CLASS 11 PHYSICS — FORMULA SHEET

Chapter 7 : Gravitation (NCERT)

7.1 Newton's Law of Gravitation

Concept	Formula / Detail
Universal law	$F = G\, m_1 m_2 \div r^2$ (attractive force along the line joining masses)
Gravitational constant	$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2} ; dimension $[M^{-1}L^3T^{-2}]$
Vector form	Force is along the line joining the two masses; always attractive
Nature	Central force, conservative, weakest of the four fundamental forces
Principle of superposition	Net force = vector sum of forces due to each mass

7.2 Acceleration due to Gravity (g)

Concept	Formula
g at Earth's surface	$g = GM \div R^2 \approx 9.8$ m/s^2
Relation g and G	$g = GM/R^2$; also $M = gR^2/G$
At height h above surface	$g_h = g\,(R \div (R+h))^2 \approx g(1 - 2h/R)$ for $h << R$
At depth d below surface	$g_d = g\,(1 - d/R)$
At centre of Earth	$g = 0$ $(d = R)$
Effect of rotation (latitude λ)	$g_\lambda = g - \omega^2 R \cos^2\lambda$
At poles vs equator	g is MAXIMUM at poles, MINIMUM at equator

7.3 Gravitational Field, Potential & PE

Quantity	Formula
Gravitational field intensity	$E = F/m = GM \div r^2$ (force per unit mass)
Gravitational potential	$V = -GM \div r$ (work done per unit mass to bring from infinity)
Gravitational PE (two masses)	$U = -G\, m_1 m_2 \div r$
PE near Earth's surface	$U = mgh$ (for small heights)
Relation E and V	$E = -dV/dr$
Potential at infinity	$V = 0$, $U = 0$ (reference point)

7.4 Orbital & Escape Velocity

Concept	Formula
Orbital velocity (radius r)	$v_o = \sqrt{(GM \div r)}$; near surface $v_o = \sqrt{(gR)} \approx 7.9$ km/s
Orbital velocity at height h	$v_o = \sqrt{(GM \div (R+h))}$
Escape velocity	$v_e = \sqrt{(2GM \div R)} = \sqrt{(2gR)} \approx 11.2$ km/s
Relation escape & orbital	$v_e = \sqrt{2} \times v_o$ (escape velocity is √2 times orbital)

Concept	Formula
Independence	Escape velocity is independent of mass & direction of projection

7.5 Satellite Motion & Energy

Quantity	Formula
Time period of satellite	$T = 2\pi \sqrt{((R+h)^3 \div GM)}$
Kinetic energy	$KE = \frac{1}{2} GMm \div r = \frac{1}{2} \lvert U \rvert$
Potential energy	$PE = -GMm \div r$
Total energy	$E = -GMm \div (2r)$ (negative → bound orbit)
Relation of energies	$KE = -E$; $PE = 2E$; $E = -KE$
Binding energy of satellite	$BE = +GMm \div (2r)$ (energy to escape orbit)

7.6 Geostationary & Polar Satellites

Type	Detail
Geostationary satellite	Period = 24 h ; height ≈ 36,000 km ; orbits over equator, west → east
Use of geostationary	Communication, TV broadcasting, weather
Polar satellite	Low altitude (500-800 km), passes over poles; used for mapping & spying
Weightlessness in orbit	Satellite & astronaut both in free fall → apparent weight = 0

7.7 Kepler's Laws of Planetary Motion

Law	Statement
First law (orbit / ellipse)	Each planet moves in an ellipse with the Sun at one focus
Second law (areal velocity)	Line joining planet & Sun sweeps equal areas in equal times → dA/dt = constant (L conserved)
Third law (period)	$T^2 \propto a^3$ (a = semi-major axis) → T^2/a^3 = constant
Consequence of 2nd law	Planet moves faster when nearer the Sun (perihelion), slower when farther (aphelion)

★ QUICK MEMORY AIDS & TRICKS

g formula	$g = GM/R^2$. Decreases with both height AND depth; zero at Earth's centre.
Height vs depth	Height: $g(1 - 2h/R)$; Depth: $g(1 - d/R)$. Height falls TWICE as fast.
g at poles/equator	Maximum at poles (no rotation effect), minimum at equator.
Escape = √2 × orbital	$v_e = \sqrt{2}\, v_o$. Surface escape ≈ 11.2 km/s, orbital ≈ 7.9 km/s.
Satellite energy	$E = -GMm/2r$. KE = −E (positive), PE = 2E (negative), Total = −KE.
Potential sign	$V = -GM/r$ (always negative) ; zero only at infinity.
Kepler's 3rd	$T^2 \propto a^3$ — bigger orbit means much longer year.

Geostationary	Period exactly 24 h, about 36,000 km up, sits over the equator.