MCAT DOCTOR

Every Physics Equation for the MCAT

All the physics equations you need to know for the MCAT — organised by topic and ranked by yield. Focus your study time on what actually gets tested.

~65 EQUATIONS

10 CATEGORIES

25% OF C/P SECTION

★★★ Must Know ★★ High Yield ★ Know It

Mechanics ~25%
Kinematics, Forces, Work, Energy, Momentum

Fluids ~20%
Pressure, Buoyancy, Flow, Bernoulli

Electricity ~15%
Coulomb, Circuits, Capacitors

Waves & Sound ~15%
Wave eq, Doppler, Decibels

Optics ~10%
Snell's, Lenses, Mirrors

Thermo & Modern ~15%
Heat, Gas Laws, Nuclear, Photoelectric

CONTENTS

How to use this guide: Equations marked ★★★ appear on almost every MCAT. Master these first. Then move to ★★ equations, which appear regularly. ★ equations show up occasionally — know the concept, but don't lose sleep over them.

1 Kinematics

Motion in 1D and 2D — constant acceleration only (no air resistance)

NAME	EQUATION	WHEN TO USE / NOTES	YIELD
Velocity	$v_f = v_0 + at$	Use this equation when **d** is not given or asked for	★★★
Displacement	$x = v_0 t + ½at^2$	Use this equation when $\mathbf{v_f}$ is not given or asked for	★★★
Velocity–Displacement	$v_f^2 = v_0^2 + 2ax$	Use this equation when **t** is not given or asked for	★★★
Average Velocity	$x = ½(v_f + v_0)t$	Use this equation when **a** is not given or asked for	★★★
Free Fall	$a = g = 9.8\ m/s^2$	Use $g \approx 10\ m/s^2$ on MCAT for fast math	★★★

MCAT tip: Projectile motion splits into independent x and y components. Horizontal: constant velocity ($a_x = 0$). Vertical: constant acceleration ($a_y = -g$). Time is the same for both. Components: $v_{0x} = v_0\cos\theta$, $v_{0y} = v_0\sin\theta$. Max range at 45°.

2 Forces & Newton's Laws

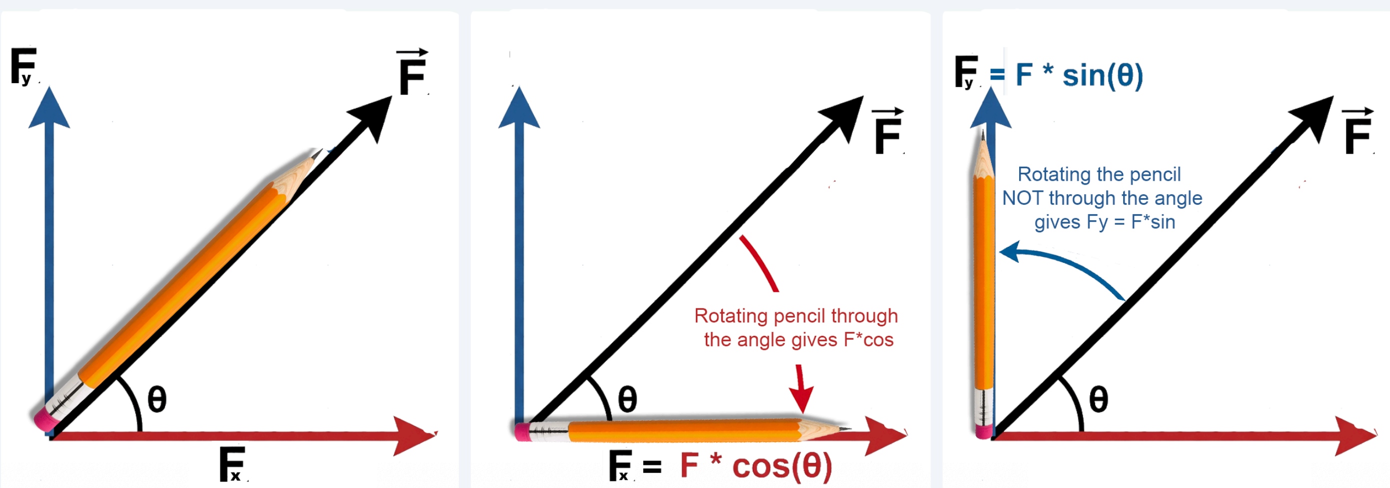
The foundation of all MCAT mechanics — appears in virtually every C/P section

