PREP101 Your Competitive Edge

MCAT Physics Equation Sheet

EQUATIONS IN MOTION

Average speed $v = \frac{d}{t}$	d = distance, t = time
Average velocity $\bar{v} = \frac{\Delta x}{\Delta t}$	Δx = displacement, Δt = elapsed time
Average acceleration $\bar{a} = \frac{\Delta v}{\Delta t}$	Δv = change in velocity, Δt = elapsed time
Linear motion kinematics 1-D (constant acceleration *a*) $v = v_0 + at$ $x = x_0 + v_0 t + \frac{1}{2}at^2$ $v^2 = v_0^2 + 2a(x - x_0)$ $v = \sqrt{2gh}$ (Free fall from 0 velocity)	To apply in two dimensions, the easiest way is to choose an x-y coordinate system so that the direction of the acceleration is entirely along either the x or the y direction. This greatly simplifies things as the acceleration in the other coordinate direction will have a component of 0 and the motion in that other direction will have constant velocity. The components of motion in the x and y directions are analyzed separately.
Vector components $v_x = v\cos\theta$, $v = \sqrt{v_x^2 + v_y^2}$ $v_y = v\sin\theta$, $\tan\theta = \frac{v_y}{v_x}$	For a vector of magnitude *v* making an angle θ with the x-axis
Centripetal acceleration $a_R = \frac{v^2}{R}$	Centripetal acceleration a_R is toward the center of the circle of radius *r* for an object traveling with constant speed *v*

FORCES AND TORQUE

Newton's first law of motion (Equilibrium) $\sum \vec{F} = 0$ $\tau_{clockwise} = \tau_{counterclockwise}$	At equilibrium, every body continues in its state of rest or of uniform speed as long as no net force and no net torque act on it.
Newton's second law of motion (Dynamics) $F = ma$	The acceleration *a* of an object is directly proportional to the net force acting on it and is inversely proportional to its mass. The direction of the acceleration is in the direction of the net force action the object.
Newton's third law of motion	Whenever one object exerts a force on a second object, the second exerts an equal and opposite force on the first.
Force of static friction $F_{fr} \le \mu_s F_N$	Opposes any impending relative motion between two surfaces, where the magnitude can assume any value up to a maximum of $\mu_s F_N$ where μ_s is the coefficient of static friction and F_N is the magnitude of the normal force.
Force of kinetic friction $F_{fr} = \mu_k F_N$	Force between two surfaces sliding against one another that opposes the relative motion of the two surfaces, where μ_k is the coefficient of kinetic friction.
Force of gravity between any two objects	The force F_G between two objects of masses m_1 and m_2 and separated by a distance *r*. The value of the universal gravitation constant is:
$F_G = G\frac{m_1 m_2}{r^2}$	$G = 6.67\times10^{-11}$ N·m²/kg²
Inclined Planes $F_{incline} = mg\sin\theta$ $F_{normal} = mg\cos\theta$	θ is the angle between the inclined plane and the horizontal surface
Hooke's Law $F = -k\Delta x$	The further a spring is stretched, the more force it pulls back with.
Torque $\tau = Fl$	Torque, which can be roughly thought of as a twisting force, is proportional to the force applied and the lever arm length.

WORK AND ENERGY

Work done by a constant force $W = Fd\cos\theta$	Work *W* done by a constant force of magnitude *F* on an object as it is displaced by a distance *d*. The angle between the directions of *F* and *d* is θ. Work is positive if the object is displaced in the direction of the force and negative if it is displaced against the force. The work is zero if the displacement is perpendicular to the direction of the force.
Kinetic energy $K = \frac{1}{2}mv^2$	Kinetic energy *K* for a mass *m* traveling at a speed *v*.
Gravitational potential energy $U = mgh$ (local) $U = -\frac{GMm}{r}$ (general)	Potential energy *U* is the energy that an object of mass *m* has by virtue of its position relative to the surface of the earth. That position is measured by the height *h* of the object relative to an arbitrary zero level.
Conservative forces • Gravitational force • Elastic spring force • Electric force **Non-conservative forces** • Frictional forces • Air resistance • Tension • Normal force • Propulsion of a motor	A force is conservative if either: • The work done by the force on an object moving from one point to another depends only on the initial and final positions and is independent of the particular path taken. • The net work done by the force on an object moving around any closed path is zero
Conservation of Mechanical Energy (Only holds true if non-conservative forces are ignored) $E_2 = E_1$ $K_2 + U_2 = K_1 + U_1$	The total mechanical energy of a system, remains constant as the object moves, provided that the net work done by external non-conservative forces (such as friction and air resistance) is zero.
Work-energy Theorem $W_{nc} = \Delta K + \Delta U + \Delta E_i$	The work due to non-conservative forces W_{nc} is equal to the change in kinetic energy ΔK plus the change in gravitational potential energy ΔU plus any changes in internal energy due to friction.
Rest Mass Energy $E = mc^2$	The energy inherent to a particle by nature of it having a mass.

