposite to F)	−15 cm = −0.15 m

b Solution

Step	Working	Result
1	Convert: 15 cm = 15/100 m	0.15 m
2	Displacement is opposite to the force, so it is negative	$s = -0.15$ m
3	$W = F \times s = 200\ \text{N} \times (-0.15\ \text{m})$	**−30 J**

Therefore, the goalkeeper does −30 J of work on the ball (negative work).

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QUESTION 3 *Example 7.3 · p. 120*

In a game of carrom, a player played the shot shown in Fig. 7.9 to pocket the black coin. Identify who does work, and the changes in energy that occur at each collision.

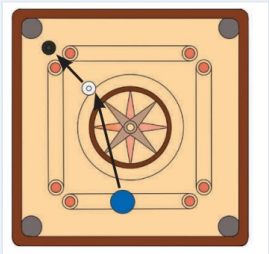


Fig. 7.9. A carrom shot

ANSWER

At each collision the two coins exert equal and opposite forces on each other (Newton's third law), so both do work.

Collision	Positive work done by	Negative work done by	Change in energy
Striker hits white coin	Striker, on the white coin	White coin, on the striker	White coin gains energy; striker loses energy
White coin hits black coin	White coin, on the black coin	Black coin, on the white coin	Black coin gains energy; white coin loses energy

Therefore, energy is passed from the striker to the white coin and then to the black coin.

QUESTION 4 *Example 7.4 · p. 122*

If the velocity of a vehicle doubles in magnitude, what will its kinetic energy be compared to its original value?

ANSWER

Compare $\frac{1}{2}mv^2$ for the speeds v and $2v$.

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Step	Working	Result
1	Initial kinetic energy	$K_1 = \frac{1}{2}mv^2$
2	New kinetic energy at $2v$: $\frac{1}{2}m(2v)^2 = \frac{1}{2}m \times 4v^2$	$K_2 = 4 \times \frac{1}{2}mv^2$
3	Ratio K_2 / K_1	**4**

Therefore, the kinetic energy becomes 4 times the original value.

QUESTION 5 *Example 7.5 · p. 122*

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.

ANSWER

a Given

Quantity	Value
Mass, m	0.2 kg
Velocity	154.8 km h^{-1}

b Solution

Step	Working	Result
1	Convert: 154.8 km h^{-1} = 154.8 × 1000 / 3600	43 m s^{-1}
2	$K = \frac{1}{2}mv^2 = \frac{1}{2} \times 0.2$ kg × (43 m s^{-1})^2	0.1 × 1849
3	Evaluate	**184.9 J**

Therefore, the kinetic energy of the ball at delivery is 184.9 J.

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QUESTION 6 *Example 7.6 · p. 123*

A jet aircraft of mass 15000 kg lands on the deck of an aircraft carrier (Fig. 7.12). 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?

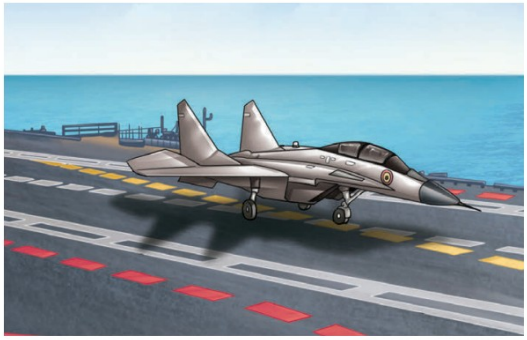


Fig. 7.12. A jet aircraft landing on an aircraft carrier

ANSWER

a Given

Quantity	Value
Mass, m	15000 kg
Backward force of wire, F	367500 N
Stopping distance	100 m
Final velocity	0

b Solution

Step	Working	Result
1	Work done by the wire (force opposite to displacement): $W = 367500\ \text{N} \times (-100\ \text{m})$	-36750000 J
2	Change in kinetic energy $= 0 - \frac{1}{2}(15000)v^2 = -7500v^2$	$-7500v^2$ J
3	Work-energy theorem: $-7500v^2 = -36750000$	$v^2 = 4900$
4	Take the square root	$v = 70\ \text{m s}^{-1}$
5	Convert: 70×3.6	**252 km h^{-1}**

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Therefore, the aircraft was moving at 70 m s^{-1} (252 km h^{-1}) just before the wire caught the hook.