NAME	EQUATION	WHEN TO USE / NOTES	YIELD
Newton's 2nd Law	$F = ma$	Net force = mass × acceleration. The single most important equation in physics.	★★★
Weight	$W = mg$	Force of gravity; use $g \approx 10\ m/s^2$	★★★
Friction	$f = \mu N$	Static ($f \le \mu_s N$) or kinetic ($f = \mu_k N$). N = normal force, not always mg.	★★★
Inclined Plane (∥)	$F_{\parallel} = mg\sin\theta$	Component of gravity along the slope	★★★
Inclined Plane (⊥)	$N = mg\cos\theta$	Normal force on a frictionless incline	★★★
Centripetal Force	$F_c = mv^2/r$	Net inward force for circular motion; not a new force	★★★
Centripetal Accel.	$a_c = v^2/r$	Always points toward center of circle	★★
Hooke's Law	$F = -kx$	Spring restoring force; k = spring constant, x = displacement from equilibrium	★★★
Universal Gravitation	$F = Gm_1m_2/r^2$	Inverse-square law; $G = 6.67 \times 10^{-11}\ N{\cdot}m^2/kg^2$	★★

Newton's 3rd Law: Every action has an equal and opposite reaction. Forces act on *different* objects. The MCAT loves to test whether you know which forces form action–reaction pairs.

Free Body Diagram strategy: Draw ALL forces on the object. Choose axes aligned with motion (tilt axes on inclines). Set $\Sigma F = ma$ in each direction. On inclines: $\Sigma F_{\parallel} = ma$ along slope, $\Sigma F_{\perp} = 0$ perpendicular.

Finding Components — The Pencil Trick



Step 1: Place pencil along **F** at the origin.

Step 2a: Rotate ***through*** θ to the x-axis → $F_x = F\cdot\cos(\theta)$

Step 2b: Rotate ***not*** through θ to the y-axis → $F_y = F\cdot\sin(\theta)$

Works every time — inclines, projectiles, tension problems. No more guessing sin vs cos.

3 Work, Energy & Power

Conservation of energy is tested on nearly every MCAT — often paired with fluids or circuits

NAME	EQUATION	WHEN TO USE / NOTES	YIELD
Work	$W = Fd\cos\theta$	Only the force component parallel to displacement does work. θ = angle between F and d.	★★★
Kinetic Energy	$KE = \frac{1}{2}mv^2$	Energy of motion; always positive	★★★
Gravitational PE	$PE = mgh$	Relative to a chosen reference point (usually ground = 0)	★★★
Spring PE	$PE = \frac{1}{2}kx^2$	Energy stored in a compressed/stretched spring	★★★
Work–Energy Theorem	$W_{net} = \Delta KE$	Net work done on an object = change in its KE	★★★
Conservation of Energy	$KE_1 + PE_1 = KE_2 + PE_2$	When only conservative forces act (no friction)	★★★
Power	$P = W/t$	Rate of doing work; SI unit = watt (W)	★★★
Power (alt.)	$P = Fv$	Instantaneous power when force and velocity are parallel	★★
Pressure	$P = F/A$	Force per unit area. SI unit = Pascal (Pa) = N/m². 1 atm ≈ 10^5 Pa.	★★★
Mechanical Advantage	$MA = F_{out} / F_{in}$	Simple machines; MA > 1 means force is amplified but distance is reduced	★★
Efficiency	$e = W_{out} / W_{in} \times 100\%$	Always ≤ 100%; energy lost to friction/heat	★★

Conservative vs. Non-conservative: Gravity and springs are conservative (path-independent, have PE). Friction and air resistance are non-conservative (path-dependent, convert KE to heat). With friction: $KE_1 + PE_1 = KE_2 + PE_2 + W_{friction}$.

