

Gravitation Equations Worksheet

Level: A-Level / AP Physics 1 & 2 | Difficulty: Advanced | Topic: Mechanics

Practice gravitation with 10 problems on Newton's universal law, field strength, and orbital motion. Includes full worked solutions.

Equations you will need

$F = Gm_1m_2/r^2$	Newton's law of universal gravitation
$g = GM/r^2$	Gravitational field strength
$v = \sqrt{GM/r}$	Orbital speed for circular orbit
$T^2 = (4\pi^2/GM)r^3$	Kepler's 3rd law
$U = -Gm_1m_2/r$	Gravitational potential energy

Symbol key

Symbol	Quantity	Unit
F	force	N
G	gravitational constant	$6.67 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2$
m	mass	kg
M	central body mass	kg
r	separation / orbit radius	m
g	field strength	N/kg or m/s^2
v	orbital speed	m/s
T	orbital period	s

Practice problems

- Find gravitational force between two 100 kg masses 2 m apart.
- Find g at Earth's surface. ($M=5.97 \times 10^{24} \text{ kg}$, $r=6.37 \times 10^6 \text{ m}$)
- Find orbital speed at $7 \times 10^6 \text{ m}$ above Earth's centre.
- Find period of a satellite orbiting Earth at radius $8 \times 10^6 \text{ m}$.
- Find gravitational PE of a 1000 kg satellite at $4 \times 10^7 \text{ m}$ from Earth's centre.

6. Find g at 2×10^7 m above Earth's centre (about 3 Earth radii).
7. At what height above Earth's surface is g half its surface value?
8. Find the mass of the Sun given Earth's orbital radius (1.5×10^{11} m) and period (3.16×10^7 s).
9. Find the escape velocity from Earth's surface.
10. A geostationary satellite has $T = 86,400$ s. Find its orbital radius.

Answer key

Full worked solutions for each problem.

1. $F = (6.67 \times 10^{-11})(104)/4 = 1.67 \times 10^{-7} \text{ N}$
2. $g = (6.67 \times 10^{-11})(5.97 \times 10^{24})/(6.37 \times 10^6)^2 = 9.81 \text{ m/s}^2$
3. $v = \sqrt{(6.67 \times 10^{-11})(5.97 \times 10^{24})/7 \times 10^6} = 7546 \text{ m/s}$
4. $v = \sqrt{GM/r} = 7058 \text{ m/s}; T = 2\pi r/v = 7123 \text{ s} \approx 119 \text{ min}$
5. $U = -(6.67 \times 10^{-11})(5.97 \times 10^{24})(1000)/4 \times 10^7 = -9.95 \times 10^9 \text{ J}$
6. $g = GM/r^2 = (3.98 \times 10^{14})/4 \times 10^{14} = 0.995 \text{ m/s}^2$
7. $r_2^2 = 2r_1^2 \rightarrow r_2 = r_1^2 = 9.01 \times 10^6 \text{ m}; h = r_2 - 6.37 \times 10^6 = 2.64 \times 10^6 \text{ m}$
8. $M = (4\pi^2 r^3)/(GT^2) = 2.0 \times 10^{30} \text{ kg}$
9. $v_{\text{esc}} = \sqrt{2GM/r} = \sqrt{2 \times 3.98 \times 10^{14}/6.37 \times 10^6} = 11,200 \text{ m/s}$
10. $r^3 = GMT^2/(4\pi^2) = 7.54 \times 10^{22} \rightarrow r = 4.23 \times 10^7 \text{ m}$