The following equations may be useful for the SP211 Final Exam.

Equation	Name	What it does	Serway
$\Delta x \equiv x_f - x_i$	Displacement	Defines displacement as the difference between final position and initial position.	p. 21
$v_{x,\text{avg}} \equiv \dfrac{\Delta x}{\Delta t}$	Average Velocity	Defines average velocity of a particle as the ratio of its displacement to the time elapsed during its motion.	p. 21
$v_x \equiv \lim\limits_{\Delta t \to 0} \dfrac{\Delta x}{\Delta t} = \dfrac{dx}{dt}$	Instantaneous Velocity	Defines instantaneous velocity of a particle as the time derivative of its position.	p. 24
$a_{x,\text{avg}} \equiv \dfrac{\Delta v_x}{\Delta t}$	Average Acceleration	Defines average acceleration of a particle as the ratio of its change in its velocity to the time elapsed during that change.	p. 28
$a_x \equiv \lim\limits_{\Delta t \to 0} \dfrac{\Delta v_x}{\Delta t} = \dfrac{dv_x}{dt}$	Instantaneous Acceleration	Defines instantaneous acceleration of a particle as the time derivative of its velocity.	p. 28
$v_{xf} = v_{xi} + a_x t$	Kinematics	Gives velocity as a function of time.	p. 33
$x_f = x_i + \dfrac{1}{2}\left(v_{xi} + v_{xf}\right)t$	Kinematics	Gives position as a function of time.	p. 33
$x_f = x_i + v_{xi}t + \dfrac{1}{2}a_x t^2$	Kinematics	Gives position as a function of velocity and time.	p. 33
$v_{xf}^2 = v_{xi}^2 + 2a_x\left(x_f - x_i\right)$	Kinematics	Gives velocity as a function of position.	p. 34
$A = \sqrt{A_x^2 + A_y^2}$	Magnitude of Vector	Identifies the magnitude of vector $\mathbf{A}$.	p. 60

Equation	Name	What it does	Serway
$\theta = \tan^{-1}\left(\frac{A_y}{A_x}\right)$	Direction of Vector	Identifies the direction of vector **A** with respect to the positive x-axis.	p. 60
$\Delta\mathbf{r} \equiv \mathbf{r}_f - \mathbf{r}_i$	Displacement (2-D)	Defines displacement as the difference between final position and initial position.	p. 72
$\mathbf{v}_{\text{avg}} \equiv \frac{\Delta\mathbf{r}}{\Delta t}$	Average Velocity (2-D)	Defines average velocity of a particle as the ratio of its displacement to the time elapsed during its motion.	p. 72
$\mathbf{v} \equiv \lim_{\Delta t \to 0} \frac{\Delta\mathbf{r}}{\Delta t} = \frac{d\mathbf{r}}{dt}$	Instantaneous Velocity (2-D)	Defines instantaneous velocity of a particle as the time derivative of its position.	p. 73
$\mathbf{a}_{\text{avg}} \equiv \frac{\Delta\mathbf{v}}{\Delta t}$	Average Acceleration (2-D)	Defines average acceleration of a particle as the ratio of its change in its velocity to the time elapsed during that change.	p. 73
$\mathbf{a} \equiv \lim_{\Delta t \to 0} \frac{\Delta\mathbf{v}}{\Delta t} = \frac{d\mathbf{v}}{dt}$	Instantaneous Acceleration (2-D)	Defines instantaneous acceleration of a particle as the time derivative of its velocity.	p. 73
$\mathbf{v}_f = \mathbf{v}_i + \mathbf{a}t$	Kinematics (2-D)	Gives velocity as a function of time.	p. 75
$\mathbf{r}_f = \mathbf{r}_i + \mathbf{v}_i t + \frac{1}{2}\mathbf{a}t^2$	Kinematics (2-D)	Gives position as a function of velocity and time.	p. 75
$h = \frac{v_i^2 \sin^2\theta_i}{2g}$	Max Height of Projectile	Relates the maximum height of a projectile to its initial velocity and angle of launch.	p. 78

Equation	Name	What it does	Serway
$R = \frac{v_i^2 \sin 2\theta_i}{g}$	Range of Projectile	Relates the range of a projectile to its initial velocity and angle of launch.	p. 79
$a_c = \frac{v^2}{r}$	Centripetal Acceleration	Defines the centripetal acceleration of a particle moving in a circular path as the ratio of the body's tangential velocity to radius of the path.	p. 85
$T = \frac{2\pi r}{v}$	Period of Circular Motion	Identifies the period of repeated circular motion.	p. 85
$\sum \mathbf{F}_i = m\mathbf{a}$	Newton's Second Law	Identifies a body's mass as the constant of proportionality between its acceleration and the net external force acting on it.	p. 104
$\mathbf{F}_{12} = -\mathbf{F}_{21}$	Newton's Third Law	States the principle of equal and opposite forces.	p. 107
$f_s \leq \mu_s n$	Static Friction	Establishes the relationship between the static frictional force and the normal force.	p. 120
$f_k = \mu_k n$	Kinetic Friction	Establishes the relationship between the kinetic frictional force and the normal force.	p. 120
$\sum \mathbf{F} = ma_c = m\frac{v^2}{r}$	Newton's Second Law for Circular Motion	Places the relationship between tangential velocity and centripetal acceleration in the context of Newton's Second Law.	p. 138
$\mathbf{R} = -b\mathbf{v}$	Resistive Force (linear)	Expresses a linear model for a force resisting the motion of a body through a fluid.	p. 148