4 Momentum & Impulse

Conservation of momentum — collisions, explosions, and recoil

NAME	EQUATION	WHEN TO USE / NOTES	YIELD
Momentum	$p = mv$	Vector quantity; has direction. SI unit = kg·m/s	★★
Impulse	$J = F\Delta t = \Delta p$	Impulse = change in momentum. Airbags increase Δt → decrease F.	★★
Conservation of Momentum	$m_1v_1 + m_2v_2 = m_1v_1' + m_2v_2'$	Always conserved in collisions (no external forces)	★★
Perfectly Inelastic	$m_1v_1 + m_2v_2 = (m_1+m_2)v'$	Objects stick together; max KE lost	★
Elastic Collision	KE conserved too	Both momentum AND KE conserved; objects bounce apart	★

5 Torque & Equilibrium

Levers, seesaws, and rotational balance

NAME	EQUATION	WHEN TO USE / NOTES	YIELD
Torque	$\tau = rF\sin\theta$	r = lever arm distance; θ = angle between r and F. SI unit = N·m	★★★
Torque (lever arm)	$\tau = r_\perp \times F$	$r_\perp$ = perpendicular distance from pivot to line of force	★★★
Translational Equil.	$\Sigma F = 0$	No net force → no acceleration (static or constant velocity)	★★★
Rotational Equil.	$\Sigma\tau = 0$	No net torque → no angular acceleration. Choose pivot wisely to eliminate unknowns.	★★★
Center of Mass	$x_{cm} = \Sigma m_i x_i / \Sigma m_i$	Weighted average position; objects topple when cm is outside base of support	★

MCAT favourite: Seesaw / lever problems. Set Στ = 0 about the pivot. Clockwise torques = counterclockwise torques → $m_1r_1 = m_2r_2$. The MCAT won't ask you to calculate moments of inertia, but know that I increases when mass is farther from the axis.

6 Fluids & Fluid Dynamics

Extremely high yield — fluids appear on virtually every C/P section of the MCAT

Why fluids matter: The MCAT tests fluids more than any other physics topic. Expect 2–4 questions per exam combining pressure, buoyancy, and flow. These equations are non-negotiable.

NAME	EQUATION	WHEN TO USE / NOTES	YIELD
Density	$\rho = m/V$	ρ_{water} = 1000 kg/m³ = 1 g/cm³. Objects float if $\rho_{object} < \rho_{fluid}$.	★★★
Specific Gravity	$SG = \rho_{substance} / \rho_{water}$	Dimensionless ratio; SG < 1 → floats in water	★★
Pressure in Fluids	$P = \rho gh$	Pressure due to fluid column of height h. Gauge pressure (above atmospheric).	★★★
Absolute Pressure	$P_{abs} = P_{atm} + \rho gh$	Total pressure = atmospheric + gauge. Open containers start at P_{atm}.	★★★
Pascal's Law	$F_1/A_1 = F_2/A_2$	Hydraulic systems: pressure transmitted equally. Small force on small area → large force on large area.	★★★
Archimedes' Principle	$F_b = \rho_{fluid} \cdot V_{disp} \cdot g$	Buoyant force = weight of displaced fluid. Object floats when F_b = W.	★★★
Fraction Submerged	$V_{sub}/V_{total} = \rho_{obj}/\rho_{fluid}$	For floating objects only. E.g., ice: 917/1000 ≈ 92% submerged.	★★
Continuity Equation	$A_1v_1 = A_2v_2$	Conservation of mass for incompressible fluids. Narrow pipe → faster flow.	★★★
Bernoulli's Equation	$P + \frac{1}{2}\rho v^2 + \rho gh = \text{const}$	Conservation of energy for flowing fluids. Faster flow → lower pressure.	★★★
Venturi Effect	$\Delta P = \frac{1}{2}\rho(v_2^2 - v_1^2)$	Derived from Bernoulli at same height. Explains airplane lift, aneurysms.	★★
Flow Rate	$Q = Av$	Volume per time (m³/s). Q is constant throughout a pipe (continuity).	★★
Poiseuille's Law	$Q = \pi r^4 \Delta P / (8\eta L)$	Viscous flow in a tube. r^4 dependence — doubling radius → 16× flow!	★★