Power $P = \frac{W}{t} = Fv$	Power P is defined as the rate at which work is done. It can also be expressed in terms of the force F being applied to the object traveling at a speed v. It is more correct to express this version of the relationship as $P = Fv\cos\theta$ where θ is the angle between F and v.

MOMENTUM

Linear momentum: $p = mv$ $\vec{p} = m\vec{v}$	Linear momentum p is the product of an object's mass m and velocity v. Linear momentum is a vector that points in the same direction of the velocity.
Principle of conservation of linear momentum: $\vec{P}_2 = \vec{P}_1$	The total linear momentum of an isolated system remains constant.
Impulse-momentum theorem: $\Delta p = F \cdot t$ $\vec{p}_2 - \vec{p}_1 = \vec{\bar{F}}_{net}\Delta t$	An impulse produces a change in an object's momentum. Impulse is given by the product of average force $\vec{\bar{F}}$ (F) and the time interval Δt (t) over which the force is applied. Impulse is a vector that points in the same direction as the average force.
Elastic collisions: • Bodies do not stick together • Kinetic energy is conserved • Momentum is conserved **Inelastic collisions:** • Bodies stick together if completely inelastic • Kinetic energy is not conserved • Momentum is conserved	A completely inelastic collision is one in which the bodies stick together completely after the collision. In inelastic collisions, kinetic energy is not conserved as some of the initial kinetic energy is converted into other forms of energy such as thermal and sound energy.
Center of Mass (CM or CofM) $x_{cm} = \frac{\sum_{i=1}^{n} m_i x_i}{M_{total}}$ For two bodies: $x_{cm} = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2}$	The center of mass is a point that represents the average location for the total mass of the system. In a collision, the velocity of the center of mass of all the colliding objects remains constant.

FLUIDS AND SOLIDS

Density $\rho = \frac{m}{V}$	Density of a liquid at rest. Density can also be measured relative to water, which is termed *specific gravity*. A specific gravity > 1 means the liquid is more dense than water, A specific gravity < 1 means the liquid is less dense than water
Pressure $P = \frac{F}{A}\ (general\ definition)$ **Hydrostatic pressure at a fixed depth**	The hydrostatic pressure on a fluid volume is dependent on its depth, and is equal in all directions.
$P = \rho g y$	
Buoyant Force $F_{buoyant} = \rho V g$	The buoyant force on an object in fluid is upward and equal to the weight of the fluid that the object displaces.
Continuity Equation $Q = Av$	The volume flow rate of a fluid is proportional to the cross-sectional area of the pipe and the velocity of the fluid. Q_{in} must be equal to Q_{out}.
Bernoulli's Equation $p + \rho g y + \frac{1}{2}\rho v^2 = \text{constar}$	One way to remember the Bernoulli equation is to think of it as an energy conservation equation. The three terms roughly correspond to pressure energy, potential energy, and kinetic energy, respectively.
Elastic modulus of a solid $Modulus = \frac{Stress}{Strain}$	A high modulus material is hard and rigid. Examples are metal and ceramic. A low modulus material is elastic, like rubber.

WAVES AND PERIODIC MOTION

Wave Velocity $v = f\lambda$	The velocity of a wave is the product of its frequency and wavelength.
Wave Period $T = \frac{1}{f}$	
Sound decibels $\beta = 10\log\frac{I}{I_o}$	A difference of 10 in decibels corresponds to sound intensity levels that differ by a factor of 10. For example, 90dB is 10 times as loud as 80dB.
Standing Waves **Both ends fixed or free** $L = \frac{n\lambda_n}{2}\ (n = 1,2,3,...)$ **One end fixed one end free** $L = \frac{n\lambda_n}{4}\ (n = 1,3,5,...)$	When a standing wave is formed on a piece of string, the string length is some fractional multiple of the standing wave wavelength. Depending on how the string is fixed, each end can be a node or an anti-node.
Beat frequency $f_{beat} = \lvert f_1 - f_2 \rvert$	When two waves of constant amplitude but different frequencies interfere with each other, the resulting wave's amplitude is confined to an envelope with some periodicity. The frequency of the envelope is the beat frequency and can be heard as distinct beats because of the amplitude variation with time.
Doppler effect $\frac{\Delta f}{f_s} = \frac{v}{c}$ $\frac{\Delta\lambda}{\lambda_s} = \frac{v}{c}$	The apparent frequency of the source is increased as the source approaches the observer, and is decreased as the sources leaves the observer.

