FREE NOTES · NCERT + JEE/NEET LEVEL

Work, Energy & Power

Work kab hota hai, kinetic aur potential energy, work-energy theorem, energy conservation, spring, power, collisions aur vertical circle. Simple Hinglish me, diagrams aur solved numericals ke saath.

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02 Variable force ka work
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04 Work-energy theorem
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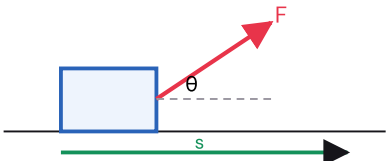
01 Work

Physics me **work tab hota hai jab force lagne se body displace ho**, aur force ka kuch hissa displacement ki direction me ho. Deewar ko poore din dhakelo, wo hili nahi, toh physics me work = 0.

FORMULA

$$W = F \cdot s = F\,s\cos\theta$$

θ = force aur displacement ke beech ka angle. Unit: joule (J) = N·m. Work scalar hai. 1 erg = 10^{-7} J, 1 eV = 1.6×10^{-19} J, 1 kWh = 3.6×10^{6} J.



Sirf F cos θ wala hissa work karta hai

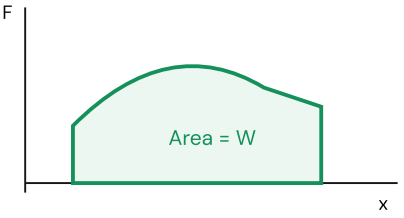
Angle θ	Work	Example
$0° \le \theta < 90°$	Positive	Girti cheez pe gravity ka work; ghoda gaadi kheenche
$\theta = 90°$	Zero	Coolie bojh uthake seedha chale (horizontal); circular motion me centripetal force; normal force
$90° < \theta \le 180°$	Negative	Friction ka work; upar phenki ball pe gravity; brake

02 Variable force ka work

Agar force position ke saath badle, toh chhote-chhote hisson ka work jodo:

$$W = \int F\,dx$$

F–x graph ke neeche ka **area** = work. x-axis ke neeche wala area negative work.



Force–displacement graph

03 Kinetic energy

Chalti hui body me motion ki wajah se jo energy hoti hai: $K = \frac{1}{2}\,m\,v^2$. Hamesha positive (ya 0).

KE AUR MOMENTUM KA RISHTA

$$K = p^2/(2m),\ p = \sqrt{(2mK)}$$

Same KE: halki body ka momentum kam. Same momentum: halki body ki KE zyada.

PERCENTAGE WALE SHORTCUTS

- v double ⇒ K 4 guna. p double ⇒ K 4 guna.
- Chhota % badlav: K me % change ≈ 2 × (v me % change). p me 10% badhe ⇒ K me 21% (exact: $1.1^2 = 1.21$).

04 Work-energy theorem

STATEMENT

Body pe lage **saare forces ka total work** uski kinetic energy ke change ke barabar hota hai.

$W_{net} = \Delta K = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

Ye har tarah ke force pe chalta hai (constant ya variable, conservative ya non-conservative). Isse lambi calculation bachti hai: acceleration nikaalne ki zaroorat nahi.

Proof (constant force): $v^2 - u^2 = 2as \Rightarrow \frac{1}{2}mv^2 - \frac{1}{2}mu^2 = mas = Fs = W$.

DHYAN DO

W_{net} me gravity, friction, normal, applied force: **sabka** work jodna hai. Sirf applied force ka work lena galat hai.

05 Potential energy & conservative force

Position ya shape ki wajah se stored energy = **potential energy (U)**. Zameen ke paas: $U = mgh$.