QUESTION 7 *Example 7.7 · p. 126*

After taking a catch, a fielder threw the cricket ball of mass 200 g high up in the air about 10 m above the ground in celebration. How much potential energy does the ball have when the ball reaches its maximum height? Assume g = 10 m s^{-2}.

ANSWER

a Given

Quantity	Value
Mass, m	200 g = 0.2 kg
Height, h	10 m
g	10 m s^{-2}

b Solution

Step	Working	Result
1	$U = mgh$ (Eq. 7.8)	Formula
2	U = 0.2 kg × 10 m s^{-2} × 10 m	**20 J**

Therefore, the ball has 20 J of potential energy at its maximum height.

QUESTION 8 *Example 7.8 · p. 128*

What will be the magnitude of velocity of the child on reaching the bottom of the slide of height h?

ANSWER

Friction is neglected, so the potential energy at the top changes entirely into kinetic energy at the bottom.

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Step	Working	Result
1	Potential energy at the top	mgh
2	Kinetic energy at the bottom	$\frac{1}{2}mv^2$
3	Equate: $\frac{1}{2}mv^2 = mgh$	$v^2 = 2gh$
4	Take the square root	$\boldsymbol{v = \sqrt{(2gh)}}$

The velocity depends only on the height h, so the shape of the slide and the mass of the child do not matter.

Therefore, the child reaches the bottom with velocity $v = \sqrt{(2gh)}$.

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QUESTION 9 *Example 7.9 · p. 128*

Escape ramps (Fig. 7.21) are inclined planes filled with sand or gravel that help stop trucks when their brakes fail on a highway. A truck of mass 10000 kg is moving at 72 km h^{-1} when its brakes fail. The driver steers it onto an escape ramp inclined at 30°, where the truck comes to a rest. If the sand exerts a force of 50000 N opposite to truck's motion, what is the minimum length of the ramp to be able to stop such a truck? Take g = 10 m s^{-2} (Hint: For a 30° incline, the truck rises 1 m vertically for every 2 m it travels along the ramp).



Fig. 7.21. Escape ramp

ANSWER

a **Given**

Quantity	Value
Mass, m	10000 kg
Speed	72 km h^{-1} = 20 m s^{-1}
Force of sand	50000 N (opposite to motion)
Rise	1 m per 2 m along the ramp

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b Solution

Step	Working	Result
1	Initial kinetic energy = ½ × 10000 × 20^2; initial potential energy = 0	2000000 J
2	Let the truck travel a distance d along the ramp; height gained = $d/2$	$h = d/2$
3	Final kinetic energy = 0; final potential energy = 10000 × 10 × $d/2$	50000 × d J
4	Work done by sand = −50000 N × d	$-50000d$ J
5	Work-energy theorem: $-50000d = 50000d - 2000000$	$100000d = 2000000$
6	Solve for d	**d = 20 m**

Check: for d = 20 m the height gained is 10 m, so potential energy = 10000 × 10 × 10 = 1000000 J, and the work done by the sand = 50000 × 20 = 1000000 J. Their sum is 2000000 J, equal to the initial kinetic energy.

Therefore, the minimum length of the ramp needed to stop the truck is 20 m.

QUESTION 10 *Example 7.10 · p. 129*

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

ANSWER

a Given

Quantity	Value
Mass, m	75 kg
Height, h	2 m
Time, t	5 s
g	10 m s^{-2} (as used in the chapter)

b Solution

Step	Working	Result
1	Work done = mgh = 75 kg × 10 m s^{-2} × 2 m	1500 J
2	Power $P = W/t$ = 1500 J / 5 s	**300 W**

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Therefore, the weightlifter requires 300 W of power.

QUESTION 11 *Example 7.11 · p. 129*

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 required to achieve this start.

ANSWER

a Given

Quantity	Value
Mass, *m*	1000 kg
Initial velocity, *u*	0
Final velocity, *v*	72 km h^{-1} = 72000 m / 3600 s = 20 m s^{-1}
Time, *t*	10 s

b Solution

Step	Working	Result
1	Work done = final kinetic energy − initial kinetic energy = ½ × 1000 × 20^2 − 0	200000 J
2	Power = work / time = 200000 J / 10 s	**20000 W**

Therefore, the engine must supply a power of 20000 W (20 kW).

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QUESTION 12 *Example 7.12 · p. 132*

A person uses an inclined ramp to raise an object over a step 30 cm high. The ramp has a width of 40 cm. What is the mechanical advantage of the ramp that helps the person achieve the task?