Bernoulli's assumptions: Ideal fluid = (1) incompressible, (2) non-viscous, (3) laminar (streamline) flow, (4) steady-state. Real blood flow violates most of these, but MCAT still applies Bernoulli.

MCAT trap — Buoyancy: Buoyant force depends on ρ_{fluid} and $V_{displaced}$, NOT on the object's mass or density. A steel ball and a hollow ball of the same size displace the same volume → same F_b.

Clinically relevant: Blood pressure = ρgh explains why BP is measured at heart level. Aneurysms: wider vessel → slower flow (continuity) → higher pressure (Bernoulli) → vessel wall weakens further. Atherosclerosis: narrower vessel → faster flow → lower pressure at stenosis but higher resistance (Poiseuille).

7 Electrostatics

Charges, electric fields, and potential — Coulomb's law is a top-5 MCAT equation

NAME	EQUATION	WHEN TO USE / NOTES	YIELD
Coulomb's Law	$F = kq_1q_2/r^2$	Force between two point charges. $k = 9 \times 10^9$ N·m²/C². Inverse-square law like gravity.	★★★
Electric Field	$E = F/q = kQ/r^2$	Force per unit charge. Points away from (+), toward (–). SI unit = N/C = V/m.	★★★
Electric Potential	$V = kQ/r$	Scalar — no direction. Positive charge creates (+) potential. SI unit = Volt.	★★★
Potential & Field	$V = Ed$	For uniform field between parallel plates. E = V/d. d = plate separation.	★★★
Electric PE	$PE = qV = kq_1q_2/r$	Energy of a charge in a potential. Positive charges move from high to low V.	★★★
Capacitance	$C = Q/V$	Charge stored per volt. SI unit = Farad (F).	★★
Parallel Plate Cap.	$C = \varepsilon_0A/d$	$\varepsilon_0 = 8.85 \times 10^{-12}$ F/m. Increase A or decrease d → more capacitance.	★★
Dielectric	$C' = \kappa C$	Inserting dielectric (κ > 1) increases capacitance by factor κ	★
Energy in Capacitor	$U = ½CV^2 = ½QV$	Energy stored in the electric field between plates	★★

8 Circuits

Ohm's law, series vs. parallel, and power — high yield every exam

NAME	EQUATION	WHEN TO USE / NOTES	YIELD
Ohm's Law	$V = IR$	Voltage = current × resistance. Most-used circuit equation.	★★★
Power	$P = IV = I^2R = V^2/R$	Energy dissipated per second. All three forms are tested.	★★★
Resistors in Series	$R_{eq} = R_1 + R_2 + \ldots$	Current is the same; voltage splits. Total R increases.	★★★
Resistors in Parallel	$1/R_{eq} = 1/R_1 + 1/R_2 + \ldots$	Voltage is the same; current splits. Total R decreases.	★★★
Capacitors in Series	$1/C_{eq} = 1/C_1 + 1/C_2 + \ldots$	Opposite of resistors! Series → smaller total C.	★★
Capacitors in Parallel	$C_{eq} = C_1 + C_2 + \ldots$	Opposite of resistors! Parallel → larger total C.	★★
Resistance	$R = \rho L/A$	ρ = resistivity, L = length, A = cross-sectional area. Longer wire → more R.	★★
Current	$I = Q/t$	Charge per second. SI unit = Ampere (A). Conventional current flows (+) to (–).	★★
Kirchhoff's Voltage	$\Sigma V = 0$ (loop)	Voltage gains = voltage drops around any closed loop	★★
Kirchhoff's Current	$\Sigma I_{in} = \Sigma I_{out}$ (junction)	Current in = current out at any junction (conservation of charge)	★★

