CLASS 9 • PHYSICS

UNIT 5
Work, Energy and Power

Work, Forms of Energy, Power & Efficiency — Complete Notes

Definitions | Explanations | Solved Examples
Numerical Problems | MCQs | Short & Comprehensive Questions

UNIT 5: Work, Energy and Power

Long Questions & Answers

1 Define and explain work.

Work: The product of the magnitude of force and the distance covered in the direction of the force.
W = F × S
If the force makes angle θ with the direction of motion: W = FS cosθ.
Special cases: θ=0° → W=FS (maximum); θ=90° → W=0 (force perpendicular to displacement).
Work is a **scalar** quantity.

2 How is work done by a constant force found graphically?

On a force–distance graph, the area under the curve represents the work done by the force.
Unit: Joule (J); 1 J = 1 N·m. Bigger units: 1 kJ = 10^3 J, 1 MJ = 10^6 J.

3 Define and explain the concept of energy.

Energy: The ability of a body to do work. It is a scalar quantity, SI unit joule (J).
Basic forms: Kinetic Energy and Potential Energy — together called mechanical energy.

4 Define K.E. State its unit. Derive an expression for it.

Kinetic Energy: The energy a body possesses due to its motion.
Derivation: E_k = work done to bring the body to rest = F×S. Using F=ma and $v^2=2aS$:
$E_k = \frac{1}{2} m v^2$ (unit: joule)

5 Define and explain Potential Energy. Derive an expression for gravitational P.E.

Potential Energy: Energy a body possesses due to its position or deformation.
Forms: Gravitational P.E, Elastic P.E (spring), Chemical P.E (battery), Nuclear energy.
Derivation: Work done to raise a block of weight w to height h = wh = mgh.
$E_p = mgh$

6 State the law of conservation of energy with an example of a falling body.

Statement: Energy cannot be created or destroyed; it changes from one form to another, but the total remains constant.
Example: A body dropped from height h: at the top E_p=mgh, E_k=0. While falling, E_p decreases and E_k increases, but E_p+E_k = mgh throughout. Just before hitting the ground, E_k=mgh, E_p=0.

7 Describe briefly different sources of energy.

- **Fossil fuels** — burning oil, coal, gas to produce steam for turbines
- **Hydraulic (hydro) generation** — falling water rotates turbines
- **Solar energy** — heating panels or photovoltaic cells
- **Nuclear energy** — heat from nuclear fission (uranium, plutonium)
- **Geothermal energy** — heat from hot rocks underground
- **Wind energy** — windmills/turbines
- **Tidal energy** — rise and fall of sea water
- **Wave energy** — floats moving with sea waves
- **Biofuel energy** — combustion or digestion of biomass

8 Differentiate between renewable and non-renewable sources of energy.

Renewable: Naturally replenished — hydroelectric, solar, wind, tidal, wave, geothermal.
Non-renewable: Formed over millions of years, limited supply — fossil fuels and nuclear fuel.

9 Give advantages and disadvantages of methods of energy production.

Advantages: Hydroelectric power is economical and pollution-free; solar/wind/tidal/wave need higher initial cost but are pollution-free.
Disadvantages: Fossil fuels/nuclear cause pollution (smoke, CO_2, heat, radioactive waste); windmills are noisy; nuclear waste disposal is a major problem, contributing to thermal pollution and global warming.

10 Define and explain power and its unit.

Power: The time rate of doing work: P = W/t. Also = energy transferred per unit time.
Unit: Watt (W); 1 W = 1 J/s. 1 kW = 10^3 W, 1 MW = 10^6 W. British unit: horsepower, 1 hp = 746 W.

11 Explain the efficiency of a machine. How is it calculated? Why is it less than 100%?

Efficiency: η = Useful output energy / Total input energy (×100 for percentage).
Why less than 100%: Energy is always partly wasted as heat during conversion (friction etc.), so no machine converts all input energy into useful output.

12 What is meant by a Perpetual Energy Machine?

A hypothetical machine that could do work indefinitely without an external energy source. It is impossible, since it would need to generate more energy than it consumes — this violates the principle of conservation of energy, as some energy is always lost as heat due to friction/air resistance.