ELECTROSTATICS AND MAGNETISM

Bolztmann's constant k and has a value of: $k = 9.0\times10^9\ N{\cdot}m/C^2$

Coulomb's law (electric force) $F = k\frac{Q_1 Q_2}{r^2}$	The magnitude of the force F between two charges (Q_1 and Q_2) in terms of the distance r between the two charges. The direction of the force is directed along the line between the two forces. This force is repulsive if the two charges are both positive or both negative, and attractive

	if the one charge is positive and the other negative.
Electric field due to a point charge q **at a distance** r $E = k\frac{Q}{r^2}$	E is a vector and points away from a positive charge and toward a negative charge.
Electric potential energy $U = k\frac{Q_1 Q_2}{r}$	The potential energy stored between the interaction between two point charges.
Electric potential $V = k\frac{Q}{r}$	The electric potential V due to a point charge q at a distance r away from the charge.
In constant electric fields $\vec{F} = q\vec{E} \quad U = qEd$ $V = Ed \quad U = Vq$	Note that the force F is in the same direction as the electric field E if the charge q is positive and in the opposite direction if the charge is negative. The energy gained by some charge in a field is simply force times the distance traveled. Potential is the energy per unit charge.
Force on a charge moving in a magnetic field $\vec{F} = q\vec{v} \times \vec{B}$ $F = qvB\sin\theta$	A charge q moving in a magnetic field $\vec{B}$ with a velocity $\vec{v}$ experiences a force $\vec{F}$. The magnitude of this force can also be expressed in terms of the angle θ between $\vec{v}$ and $\vec{B}$.

ELECTRONIC CIRCUITS

Ohm's law $V = IR$	The potential difference V across a device is given by its resistance R and the current I that flows through it
Resistance of a wire $R = \rho\frac{L}{A}$	The resistance R of a length L of wire with a cross-sectional area A and resistivity ρ. Resistivity has units $\Omega \cdot m$.
Electric power $P = IV = I^2R = \frac{V^2}{R}$	With help from Ohm's law, electric power P can be calculated using any combination of two of the following quantities: resistance R, voltage V or current I
RMS voltage and current (AC circuits) $V_{rms} = V_0/\sqrt{2}$ $I_{rms} = I_0/\sqrt{2}$	The root-mean-square values can be calculated from the peak values (V_0 and I_0) and are used to calculate the average power $\overline{P}$ in AC circuits: $\overline{P} = I_{rms}^2 R = \frac{V_{rms}^2}{R}$
Resistances in series $R_{eq} = R_1 + R_2$	For more than two resistances in series: $R_{eq} = R_1 + R_2 + R_3 + R_4 + \ldots$
Resistances in parallel $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$	For more than two resistances in parallel: $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \ldots$
Capacitance $C = \frac{Q}{V}$	A higher capacitance capacitor can store more charge at the same voltage.

Capacitors in series C_S **and parallel** C_P $\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2}$ $C_P = C_1 + C_2$	For more than two capacitors: $\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \frac{1}{C_4} + \ldots$ $C_P = C_1 + C_2 + C_3 + C_4 + \ldots$
Electric energy stored by a capacitor $U_E = \frac{1}{2}CV^2 = \frac{1}{2}QV = \frac{1}{2}\frac{Q^2}{C}$	Amount of electric energy stored in a capacitor is given in terms of the capacitance C and the potential difference between the conductors V.

LIGHT AND GEOMETRICAL OPTICS

Snell's law $n_1 \sin\theta_1 = n_2 \sin\theta_2$	The angle of incidence θ_1 is with respect to the perpendicular of the surface between the two media (with indices of refraction n_1 and n_2). The angle of refraction θ_2 is also with respect to the perpendicular.
Total internal reflection $\sin\theta_c = \frac{n_2}{n_1}$	The critical angle θ_c is the angle of incidence beyond which total internal reflection occurs. The index of refraction for the medium in which the incident ray is traveling is n_1
Energy of one photon $E = hf$	The energy of light is dependent on its frequency. H is the planck constant 6.626068×10^{-34} m^2 kg / s
Index of refraction $n = \frac{c}{v}$	The higher the index of refraction is for a medium, the slower is the speed of light in that medium.
The lens equation $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$	The focal length of the lens f is: • Positive for a converging lens • Negative for a diverging lens The object distance d_o is: • Positive if it is on the side of the lens from which the light is coming • Negative if on the opposite side The image distance d_i is: • Positive if it is on the opposite side of the lens from which the light is coming • Negative if on the same side
Lateral magnification $m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$	For an upright image, the magnification m is positive and for an inverted image m is negative.
Power of a lens $P = \frac{1}{f}$	
Focal length of a spherical mirror $f = \frac{1}{2}r$	For a spherical mirror, the focal length is half of the radius of curvature.