Series vs. Parallel cheat sheet: In **series**, current (I) is the same everywhere and voltage (V) splits. In **parallel**, voltage (V) is the same across each branch and current (I) splits. Remember: resistors and capacitors have *opposite* combination rules.

9A Waves & Sound

Wave equation + Doppler + decibels — consistently tested every exam

NAME	EQUATION	WHEN TO USE / NOTES	YIELD
Wave Equation	$v = f\lambda$	Speed = frequency × wavelength. Applies to all waves.	★★★
Period–Frequency	$f = 1/T$	Frequency in Hz = cycles/second; T in seconds	★★★
Speed of Sound	$v \approx 340$ m/s (in air)	Faster in solids > liquids > gases. Increases with temperature.	★★
Intensity	$I = P/A$	Power per unit area (W/m²). For point source: $I = P/(4\pi r^2)$	★
Decibel Scale	$\beta = 10 \log_{10}(I/I_0)$	$I_0 = 10^{-12}$ W/m². Every 10× intensity = +10 dB. Every 2× intensity ≈ +3 dB.	★★★
Doppler Effect	$f' = f \cdot (v \pm v_o)/(v \mp v_s)$	Top sign: moving toward. Bottom sign: moving away. Source/observer approach → higher pitch.	★★★
Doppler (simple)	$\Delta f/f = v/c$	Quick approximation when source or observer speed ≪ wave speed. v = relative speed, c = wave speed.	★★★
Beat Frequency	$f_{beat} = \|f_1 - f_2\|$	Pulsing sound when two close frequencies interfere	★★
Standing Wave (string)	$\lambda_n = 2L/n$	Both ends fixed. n = 1, 2, 3... (harmonics). $f_n = nf_1$.	★★
Standing Wave (open pipe)	$\lambda_n = 2L/n$	Both ends open. All harmonics (n = 1, 2, 3...).	★★
Standing Wave (closed pipe)	$\lambda_n = 4L/n$	One end closed. Odd harmonics only (n = 1, 3, 5...).	★★
Pendulum Period	$T = 2\pi\sqrt{L/g}$	Independent of mass and amplitude (for small angles). Longer → slower.	★★
Spring Period	$T = 2\pi\sqrt{m/k}$	Independent of amplitude. Heavier mass or weaker spring → slower.	★★

9B Optics

Refraction, lenses, and mirrors — know Snell's law and the thin lens equation cold

NAME	EQUATION	WHEN TO USE / NOTES	YIELD
Index of Refraction	$n = c/v$	n ≥ 1 always. Higher n → slower light → more bending. $c = 3 \times 10^8$ m/s.	★★★
Snell's Law	$n_1\sin\theta_1 = n_2\sin\theta_2$	Light bends toward normal when entering denser medium (higher n).	★★★
Critical Angle (TIR)	$\sin\theta_c = n_2/n_1$	Total internal reflection when going from high n to low n ($n_1 > n_2$)	★★
Thin Lens / Mirror	$1/f = 1/d_o + 1/d_i$	f = focal length. Sign conventions: real image → d_i (+); virtual → d_i (–).	★★★
Magnification	$m = -d_i/d_o = h_i/h_o$	$\|m\| > 1$ = enlarged. m (+) = upright. m (–) = inverted.	★★★
Lens Power	$P = 1/f$	In diopters (D) when f is in meters. Converging = (+), diverging = (–).	★★

Real image: d_i is **positive**. Image is **inverted**. Located *behind* the lens (opposite side from object) or *in front of* the mirror (same side as object). Can be projected onto a screen.