Equation	Name	What it does	Serway
$v_T = \dfrac{mg}{b}$	Terminal Speed (linear)	Identifies the terminal speed of a body moving through a fluid when the resistive force obeys a linear model.	p. 149
$R = \dfrac{1}{2}D\rho A v^2$	Resistive Force (quadratic)	Expresses a quadratic model for a force resisting the motion of a body through a fluid.	p. 150
$v_T = \sqrt{\dfrac{2mg}{D\rho A}}$	Terminal Speed (quadratic)	Identifies the terminal speed of a body moving through a fluid when the resistive force obeys a quadratic model.	p. 151
$W \equiv \mathbf{F} \cdot \Delta\mathbf{r} = F\Delta r \cos\theta$	Work (constant force)	Defines work done by a constant force as the scalar product of the force and the displacement of the body accelerated by the force.	p. 165
$W = \int_{\mathbf{r}_i}^{\mathbf{r}_f} \mathbf{F} \cdot d\mathbf{r}$	Work (varying force)	Defines work done by a varying force as that force integrated over the displacement of the body accelerated by the force.	p. 170
$F = -kx$	Hooke's Law	Identifies the force exerted by a spring stretched or compressed by a distance x.	p. 171
$K \equiv \dfrac{1}{2}mv^2$	Definition of Kinetic Energy	Relates the energy of a body to its velocity.	p. 174
$W_{\text{net}} = K_f - K_i = \Delta K$	Work-Kinetic Energy Theorem	Expresses the equivalence of the work done on a system and its change in kinetic energy.	p. 174
$U_g \equiv mgy$	Gravitational Potential Energy	Relates the gravitational potential energy of a body to its mass and height above a zero-point.	p. 178

Equation	Name	What it does	Serway
$U_s \equiv \frac{1}{2}kx^2$	Elastic Potential Energy	Identifies the potential energy stored in a spring stretched or compressed by a distance x.	p. 180
$\Delta U = -\int_{\mathbf{r}_i}^{\mathbf{r}_f} \mathbf{F} \cdot d\mathbf{r}$	Potential Energy for Conservative Forces	Identifies the potential energy function for conservative forces.	p. 183
$\mathbf{F} = -\frac{\partial U}{\partial x}\mathbf{i} - \frac{\partial U}{\partial y}\mathbf{j} - \frac{\partial U}{\partial z}\mathbf{k}$	Potential Energy for Conservative Forces	Identifies the potential energy function for conservative forces.	p. 184
$E_{\text{mech}} \equiv K + U$	Mechanical Energy	Defines mechanical energy of a system as the sum of its kinetic and potential energies.	p. 199
$K_f + U_f = K_f + U_f$	Conservation of Energy	Expresses the conservation of mechanical energy in a system upon which no nonconservative forces act.	p. 199
$K_f = K_i - f_k d + \sum W_{\text{other}}$	Work-Kinetic Energy Theorem (with friction)	Adapts the Work-Kinetic Energy Theorem for use with problems involving kinetic friction.	p. 205
$\mathscr{P} \equiv \frac{dE}{dt} = \frac{dW}{dt} = \mathbf{F} \cdot \mathbf{v}$	Instantaneous Power	Defines instantaneous power in terms of: energy; work; force and velocity.	p. 213
$\mathscr{P}_{\text{avg}} = \frac{W}{\Delta t}$	Average Power	Defines average power in terms of work done over time.	p. 214
$\mathbf{p} \equiv m\mathbf{v}$	Momentum	Defines momentum of a particle as the product of its mass and velocity.	p. 228

Equation	Name	What it does	Serway
$\sum \mathbf{F} = \frac{d\mathbf{p}}{dt}$	Newton's Second Law	Identifies the forces acting on a particle as equivalent to the time rate of change of the particles momentum.	p. 229
$\mathbf{p}_{1i} + \mathbf{p}_{2i} = \mathbf{p}_{1f} + \mathbf{p}_{2f}$	Conservation of Linear Momentum	Expresses the unchanging total linear momentum of an isolated system of particles.	p. 229
$\mathbf{I} \equiv \int_{t_i}^{t_f} \sum \mathbf{F}\, dt$	Impulse	Defines impulse of a force as its time integral.	p. 232
$\Delta\mathbf{p} = \mathbf{I}$	Impulse-Momentum Theorem	Equates impulse of a force to the change in momentum of the particle upon which the force acts.	p. 232
$\mathbf{r}_{\text{CM}} = \frac{1}{M}\sum_i m_i \mathbf{r}_i$	Center of Mass (system of particles)	Identifies the center of mass of a system of particles.	p. 246
$\mathbf{r}_{\text{CM}} = \frac{1}{M}\int \mathbf{r}\, dm$	Center of Mass (extended body)	Identifies the center of mass of an extended body.	p. 246
$\sum \mathbf{F}_{\text{external}} = M\mathbf{a}_{\text{CM}}$	Newton's Second Law (system of particles)	Explicitly identifies the behavior of the center of mass of a system of particles under an external force as governed by the laws of motion.	p. 250
$s = r\theta$	Arc Length	Relates circular arc length to radius and subtended angle.	p. 270
$\omega \equiv \lim_{\Delta t \to 0} \frac{\Delta\theta}{\Delta t} = \frac{d\theta}{dt}$	Instantaneous Angular Speed	Identifies instantaneous angular speed as the time derivative of angular position.	p. 270
$\alpha \equiv \lim_{\Delta t \to 0} \frac{\Delta\omega}{\Delta t} = \frac{d\omega}{dt}$	Instantaneous Angular Acceleration	Identifies instantaneous angular acceleration as the time derivative of angular speed.	p. 271