	Conservative force	Non-conservative force
Work kis pe depend	Sirf shuru aur aakhri position pe, raaste pe nahi	Raaste pe depend karta hai
Band raaste (closed loop) me work	Zero	Zero nahi
Potential energy	Define ho sakti hai	Nahi
Examples	Gravity, spring force, electrostatic force	Friction, air resistance, viscous force

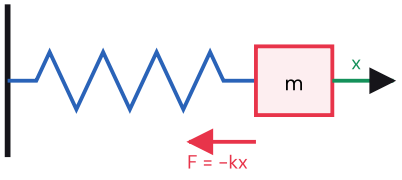
FORCE AUR PE KA RISHTA

$$F = -dU/dx$$

Conservative force ka work = $-\Delta U$. Equilibrium tab jab $F = 0$, yaani $dU/dx = 0$. U minimum ⇒ **stable**, U maximum ⇒ **unstable**, U constant ⇒ **neutral** equilibrium.

06 Spring ki energy

Spring ko x kheencho ya dabao toh wo wapas aane ka force lagati hai: $F = -kx$ (Hooke's law). k = spring constant (N/m), jitna zyada utni sakht spring.



Spring force hamesha natural length ki taraf

$$U = ½\, k\, x^2$$

x_1 se x_2 tak kheenchne me work = ½k(x_2^2 − x_1^2). Spring kheencho ya dabao, U dono me positive.

SPRINGS JODNA

Series: $1/k = 1/k_1 + 1/k_2$ (narm ho jaati). Parallel: $k = k_1 + k_2$ (sakht ho jaati). Spring ko n barabar tukdon me kaato: har tukde ka k' = nk.

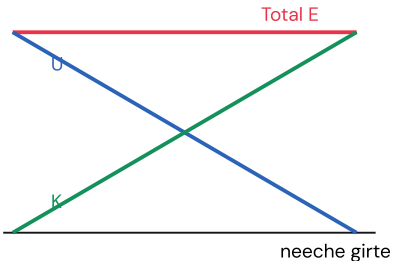
07 Conservation of mechanical energy

STATEMENT

Agar sirf **conservative forces** work karein, toh $K + U = \text{constant}$. Energy ek form se doosre me badalti hai, kho nahi jaati.

Girti ball (height H se): upar sab PE (mgH), beech me kuch KE kuch PE, neeche sab KE (½mv² = mgH ⇒ v = √(2gH)).

Friction ho toh: $K_1 + U_1 = K_2 + U_2 + W_{\text{friction}}$. Friction wali energy heat ban jaati hai.



U ghatta, K badhta, total same

Energy ke aur forms: heat, chemical, electrical, nuclear ($E = mc^2$). Total energy hamesha conserved rehti hai.

08 Power

FORMULA

$$P = dW/dt = F \cdot v$$

Average power = total work / total time. Unit watt (W) = J/s. 1 horsepower (hp) = 746 W. kWh **energy** ki unit hai, power ki nahi.

EXAMPLE

Pump h oonchai tak har second m kg paani chadhaaye: $P = mgh/t$. Efficiency = useful output / input × 100%.

09 Collisions

Takkar me bahut thodi der ke liye bade andar ke forces lagte hain, isliye **momentum hamesha conserved** rehta hai. KE har baar nahi.

	Elastic	Inelastic	Perfectly inelastic
Momentum	Conserved	Conserved	Conserved
Kinetic energy	Conserved	Kam hoti hai	Sabse zyada kam hoti hai
e (coefficient of restitution)	1	0 < e < 1	0 (chipak jaate hain)

COEFFICIENT OF RESTITUTION

$$e = (v_2 - v_1)/(u_1 - u_2)$$

Alag hone ki speed / paas aane ki speed.

1D ELASTIC COLLISION

$$v_1 = ((m_1 - m_2)u_1 + 2m_2u_2)/(m_1 + m_2)$$

$$v_2 = ((m_2 - m_1)u_2 + 2m_1u_1)/(m_1 + m_2)$$

SPECIAL CASES (U_2 = 0)

- $m_1 = m_2$: velocities **exchange** (pehli ruk jaati).
- $m_1 \gg m_2$: bhaari same speed se, halki $2u_1$ se.
- $m_1 \ll m_2$ (ball deewar se): ball ulti $-u_1$ se lautti.

