FREE NOTES · NCERT + JEE/NEET LEVEL

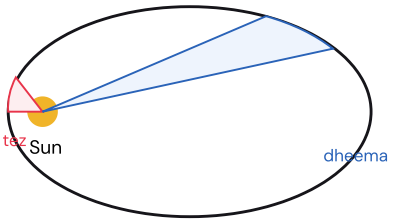
Gravitation

Kepler ke laws, Newton ka gravitation law, g kaise badalta hai, gravitational potential, escape speed, satellites aur weightlessness. Simple Hinglish me, graphs aur solved numericals ke saath.

01 Kepler's laws
02 Universal law of gravitation
03 G vs g
04 Height ke saath g
05 Depth ke saath g aur poora graph
06 Rotation & latitude ka asar
07 Gravitational field & potential
08 Gravitational potential energy
09 Escape speed
10 Satellites
11 Weightlessness
12 JEE Extra + Tricks
13 Solved numericals (g = 9.8 m/s², R = 6400 km)
14 Common mistakes
15 Formula sheet
16 Practice questions
17 Quick revision: exam se pehle 5 minute

01 Kepler's laws

Law	Kya kehta hai
1. Law of orbits	Har planet Sun ke chaaron taraf **ellipse** me ghoomta hai, Sun ek focus pe hai.
2. Law of areas	Sun se planet tak ki line **barabar time me barabar area** banati hai. Isliye planet Sun ke paas (perihelion) tez, door (aphelion) dheema.
3. Law of periods	$T^2 \propto a^3$ (a = semi-major axis)



Dono shaded areas barabar time me bane

2ND LAW KA MATLAB

Areal velocity $dA/dt = L/(2m)$ constant hai, yaani **angular momentum conserved** hai (gravity central force hai, torque zero). Perihelion aur aphelion pe: $v_1 r_1 = v_2 r_2$.

02 Universal law of gravitation

$$F = G\, m_1\, m_2 \,/\, r^2$$

G = 6.67 × 10^{-11} N·m²/kg² (universal constant, Cavendish ne naapa). Force hamesha attractive, dono masses ko jodne wali line pe.

- Bahut kamzor force, par range infinite.
- Beech me koi bhi medium ho, force same (medium pe depend nahi).
- Action-reaction pair: Earth seb ko jitna kheenchti hai, seb Earth ko utna hi.
- Kai masses ho toh har ek ka force alag nikaal ke **vector sum** (superposition).

SHELL THEOREM

Uniform hollow shell ke **bahar** ke point pe: poora mass centre pe maan lo. Shell ke **andar** kahin bhi: force zero.

03 G vs g

	G	g
Kya hai	Universal gravitational constant	Acceleration due to gravity
Value	6.67×10^{-11} N·m²/kg², har jagah same	≈ 9.8 m/s², jagah ke hisaab se badalta
Type	Scalar constant	Vector

RISHTA

$$g = G\,M\,/\,R^2$$

M, R = Earth ka mass aur radius. Density ρ se: $g = (4/3)\pi G \rho R$. Body ke mass pe depend nahi karta.

04 Height ke saath g

HEIGHT H PE

$$g_h = g\,R^2\,/\,(R+h)^2$$

Chhoti height ($h \ll R$): $g_h \approx g(1 - 2h/R)$.

DEPTH D PE

$$g_d = g\,(1 - d/R)$$

Centre pe (d = R): g = 0.

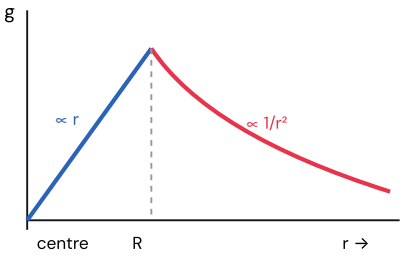
05 Depth ke saath g aur poora graph

Neeche jaane pe sirf andar wale gole ka mass kaam karta hai (bahar wala shell zero force deta hai). Isliye g **seedhi line me** kam hota hai aur centre pe 0.

Surface pe g **sabse zyada**. Upar jao ya neeche, dono taraf kam hota hai.

COMPARISON

Chhoti doori x ke liye: x height pe kami ≈ 2x/R, x depth pe kami = x/R. Yaani **height pe zyada tezi se** ghatta hai.



Andar g ∝ r, bahar g ∝ 1/r²

06 Rotation & latitude ka asar

$$g' = g - \omega^2 R \cos^2\lambda$$

λ = latitude, ω = Earth ka angular velocity. Equator ($\lambda = 0$): g sabse kam, $g - \omega^2 R$. Poles ($\lambda = 90°$): g pe koi asar nahi, sabse zyada.

- Earth poles pe thodi chapti hai ($R_{pole} < R_{equator}$), isliye bhi poles pe g zyada.
- Agar Earth $\omega = \sqrt{(g/R)} \approx 1/800$ rad/s se ghoome (lagbhag 17 guna tez), toh equator pe cheezein weightless ho jaayengi.
- Earth ghoomna band kar de toh poles pe g nahi badlega, equator pe badhega.