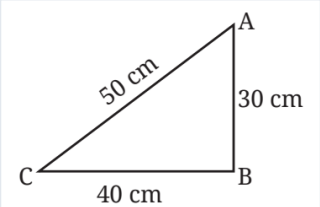


Fig. 7.29

ANSWER

The ramp forms a right-angled triangle ABC with height AB = 30 cm, width BC = 40 cm and length AC = L.

Step	Working	Result
1	Length of the ramp: $L = \sqrt{(30^2 + 40^2)} = \sqrt{2500}$	50 cm
2	Mechanical advantage = L / h (Eq. 7.13) = 50 cm / 30 cm	**1.67**

Therefore, the mechanical advantage of the ramp is 1.67 (greater than 1).

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QUESTION 13 *Example 7.13 · p. 134*

For a seesaw having four seats A, B, D, E and fulcrum at C (Fig. 7.34), AC = EC = 2 m and BC = DC = 1 m. On which seats should children of masses 15 kg and 30 kg sit to make the seesaw balanced?

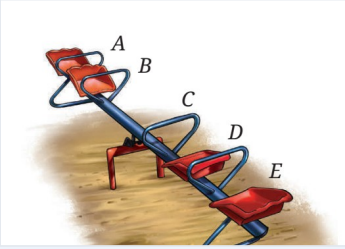


Fig. 7.34. A seesaw

ANSWER

A, B are on one side of C and D, E on the other. The seesaw is balanced when effort × effort arm = load × load arm (Eq. 7.15).

Step	Working	Result
1	Let the 15 kg child sit at A, at 2 m from the fulcrum, and the other child at a distance L	—
2	15 kg × 2 m = 30 kg × L	$30 = 30L$
3	Solve for L	L = 1 m
4	The seat 1 m from C on the other side is D	**Seat D**

By symmetry, the 15 kg child on E and the 30 kg child on B also balances (15 × 2 = 30 × 1).

Therefore, the 15 kg child sits on A and the 30 kg child on D (or 15 kg on E and 30 kg on B).

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7.4

CLASS 9 SCIENCE · CHAPTER 7

Revise, Reflect, Refine

Solutions · 15 questions

Directions (Questions 1–15): These are the questions of Revise, Reflect, Refine at the end of the chapter (pages 136–138). Each is solved step by step with units and a final check where possible.

QUESTION 1

Question 1 · p. 136

State whether True or False.
(i) Work is said to be done when a force is applied, even if the object does not move.
(ii) Lifting a bucket vertically upward results in positive work done on the bucket.
(iii) The SI unit for both work and energy is joule (J).
(iv) A motionless stretched rubber band has kinetic energy.
(v) Energy can change from one form to another.

ANSWER

Part	Answer	Reason
(i)	**False**	Work needs a displacement in the direction of the force; with no movement, $W = F \times 0 = 0$.
(ii)	**True**	The upward force and the upward displacement are in the same direction, so the work is positive.
(iii)	**True**	Work and energy are both measured in joules (1 J = 1 N × 1 m).
(iv)	**False**	It is not moving, so its kinetic energy is zero. It has elastic potential energy due to its stretched shape.
(v)	**True**	For example, electrical energy changes into light and heat in a bulb.

Therefore, the statements are: (i) False, (ii) True, (iii) True, (iv) False, (v) True.

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QUESTION 2 *Question 2 · p. 137*

Fill in the blanks.
(i) Work done = _____ × _____ (in the direction of force).
(ii) 1 joule of work is done when a force of _____ newton displaces an object by 1 metre in the direction of the force.
(iii) The expression for kinetic energy of a body of mass m and velocity v is _____.
(iv) The potential energy of an object of mass m at a small height h from the Earth's surface is _____.
(v) Power is defined as the _____ at which work is done.

ANSWER

Part	Completed statement
(i)	Work done = **force** × **displacement** (in the direction of force).
(ii)	1 joule of work is done when a force of **1** newton displaces an object by 1 metre in the direction of the force.
(iii)	The kinetic energy is $\frac{1}{2}mv^2$.
(iv)	The potential energy is mgh.
(v)	Power is defined as the **rate** at which work is done.

Therefore, the answers are: force, displacement; 1; $\frac{1}{2}mv^2$; mgh; rate.

QUESTION 3 *Question 3 · p. 137*

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.