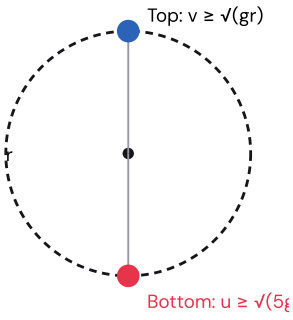
PERFECTLY INELASTIC

$$v = (m_1u_1 + m_2u_2)/(m_1 + m_2),\ \text{KE loss} = m_1m_2(u_1 - u_2)^2/(2(m_1 + m_2))$$

Ball ka bounce: height h se giri, n baar uchhalne ke baad height $h_n = e^{2n}\,h$.

10 Vertical circular motion

Rassi se bandhi patthar (ya bucket) ko vertical circle me ghumao. Neeche speed sabse zyada, upar sabse kam.



Poora chakkar lagane ki shart

RASSI WALA CASE

Top pe kam se kam speed: $v = \sqrt{(gr)}$

Bottom pe kam se kam speed: $u = \sqrt{(5gr)}$

Horizontal point pe: $\sqrt{(3gr)}$

$T_{bottom} - T_{top} = 6mg$

Rod ho (rassi ki jagah) toh top pe speed 0 bhi chalegi: bottom pe √(4gr) kaafi.

Bottom pe speed u	Kya hoga
$u \geq \sqrt{(5gr)}$	Poora chakkar
$\sqrt{(2gr)} < u < \sqrt{(5gr)}$	Upar ke aadhe hisse me rassi dheeli, projectile ban ke girta
$u \leq \sqrt{(2gr)}$	Neeche ke aadhe me hi jhoolta (pendulum jaisa)

11 JEE Extra + Tricks

JEE LEVEL

- Conservative force: F = −dU/dx. dU/dx = 0 pe equilibrium; U minimum pe **stable**, maximum pe unstable.
- Vertical circle (dori): neeche min speed √(5gr), upar √(gr); $T_{neeche} - T_{upar} = 6mg$.
- Collisions: coefficient of restitution e = (door jaane ki speed)/(paas aane ki speed); elastic e = 1, perfectly inelastic e = 0.
- Barabar masses ka 1D elastic collision: velocities **badal jaati**. Bhaari halki ruki ko maare: halki ~2u se.
- Perfectly inelastic: KE loss = $\frac{1}{2} \cdot m_1 m_2/(m_1 + m_2) \cdot (u_1 - u_2)^2$.
- Power = F·v; constant power pe F = P/v.

12 Solved numericals (g = 10 m/s²)

Q1. 50 N ka force horizontal se 60° pe lagake box 10 m kheencha. Work?
W = 50 × 10 × cos 60° = 250 J. **Ans: 250 J**

Q2. 2 kg ki body ki speed 3 m/s se 5 m/s hui. Net work?
W = ½ × 2 × (25 − 9) = 16 J. **Ans: 16 J**

Q3. Momentum 20% badha. KE me kitna % badhega?
$K \propto p^2 \Rightarrow (1.2)^2 = 1.44 \Rightarrow$ 44% badhega. **Ans: 44%**

Q4. k = 200 N/m wali spring ko 10 cm dabaya. Stored energy? 0.5 kg ki ball ko chhodne pe kis speed se nikalegi?
U = ½ × 200 × 0.01 = 1 J. ½ × 0.5 × v^2 = 1 ⇒ v = 2 m/s. **Ans: 1 J, 2 m/s**

Q5. 1 kg ka block 5 m oonchi smooth slope se neeche aaya, phir rough floor (μ = 0.5) pe kitni door jaake rukega?
Neeche KE = mgh = 50 J. Friction ka work = μmg d = 5d ⇒ d = 10 m. **Ans: 10 m**