07 Gravitational field & potential

FIELD (INTENSITY)

$$E = F/m = GM/r^2$$

Unit mass pe lagne wala force. Vector, mass ki taraf. Surface pe E = g.

POTENTIAL

$$V = -GM/r$$

Unit mass ko infinity se r tak laane me work. Scalar, hamesha negative (infinity pe 0). Rishta: $E = -dV/dr$.

Body	Andar (r < R)	Bahar (r ≥ R)
Hollow shell: field	0	GM/r^2
Hollow shell: potential	$-GM/R$ (constant)	$-GM/r$
Solid sphere: field	GMr/R^3	GM/r^2
Solid sphere: potential	$-GM(3R^2 - r^2)/(2R^3)$	$-GM/r$

Solid sphere ke centre pe potential $-3GM/(2R)$ = surface ka 1.5 guna (sabse kam).

08 Gravitational potential energy

$$U = -G\,M\,m\,/\,r$$

Infinity pe U = 0, isliye paas aane pe negative. Negative matlab system **bound** hai (alag karne ke liye energy deni padegi).

MGH KAB CHALTA HAI

Surface se h upar le jaane me PE ka badlav: $\Delta U = GMm\,h/(R(R+h)) = mgh/(1+h/R)$. Sirf jab **h ≪ R** tab ≈ mgh. Badi height pe mgh galat answer dega.

Do se zyada particles: har pair ka U alag nikaal ke jodo. Teen barabar masses (m) side a ke triangle pe: $U = -3Gm^2/a$.

09 Escape speed

Surface se kam se kam itni speed do ki body wapas na aaye (infinity tak chali jaaye).

$$v_e = \sqrt{(2GM/R)} = \sqrt{(2gR)}$$

Earth: ≈ 11.2 km/s. Moon: ≈ 2.3 km/s (isliye Moon pe atmosphere nahi, gas molecules bhaag gaye). Body ke mass aur phenkne ki direction pe depend nahi karta.

DERIVATION (1 LINE)

½mv_e^2 − GMm/R = 0 (infinity pe KE aur PE dono 0) ⇒ v_e = √(2GM/R).

10 Satellites

Gravity hi centripetal force deti hai: $mv^2/r = GMm/r^2$, r = R + h.

ORBITAL SPEED & PERIOD

$$v_0 = \sqrt{(GM/r)}$$

Surface ke paas: $v_0 = \sqrt{(gR)} \approx 7.9\ km/s$

$$T = 2\pi\sqrt{(r^3/GM)}$$

Satellite ke mass pe depend nahi. Upar wala satellite dheema aur zyada time leta hai. $v_e = \sqrt{2} \times v_o$.

ENERGIES

$KE = GMm/(2r)$

$PE = -GMm/r$

$Total\ E = -GMm/(2r)$

$KE : PE : E = 1 : -2 : -1$

Binding energy = GMm/(2r). r se 2r pe le jaane me energy = GMm/(4r).

	Geostationary	Polar
Height	≈ 36,000 km (r ≈ 42,250 km)	≈ 500–800 km
Period	24 h (Earth ke saath)	≈ 100 min
Orbit	Equator ke upar, west → east	Poles ke upar se (north–south)
Use	TV, communication	Weather, remote sensing, spying

11 Weightlessness

Satellite me astronaut aur satellite **dono same acceleration se gir rahe hain** (free fall). Isliye astronaut floor ko nahi dabata, normal force 0 ⇒ weight mehsoos nahi hota. Gravity zero **nahi** hai.

DHYAN DO

Satellite me pendulum nahi jhoolega (T = ∞), paani glass me nahi bhar sakte, par spring balance ki jagah inertial balance se mass naap sakte hain.

12 JEE Extra + Tricks

JEE LEVEL

- Height h pe g ($h \ll R$): $g(1 - 2h/R)$; gehraai d pe: $g(1 - d/R)$ (centre pe zero); latitude λ pe ghoomne se: $g - \omega^2 R \cos^2\lambda$.
- Escape speed $v_e = \sqrt{(2GM/R)} \approx 11.2$ km/s = surface ke paas orbital speed ka $\sqrt{2}$ guna.
- Satellite: KE = GMm/2r, PE = -GMm/r = -2KE, total E = -KE (bound). $T = 2\pi\sqrt{(r^3/GM)}$.
- Geostationary: surface se ~36,000 km, T = 24 h, equator ke upar, west se east.
- Kepler: $T^2 \propto r^3$; areal velocity constant (angular momentum conserved).
- Shell theorem: khokhle shell ke andar field = 0, potential constant.