ANSWER

Part	Correct?	Reason
(i)	No	Gravity (the weight mg) still acts on the ball.
(ii)	No	The acceleration is g downwards at every point of the motion.
(iii)	**Yes**	At the highest point the ball is momentarily at rest, so $K = \frac{1}{2}mv^2 = 0$.

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Part	Correct?	Reason
(iv)	**Yes**	The height is greatest, so $U = mgh$ is maximum.

Therefore, statements (iii) and (iv) are correct.

QUESTION 4 *Question 4 · p. 137*

For each of the following situations, identify the energy transformation that takes place: (i) a truck moving uphill, (ii) unwinding of a watch spring, (iii) photosynthesis in green leaves, (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 electric bulb, and (ix) a solar panel.

ANSWER

Part	Situation	Energy transformation
(i)	Truck moving uphill	Chemical energy of fuel → kinetic energy and gravitational potential energy (with some heat and sound)
(ii)	Unwinding of a watch spring	Elastic potential energy → kinetic energy of the moving parts
(iii)	Photosynthesis in green leaves	Light energy (sunlight) → chemical energy stored in food
(iv)	Water flowing from a dam	Gravitational potential energy → kinetic energy (which can then be used to generate electrical energy)
(v)	Burning of a matchstick	Chemical energy → thermal (heat) and light energy
(vi)	Explosion of a fire cracker	Chemical energy → sound, light, heat and kinetic energy
(vii)	Speaking into a microphone	Sound energy → electrical energy
(viii)	A glowing electric bulb	Electrical energy → light and thermal energy
(ix)	A solar panel	Light energy → electrical energy

Therefore, in every case energy changes from one form to another, as listed above.

NCERT ARCHIVE

QUESTION 5 *Question 5 · p. 137*

A student is slowly lifted straight up in an elevator from the ground level to the top floor of a building. Later, the same student climbs the staircase, all the way to the top. Given that the height of the building is h = 72.5 m, acceleration due to gravity is g = 10 m s^{-2}, and student's mass is m = 50 kg.
(i) Find the gain in the potential energy if the student is lifted straight up to the top.
(ii) Find the gain in the potential energy when the student climbs the stairs to the same top.
(iii) What do you conclude about the dependence of the potential energy on the path taken?

ANSWER

a Given

Quantity	Value
Mass, m	50 kg
Height, h	72.5 m
g	10 m s^{-2}

b Solution

Step	Working	Result
(i)	Elevator: gain in potential energy = mgh = 50 × 10 × 72.5	**36250 J**
(ii)	Stairs: the final height above the ground is again 72.5 m, so mgh = 50 × 10 × 72.5	**36250 J**
(iii)	Both gains are equal	Same for both paths

Therefore, the gain is 36250 J by either route; the potential energy depends only on the height reached, not on the path taken.

NCERT ARCHIVE

QUESTION 6 *Question 6 · p. 137*

A crane lifts a mass *m* to the 10th floor of a building in a certain time. It then raises the same mass to the 20th floor of the same building in double the time. How much more energy and power are required? Assume that the height of all floors is equal.

ANSWER

Let each floor have height H and let the lift start from the ground, so the 10th floor is at $10H$ and the 20th floor at $20H$. Let the first lift take time t and the second $2t$.

Step	Working	Result
1	Energy to the 10th floor: $E_1 = mg(10H)$	$10mgH$
2	Energy to the 20th floor: $E_2 = mg(20H)$	$20mgH = 2E_1$
3	Power for the first lift: $P_1 = E_1/t$	$10mgH/t$
4	Power for the second lift: $P_2 = E_2/(2t) = 20mgH/(2t)$	$10mgH/t = P_1$

Therefore, twice the energy (an additional $10mgH$) is required, but the power required is the same.

QUESTION 7 *Question 7 · p. 137*

Which factors determine the energy required to raise a flag from the ground to the top of a tall flagpole using a pulley? Does raising the flag slowly or quickly change the amount of work done? If the speed at which the flag is raised is doubled, how does the power requirement change? Explain your answers.

ANSWER

A fixed pulley only changes the direction of the effort (mechanical advantage 1); it does not reduce the work.

a Factors that determine the energy

- The mass (weight) of the flag, *mg*, and the height *h* of the flagpole.
- The energy required is *mgh* (ignoring friction in the pulley).

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b Slow or quick?

No. The work done equals the gain in potential energy, mgh, which depends only on the weight and the height, not on how fast the flag is raised.

c Doubling the speed

The time taken is halved, while the work is the same. Power = W/t, so the power requirement becomes double.