Solved Examples

Example 5.1 — Force from work done

W = 200 J, S = 5 m

F = W/S = 200/5 = 40 N

Example 5.2 — Work at an angle

F=65 N, S=20 m, θ=30°

W = FS cosθ = 65×20×0.866

W = 1125.8 J

Example 5.3 — Kinetic energy of a truck

m=3000 kg, v=54 km/h=15 m/s

Ek = ½mv² = ½×3000×15²

Ek = 337.5 kJ

Example 5.4 — Potential energy of a ball

m=0.18 kg, h=12 m, g=10

Ep = mgh = 0.18×10×12 = 21.6 J

Example 5.5 — Power of a car engine

m=1000kg, a=4 m/s², S=50 m, t=5 s

F=ma=4000 N, W=FS=2×10^5 J

P=W/t=40 kW

Example 5.6 — Efficiency of a system

W=120 N, F=100 N, S=20 m, h=10 m

Win=F×S=2000 J, Useful=W×h=1200 J

Efficiency = 1200/2000×100 = 60%

Numerical Problems

1. Force 20 N at 60° pulls a box 3 m. Find work done.

$W = FS\cos\theta = 20\times3\times\cos60° = 30$ J

2. Body moves 5 m under 8 N force; work done = 20 J. Find angle.

$20 = 8\times5\times\cos\theta$

$\cos\theta = 0.5,\ \theta = 60°$

3. Engine raises 100 kg water 80 m in 25 s. Find power.

$P = mgh/t = 100\times10\times80/25 = 3200$ W

4. Body of mass 20 kg, 40 N force acts for 5 s. Find K.E.

$a = F/m = 2$ m/s², $v = at = 10$ m/s

$Ek = \frac{1}{2}\times20\times10^2 = 1000$ J

5. Ball 160 g thrown up reaches 20 m. Find P.E gained.

$Ep = mgh = 0.16\times10\times20 = 32$ J

6. 0.14 kg ball thrown up at 35 m/s. Find max height.

$v^2=u^2-2gh;\ 0 = 35^2-20h$

$h = 61.25$ m

7. 600 N force pushes a box 5 m in 15 s. Find power.

$P = FS/t = 600\times5/15 = 200$ W

8. 40 kg boy runs upstairs 10 m high in 8 s. Find power.

$P = mgh/t = 40\times10\times10/8 = 500$ W

Short Questions

1. What is work done on an object that remains at rest when a force is applied?

Zero — since S=0, W = F×0 = 0.

2. A slow car may have more K.E than a fast motorcycle. How?

K.E = ½mv² depends on mass too. The car's much larger mass can outweigh the motorcycle's higher speed.

3. Force F1 does 5 J in 10 s, F2 does 3 J in 5 s. Which delivers greater power?
P1 = 5/10 = 0.5 W; P2 = 3/5 = 0.6 W. F2 delivers greater power.

4. Woman runs upstairs; gain in P.E is 4500 J. If she runs at twice the speed, new gain in P.E?
Unchanged (4500 J) — P.E = mgh is independent of speed.

5. How does a stretched bow store and transfer energy to the arrow?
The bow stores elastic potential energy when drawn back; on release this converts to kinetic energy, propelling the arrow forward.

6. According to Einstein, how are matter and energy related?
Matter and energy are interchangeable — mass lost in nuclear reactions converts to energy, leading to conservation of mass-energy rather than each separately.

7. Is timber/wood a renewable source of heat energy?
Yes — trees can be replanted and regrown, maintaining a sustainable supply.

8. Can K.E of a body ever be negative?
No — since it depends on v² (always positive) and mass is always positive, K.E is always positive or zero.

Multiple Choice Questions

1. Work done is maximum when angle between F and d is:

(a) 0° (b) 30° (c) 60° (d) 90°

Answer: (a)

2. A joule can also be written as:

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

Answer: (d)

3. SI unit of power is:

(a) Joule (b) Newton (c) Watt (d) Second

Answer: (c)

4. 2 kW pump raises water 5 m in one minute. Volume raised:

(a) 1000 L (b) 1200 L (c) 2000 L (d) 2400 L

Answer: (d)

5. Bullet 0.05 kg at 300 m/s. Its K.E:

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

Answer: (a)

6. Car doubles its speed; its K.E becomes:

(a) same (b) doubled (c) 3 times (d) 4 times

Answer: (d)

7. Energy possessed due to position is:

(a) kinetic (b) potential (c) chemical (d) solar

Answer: (b)

8. Momentum of an object doubled; K.E:

(a) doubles (b) increases 4× (c) halves (d) stays same

Answer: (b)

9. Not a renewable energy source:

(a) Hydroelectric (b) Fossil fuels (c) Wind (d) Solar

Answer: (b)

10. Unit of work/energy joule equals:

(a) horsepower (b) watt metre (c) newton metre (d) newton second

Answer: (c)

11. Car, elephant, cricket ball — same K.E. Greater speed:

(a) car (b) elephant (c) cricket ball (d) all same

Answer: (c)

12. One horsepower equals:

(a) 756 W (b) 716 W (c) 736 W (d) 746 W

Answer: (d)

13. Box taken to 2nd floor — work converts to:

(a) kinetic (b) potential (c) heat (d) sound

Answer: (b)

14. Heated ground water gives which energy:

(a) tidal (b) geothermal (c) hydroelectric (d) nuclear

Answer: (b)

15. Renewable energy source:

(a) Coal (b) Natural gas (c) Sunlight (d) Uranium

Answer: (c)

16. Practical engine cannot have efficiency equal to:

(a) 0 (b) 0.5 (c) 0.8 (d) 1

Answer: (d)