13 Solved numericals (g = 9.8 m/s², R = 6400 km)

Q1. Do 100 kg ke gole 1 m door. Gravitational force?
$F = 6.67 \times 10^{-11} \times 10^4/1 = 6.67 \times 10^{-7}$ N (bahut chhota!). **Ans: 6.67×10^{-7} N**

Q2. Kis height pe g surface ka ¼ ho jaayega?
$R^2/(R + h)^2 = ¼ \Rightarrow R + h = 2R \Rightarrow h = R = 6400$ km. **Ans: 6400 km**

Q3. Kis depth pe g surface ka 75% hoga?
$1 - d/R = 0.75 \Rightarrow d = R/4 = 1600$ km. **Ans: 1600 km**

Q4. Ek planet ka mass Earth ka 2 guna aur radius bhi 2 guna. Wahan g?
$g \propto M/R^2 \Rightarrow 2/4 = ½ \Rightarrow 4.9$ m/s². **Ans: g/2**

Q5. Upar wale planet ki escape speed Earth (11.2 km/s) ke hisaab se?
$v_e \propto \sqrt{(M/R)} \Rightarrow \sqrt{(2/2)} = 1 \Rightarrow 11.2$ km/s. **Ans: same, 11.2 km/s**

Q6. Satellite Earth surface se R height pe. Orbital speed? (√(gR) = 7.9 km/s)
$r = 2R \Rightarrow v = \sqrt{(GM/2R)} = \sqrt{(gR/2)} = 7.9/\sqrt{2} \approx 5.6$ km/s. **Ans: ≈ 5.6 km/s**

Q7. Ek satellite ka period T hai. Orbit ka radius 4 guna kar do toh period?
$T^2 \propto r^3 \Rightarrow T' = T \times 4\text{^}(3/2) = 8T$. **Ans: 8T**

Q8. 1000 kg satellite ko surface se 2R radius wali orbit me bhejne ki energy (GMm/R = mgR)?
$E_{orbit} - E_{surface} = -GMm/(4R) - (-GMm/R) = 3GMm/(4R) = ¾\ mgR = 0.75 \times 1000 \times 9.8 \times 6.4 \times 10^6 \approx 4.7 \times 10^{10}$ J. **Ans: ≈ 4.7×10^{10} J**

14 Common mistakes

- Satellite me weightlessness ka matlab "gravity zero" samajhna.
- Badi height pe PE ka badlav mgh se nikaalna.
- Earth ke centre pe g infinite maan lena. Centre pe g = 0.
- Escape speed ko direction pe depend maan lena.
- Satellite ka period ya speed uske mass pe depend maan lena.
- Height h ki jagah r (centre se) ko seedha R se confuse karna: r = R + h.

15 Formula sheet

Newton's law	$F = Gm_1m_2/r^2$
g at surface	$g = GM/R^2 = (4/3)\pi G\rho R$
Height / depth	$g(1 - 2h/R)$ / $g(1 - d/R)$
Latitude	$g' = g - \omega^2 R\cos^2\lambda$
Field, potential	$E = GM/r^2$, $V = -GM/r$
Potential energy	$U = -GMm/r$
Escape speed	$v_e = \sqrt{(2gR)} \approx 11.2$ km/s
Orbital speed	$v_0 = \sqrt{(GM/r)}$, near surface $\sqrt{(gR)}$
Period	$T = 2\pi\sqrt{(r^3/GM)}$, $T^2 \propto r^3$
Satellite energy	$E = -GMm/2r$, $KE = -E$
Kepler 2nd	$dA/dt = L/2m = \text{constant}$

16 Practice questions

1. Do masses ke beech doori aadhi kar do, force kitna?
2. Planet ka density same, radius 2 guna. g kitna?
3. Ek planet ka orbital radius Earth ka 4 guna. Uska saal kitna lamba?
4. Satellite ki KE 5×10^9 J. Total energy aur PE?
5. Earth ka radius sikud ke aadha ho jaaye (mass same). Escape speed?

ANSWERS

1) 4 guna · 2) $g \propto \rho R \Rightarrow 2g$ · 3) 4^(3/2) = 8 saal · 4) E = -5 × 10^9 J, PE = -10^{10} J · 5) √2 × 11.2 ≈ 15.8 km/s

17 Quick revision: exam se pehle 5 minute

LAWS

- Kepler: ellipse, equal areas (L conserved), $T^2 \propto a^3$.
- $F = Gm_1m_2/r^2$, $G = 6.67 \times 10^{-11}$.
- Shell ke andar force 0.

G KA BADLAV

- $g = GM/R^2$, surface pe max.
- Height: $g(1 - 2h/R)$; depth: $g(1 - d/R)$.
- Equator pe kam, poles pe zyada.
- Centre pe g = 0.

POTENTIAL & ESCAPE

- $V = -GM/r$, $U = -GMm/r$.
- mgh sirf $h \ll R$ pe.
- $v_e = \sqrt{(2gR)} = 11.2$ km/s.

SATELLITES

- $v_o = \sqrt{(GM/r)}$; $v_e = \sqrt{2}\, v_o$.
- KE : PE : E = 1 : −2 : −1.
- Geostationary: 36,000 km, 24 h.
- Weightless = free fall, gravity hai.

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