Therefore, the energy depends on the flag's mass and the pole's height; speed does not change the work, but doubling the speed doubles the power.

QUESTION 8 *Question 8 · p. 137*

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.

ANSWER

All the fuel energy becomes kinetic energy of the scooter and riders, so the fuel used is proportional to $\frac{1}{2}Mv^2$, where M is the total mass.

Step	Working	Result
1	Day 1: $M_1 = 60 + 100$	160 kg
2	Day 2: $M_2 = 60 + 40 + 100$	200 kg
3	Energy (fuel) $\propto M$ for the same v: $E_1 : E_2 = \frac{1}{2}(160)v^2 : \frac{1}{2}(200)v^2$	160 : 200
4	Simplify	**4 : 5**

Therefore, the ratio of the fuel used on the first day to the second day is 4 : 5.

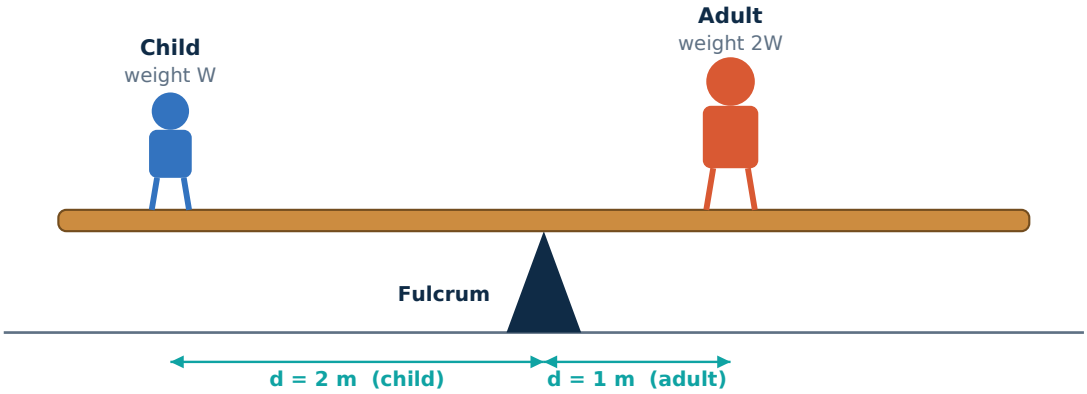
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QUESTION 9 *Question 9 · p. 138*

On a seesaw with sliding seats, a child is sitting on one side and an adult on the other side. The adult weighs twice that of the child. The seesaw however is balanced. Draw a figure which depicts this situation showing the distances from the fulcrum where the child and the adult are seated.

ANSWER

The seesaw is balanced when effort × effort arm = load × load arm. The adult is twice as heavy, so the adult must sit at half the distance of the child.



a Check

Person	Weight × distance	Value
Child (weight W) at 2 m	$W \times 2$ m	$2W$
Adult (weight $2W$) at 1 m	$2W \times 1$ m	$2W$

The distances 2 m and 1 m are chosen as an example; any pair of distances in the ratio 2 : 1 (child : adult) balances the seesaw.

Therefore, the child sits twice as far from the fulcrum as the adult, e.g. child 2 m and adult 1 m.

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QUESTION 10 *Question 10 · p. 138*

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 m s^{-2}).

ANSWER

i Sign of the work done by gravity

Motion	Gravity and displacement	Work by gravity
Upward	Gravity is downward, displacement is upward (opposite)	**Negative**
Downward	Gravity and displacement both downward (same direction)	**Positive**

ii Work done by air resistance

Step	Working	Result
1	Initial kinetic energy = ½ × 2 × 20^2	400 J
2	At the highest point the kinetic energy is zero and the potential energy = mgh = 2 × 10 × 19.4	388 J
3	Work done by air resistance = change in mechanical energy = 388 J − 400 J	**−12 J**

Check: without air resistance the ball would rise to $v^2/2g$ = 400/20 = 20 m. The 0.6 m shortfall corresponds to 2 × 10 × 0.6 = 12 J of energy lost.

Therefore, gravity does negative work going up and positive work coming down, and air resistance does −12 J of work (12 J of energy is lost).