Virtual image: d_i is **negative**. Image is **upright**. Located *in front of* the lens (same side as object) or *behind* the mirror (opposite side from object). Cannot be projected — only seen by looking into the lens/mirror.

Converging lens/mirror: f (+). Real, inverted image when $d_o > f$. Virtual, upright, enlarged image when $d_o < f$ (magnifying glass).

Diverging lens/mirror: f (–). Always produces virtual, upright, reduced images. Think: peephole in a door.

10A Thermodynamics

Heat, temperature, gas laws, and entropy — bridges physics and chemistry on the MCAT

NAME	EQUATION	WHEN TO USE / NOTES	YIELD
Heat Transfer	$q = mc\Delta T$	c = specific heat capacity. Water: c = 4184 J/(kg·K). No phase change.	★★★
Phase Change	$q = mL$	L = latent heat (fusion or vaporisation). No temperature change during phase transition.	★★★
Ideal Gas Law	$PV = nRT$	R = 8.314 J/(mol·K). T must be in Kelvin. n = moles.	★★★
Combined Gas Law	$P_1V_1/T_1 = P_2V_2/T_2$	Fixed amount of gas; any variable can change	★★★
Boyle's Law	$P_1V_1 = P_2V_2$	Constant T: pressure and volume are inversely proportional	★★
Charles's Law	$V_1/T_1 = V_2/T_2$	Constant P: volume and temperature are directly proportional	★★
KE of Gas	$KE_{avg} = (3/2)kT$	$k = 1.38 \times 10^{-23}$ J/K (Boltzmann). KE depends only on T, not gas identity.	★★
RMS Speed	$v_{rms} = \sqrt{3RT/M}$	M = molar mass in kg/mol. Lighter gases move faster at same T.	★
1st Law of Thermo	$\Delta U = Q - W$	Internal energy change = heat added – work done BY system. W = PΔV for expansion.	★★★
Work (gas expansion)	$W = P\Delta V$	Work done by gas during expansion at constant pressure	★★★
Entropy	$\Delta S = Q_{rev}/T$	Entropy always increases for the universe (2nd Law). Disorder increases.	★★
Heat Engine Efficiency	$e = W/Q_H = 1 - Q_C/Q_H$	Maximum (Carnot): $e = 1 - T_C/T_H$. Always < 100%.	★

10B Atomic & Nuclear Physics

Radioactive decay, photoelectric effect, and $E = mc^2$ — moderate yield but straightforward points

NAME	EQUATION	WHEN TO USE / NOTES	YIELD
Photon Energy	$E = hf = hc/\lambda$	$h = 6.63 \times 10^{-34}$ J·s. Higher frequency (shorter λ) = more energy.	★★★
Photoelectric Effect	$KE_{max} = hf - \varphi$	φ = work function (threshold energy). Below threshold frequency → no electrons ejected, regardless of intensity.	★★★
Mass–Energy	$E = mc^2$	Mass defect → binding energy. $c = 3 \times 10^8$ m/s.	★★
Radioactive Decay	$N = N_0(½)^{(t/t_{½})}$	Usually avoidable: just count the number of half-lives and halve the original amount that many times (e.g., 3 half-lives → $N_0/8$).	★

Decay types:
α — emits a helium nucleus (2p + 2n). Z drops by 2, A drops by 4.
β^- — neutron → proton + electron. Z increases by 1, A unchanged.
β^+ — proton → neutron + positron. Z decreases by 1, A unchanged.
γ — pure energy (photon). No change in Z or A.
Ionising power: α > β > γ. Penetration: γ > β > α.

Photoelectric vs. intensity: Intensity ↑ → more electrons ejected (higher current), NOT higher KE. Only increasing frequency increases KE. This is the #1 MCAT trap for this topic.