Q6. Motor 100 kg ko 20 m upar 10 s me uthaati hai. Power?
P = mgh/t = 100 × 10 × 20/10 = 2000 W ≈ 2.7 hp. **Ans: 2 kW**

Q7. 2 kg ki ball 3 m/s se ruki hui 1 kg ball se chipak jaati hai. Common velocity aur KE loss?
v = 2 × 3/3 = 2 m/s. KE pehle 9 J, baad me ½ × 3 × 4 = 6 J ⇒ loss 3 J. **Ans: 2 m/s, 3 J**

Q8. 1 m lambi rassi pe patthar vertical circle me poora ghumaana hai. Bottom pe kam se kam speed?
u = √(5gr) = √50 ≈ 7.07 m/s. **Ans: ≈ 7.1 m/s**

13 Common mistakes

- "Mehnat ki toh work hua" maan lena. Displacement 0 ya force ⊥ displacement ⇒ work 0.
- Work-energy theorem me sirf applied force ka work lena, gravity aur friction bhool jaana.
- Har collision me KE conserve maan lena. Sirf elastic me.
- kWh ko power ki unit samajhna. Ye energy ki unit hai.
- Vertical circle me rod aur rassi ke case mix karna.
- Spring PE me x ko cm me rakh dena. Metre me badlo.

14 Formula sheet

Work	$W = Fs\cos\theta,\ W = \int F\,dx$
Kinetic energy	$K = \frac{1}{2}mv^2 = p^2/2m$
Work-energy theorem	$W_{net} = \Delta K$
Gravitational PE	$U = mgh$
Spring	$F = -kx,\ U = \frac{1}{2}kx^2$
Force from PE	$F = -dU/dx$
Power	$P = dW/dt = F\cdot v,\ 1\ hp = 746\ W$
Coefficient of restitution	$e = (v_2 - v_1)/(u_1 - u_2)$
Perfectly inelastic	$v = (m_1u_1 + m_2u_2)/(m_1 + m_2)$
Bounce height	$h_n = e^{2n}\,h$
Vertical circle (string)	$v_{top} \geq \sqrt{(gr)},\ u_{bottom} \geq \sqrt{(5gr)}$

15 Practice questions

1. Coolie 20 kg bojh sir pe rakh ke 50 m horizontal chalta hai. Gravity ka work?
2. Same KE wali do bodies ke mass 1 : 4 hain. Momentum ka ratio?
3. F = (3x² + 2) N. x = 0 se 2 m tak work?
4. Ball 10 m se giri, e = 0.5. Pehle bounce ke baad kitni upar jaayegi?
5. Car 20 m/s se chal rahi hai aur engine 1000 N ka force laga raha hai. Power?

ANSWERS

1) 0 (force ⊥ displacement) · 2) $p \propto \sqrt{m} \Rightarrow 1:2$ · 3) $[x^3 + 2x]_0^2 = 12$ J · 4) $e^2h = 2.5$ m · 5) 20 kW

16 Quick revision: exam se pehle 5 minute

WORK & ENERGY

- W = Fs cos θ; θ = 90° ⇒ 0.
- F–x graph ka area = work.
- W_{net} = ΔK (saare forces).
- K = $p^2/2m$.

PE & CONSERVATION

- Conservative: work path-independent, loop me 0.
- F = -dU/dx; U min ⇒ stable.
- Spring U = ½kx^2.
- Sirf conservative ⇒ K + U constant.

POWER & COLLISIONS

- P = F·v; 1 hp = 746 W.
- Momentum hamesha conserved; KE sirf elastic me.
- Same mass elastic ⇒ velocity exchange.
- $h_n = e^{2n}h$.

VERTICAL CIRCLE

- Rassi: top √(gr), bottom √(5gr).
- $T_{bottom} - T_{top}$ = 6mg.
- Rod: bottom √(4gr) kaafi.

Doubt hai? padhaiadda.netlify.app pe AI Doubt Solver se poocho, ya is chapter ka mock test do.