NCERT ARCHIVE

QUESTION 11 *Question 11 · p. 138*

A 10.0 kg block is moving on horizontal floor with negligible friction. As shown in the Fig. 7.37, a variable force is applied on the block in its direction of motion from its position at 0 m till 4 m. If the block had a kinetic energy of 180 J when it was at 0 m, find the block's speed (i) at 0 m, and (ii) at 4 m. Does the block have negative acceleration in any portion of its motion?

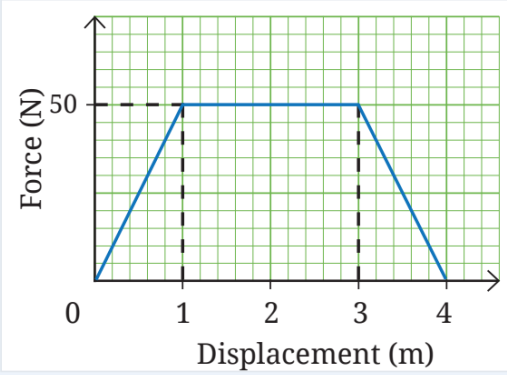


Fig. 7.37. Force-displacement graph

ANSWER

The work done by the force is the area under the force-displacement graph (Fig. 7.37), and by the work-energy theorem it equals the gain in kinetic energy.

i Speed at 0 m

Step	Working	Result
1	$K = \frac{1}{2}mv^2 = 180$ J, so $v^2 = 2 \times 180 / 10$	36
2	$v = \sqrt{36}$	**6 m s^{-1}**

ii Speed at 4 m

Step	Working	Result
1	The area under the graph is a trapezium with parallel sides 4 m and 2 m and height 50 N: work = $\frac{1}{2}(4 + 2) \times 50$	150 J
2	Kinetic energy at 4 m = 180 J + 150 J	330 J
3	$v^2 = 2 \times 330 / 10$	66
4	$v = \sqrt{66}$	**≈ 8.1 m s^{-1}**

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a **Negative acceleration?**

- No. The force is always in the direction of motion and never negative (it is 0 at the start and at 4 m, and rises to 50 N between 1 m and 3 m).
- So the acceleration, $a = F/m$, is never negative; it is 5 m s^{-2} between 1 m and 3 m, and the speed never decreases.

Therefore, the speed is 6 m s^{-1} at 0 m and about 8.1 m s^{-1} at 4 m, and the block never has negative acceleration.

QUESTION 12 *Question 12 · p. 138*

The gravitational attraction on the surface of the Moon (lunar surface) is about 1/6th of that on the surface of the Earth. An astronaut can throw a ball up to a height of 8 m from the surface of the Earth. How far up will the ball thrown with the same upward velocity travel from the surface of the Moon?

ANSWER

The kinetic energy at the start becomes potential energy at the highest point: $\frac{1}{2}mu^2 = mgh$, so $h = u^2/2g$. With the same u, h is inversely proportional to g.

Step	Working	Result
1	On Earth: $h_E = u^2/(2g)$	8 m
2	On the Moon: $g_M = g/6$, so $h_M = u^2/(2g/6) = 6 \times h_E$	6 × 8 m
3	Evaluate	**48 m**

Therefore, the ball will travel 48 m up on the surface of the Moon.

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QUESTION 13 *Question 13 · p. 138*

A 1000 kg car is moving along a road at a constant speed. Suddenly, the driver notices some obstruction ahead and applies the brakes to come to a complete stop. The graphical representation of motion of the car starting from the instant the driver spots the traffic ahead is shown in Fig. 7.38.
(i) Describe how the car moves between positions A and B.
(ii) Calculate the kinetic energy of the car at A.
(iii) State the work done by the brakes in bringing the car to a halt between B and C.
(iv) What does the kinetic energy of the car transform into?

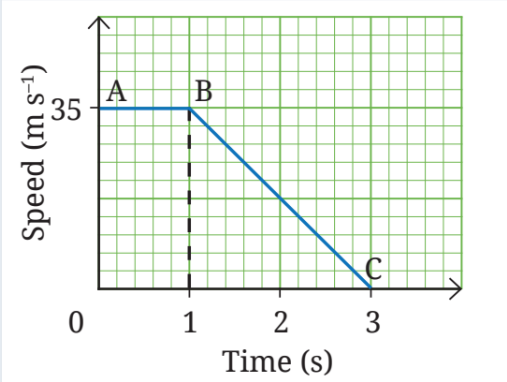


Fig. 7.38. Speed-time graph of the car

ANSWER

i Motion between A and B

The speed-time graph is a horizontal line from A to B: the car moves at a constant speed of 35 m s^{-1} for 1 s (zero acceleration) before the brakes are applied at B.