Must-Know Equations — The Top 30

If you only have time to memorize 30 equations, these are the ones. They cover ~80% of MCAT physics questions.

#	EQUATION	EQUATION
1–2	$F = ma$	$W = mg$
3–4	$v = v_0 + at$	$v^2 = v_0^2 + 2ax$
5–6	$x = v_0t + ½at^2$	$f = \mu N$
7–8	$F_c = mv^2/r$	$F = -kx$ (Hooke's)
9–10	$KE = ½mv^2$	$PE = mgh$
11–12	$W = Fd \cos\theta$	$P = W/t$
13–14	$p = mv$	$J = F\Delta t = \Delta p$
15–16	$\tau = rF \sin\theta$	$P = F/A$
17–18	$P = \rho gh$	F_b = ρVg
19–20	$A_1v_1 = A_2v_2$	$P + ½\rho v^2 + \rho gh = \text{const}$
21–22	$F = kq_1q_2/r^2$	$V = IR$
23–24	$P = IV$	$v = f\lambda$
25–26	$\beta = 10 \log(I/I_0)$	$n_1\sin\theta_1 = n_2\sin\theta_2$
27–28	$1/f = 1/d_o + 1/d_i$	$q = mc\Delta T$
29–30	$PV = nRT$	$E = hf$

Fundamental Constants

$g = 10$ m/s² (round from 9.8)
$c = 3.0 \times 10^8$ m/s
$e = 1.6 \times 10^{-19}$ C
$k = 9 \times 10^9$ N·m²/C²
$\varepsilon_0 = 8.85 \times 10^{-12}$ F/m
$h = 6.6 \times 10^{-34}$ J·s
$N_A = 6.02 \times 10^{23}$ /mol

Thermo & Fluids

$\rho_{water} = 1000$ kg/m³ (calculations)
$\rho_{water} = 1$ g/cm³ (specific gravity)
$P_{atm} = 101{,}300$ Pa $\approx 10^5$ Pa
1 atm = 760 mmHg = 760 torr
R = 8.314 J/(mol·K)
R = 0.0821 L·atm/(mol·K)
$k_B = 1.38 \times 10^{-23}$ J/K

Unit Conversions

1 J = 1 kg·m²/s² = 1 N·m
1 W = 1 J/s
1 Pa = 1 N/m²
1 cal = 4.184 J
1 L = 10^{-3} m³
K = °C + 273
1 eV = 1.6×10^{-19} J

Trig Values (Memorize These)

θ	0°	30°	45°	60°	90°
sin	0	0.5	0.7	0.87	1
cos	1	0.87	0.7	0.5	0

SI Prefixes

pico (p)	10^{-12}
nano (n)	10^{-9}
micro (μ)	10^{-6}
milli (m)	10^{-3}
centi (c)	10^{-2}
deci (d)	10^{-1}
kilo (k)	10^{3}
mega (M)	10^{6}
giga (G)	10^{9}
tera (T)	10^{12}

Math "Cheats"

$\sqrt{2} \approx 1.4$
$\sqrt{3} \approx 1.7$
$\log_{10}(2) \approx 0.3$
$\log_{10}(3) \approx 0.48$
$\pi \approx 3.14$

Inverse-square laws: Gravity ($F \propto 1/r^2$), Coulomb's ($F \propto 1/r^2$), sound intensity ($I \propto 1/r^2$), light intensity ($I \propto 1/r^2$). Double the distance → ¼ the force/intensity. This pattern is tested constantly.

Decibel shortcuts: ×10 intensity = +10 dB. ×100 = +20 dB. ×2 ≈ +3 dB. ×4 ≈ +6 dB. Moving 2× farther → ¼ intensity → −6 dB. These shortcuts save massive time on test day.

Pro-tip: Focus on the *units* of constants, not just their values. If you forget a formula during the exam, you can often reverse-engineer it using dimensional analysis — if your units don't work out, you picked the wrong equation.