ii Kinetic energy at A, work by brakes and energy change

Step	Working	Result
(ii)	$K_A = ½mv^2 = ½ \times 1000 \times 35^2 = 500 \times 1225$	**612500 J**
(iii)	Work by brakes = change in kinetic energy = 0 − 612500 J	**−612500 J**
(iv)	The kinetic energy is changed by braking into heat	Thermal energy

The work is negative because the braking force is opposite to the motion. The kinetic energy changes mainly into thermal energy (heat) in the brakes, tyres and road, with a little sound. Check: from the graph the car slows from 35 m s^{-1} to 0 in 2 s (deceleration 17.5 m s^{-2}, force 17500 N) over ½ × 2 × 35 = 35 m, and 17500 × 35 = 612500 J.

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Therefore, the car moves uniformly from A to B, its kinetic energy at A is 612500 J, the brakes do −612500 J of work, and the energy becomes heat.

QUESTION 14 *Question 14 · p. 138*

The potential energy-displacement graph of a 0.5 kg ball moving along a frictionless track is shown in Fig. 7.39. At O, the velocity of the ball is 0 m s^{-1} and potential energy is 30 J. Calculate the velocity of the ball at P, Q and R.

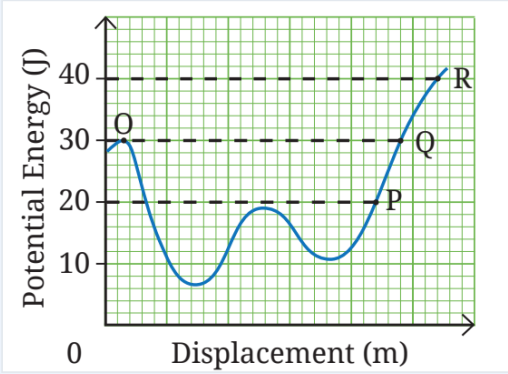


Fig. 7.39. Potential energy-displacement graph

ANSWER

The track is frictionless, so the total mechanical energy stays equal to the energy at O: 30 J (all potential, since $v = 0$). At any point, kinetic energy = 30 J − potential energy, and $v = \sqrt{(2K/m)}$.

Point	Potential energy (graph)	Kinetic energy = 30 − *U*	Velocity
P	20 J	10 J	$v = \sqrt{(2 \times 10 / 0.5)} = \sqrt{40} \approx$ **6.3 m s^{-1}**
Q	30 J	0 J	**0** (the ball momentarily stops and turns back)
R	40 J	−10 J (impossible)	The ball **cannot reach R**

At R the potential energy (40 J) would exceed the total energy (30 J), which would need a negative kinetic energy. So the ball starting from rest at O reaches Q, stops there, and returns; it never gets to R.

Therefore, the velocity at P is about 6.3 m s^{-1}, at Q it is zero, and the ball cannot reach R.

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QUESTION 15 *Question 15 · p. 138*

A coconut of mass 1.5 kg falls from the top of a coconut tree onto the wet sand on a beach. The height of the tree is 10 m. On impact, the coconut comes to rest by making a depression in the sand.
(i) Calculate the velocity of the coconut just before it hits the sand.
(ii) Assume that the average resistive force of sand is 3000 N and all of the coconut's energy is used to create the depression in the sand. Calculate the depth of the depression the coconut makes in the sand. Assume $g = 10\ \text{m s}^{-2}$.

ANSWER

a Given

Quantity	Value
Mass, m	1.5 kg
Height, h	10 m
Resistive force of sand	3000 N
g	10 m s^{-2}

i Velocity just before impact

Step	Working	Result
1	Potential energy at the top = kinetic energy just before impact: $mgh = \frac{1}{2}mv^2$	$v^2 = 2gh = 200$
2	$v = \sqrt{200}$	**$\approx 14.1\ \text{m s}^{-1}$**

ii Depth of the depression

Step	Working	Result
1	Energy to be used up = $mgh = 1.5 \times 10 \times 10$	150 J
2	Work done by sand = force × depth: 3000 N × d = 150 J	$d = 150/3000$
3	Evaluate	**$d = 0.05$ m = 5 cm**

Therefore, the coconut hits the sand at about 14.1 m s^{-1} and makes a depression about 5 cm deep.

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