Equation	Name	What it does	Serway
$\omega_f = \omega_i + \alpha t$	Rotational Kinematics	Gives angular speed as a function of time.	p. 272
$\theta_f = \theta_i + \frac{1}{2}\left(\omega_i + \omega_f\right)t$	Rotational Kinematics	Gives angular position as a function of time.	p. 272
$\omega_f^2 = \omega_i^2 + 2\alpha\left(\theta_f - \theta_i\right)$	Rotational Kinematics	Gives angular speed as a function of angular position.	p. 272
$\theta_f = \theta_i + \omega_i t + \frac{1}{2}\alpha t^2$	Rotational Kinematics	Gives angular position as a function of angular speed and time.	p. 272
$v = r\omega$	Tangential Speed	Relates tangential speed to angular speed.	p. 274
$a_t = r\alpha$	Tangential Acceleration	Relates tangential acceleration to angular acceleration.	p. 274
$a_c = \frac{v^2}{r} = r\omega^2$	Centripetal Acceleration	Relates centripetal acceleration to angular speed.	p. 274
$I \equiv \sum_i m_i r_i^2$	Moment of Inertia (system of particles)	Defines moment of inertia of a system of particles as the sum of the products of their masses and the squares of their distances from the axis of rotation of the system.	p. 276
$K_R = \frac{1}{2}I\omega^2$	Rotational Kinetic Energy	Relates the energy of a rotating system to the speed of its rotation.	p. 276
$I = \int r^2\, dm$	Moment of Inertia (rigid object)	Defines the moment of inertia of a rigid object about an axis of rotation.	p. 278

Equation	Name	What it does	Serway
$I = I_{\text{CM}} + MD^2$	Parallel-Axis Theorem	Relates the moment of inertia of a rigid object about an axis of rotation passing through its center of mass to any parallel axis of rotation a distance D away.	p. 281
$\boldsymbol{\tau} \equiv \mathbf{r} \times \mathbf{F} = rF \sin\phi = Fd$	Torque	Defines torque as the vector product of position of application of force and the force itself. Often its magnitude is the product of the magnitude of applied force and the moment arm d (the distance from the point of application to the axis of rotation).	p. 311
$\mathbf{L} \equiv \mathbf{r} \times \mathbf{p}$	Angular Momentum	Defines angular momentum of a particle as the vector product of the particle's position with respect to a center of rotation and its linear momentum.	p. 315
$\sum \boldsymbol{\tau} = \frac{d\mathbf{L}}{dt}$	Newton's Second Law (rotational)	Identifies the sum of the torques acting on a body (or system of particles) as the time derivative of the body's (or system's) angular momentum.	p. 315
$L = I\omega$	Angular Momentum (rigid object)	Identifies the magnitude of the angular momentum of a rotating rigid object as the product of its moment of inertia about the axis of rotation and its speed of rotation.	p. 318
$\sum \tau_{\text{external}} = I\alpha$	Newton's Second Law (rotational, scalar)	Identifies the moment of inertia of a body as the constant of proportionality between its angular acceleration and the net external torque acting on it.	p. 318

Equation	Name	What it does	Serway
$I_i\omega_i = I_f\omega_f$	Conservation of Angular Momentum	Expresses the unchanging total angular momentum of an isolated system of particles.	p. 321
$F_g = G\frac{m_1 m_2}{r^2}$	Law of Universal Gravitation	*Every particle in the universe attracts every other particle with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.*	p. 363
$g = \frac{GM_E}{(R_E + h)^2}$	Variation of Gravitational Acceleration with Altitude	Expresses the dependence of gravitational acceleration experienced by an object in freefall on its height above the Earth's surface.	p. 365
$T^2 = \left(\frac{4\pi^2}{GM}\right)a^3$	Kepler's Third Law	*The square of the orbital period of any planet is proportional to the cube of the semimajor axis of the elliptical orbit.*	p. 369
$U = -\frac{Gm_1 m_2}{r}$	Gravitational Potential Energy	Identifies the potential energy function for universal gravitation.	p. 374
$E = \frac{1}{2}mv^2 - \frac{GMm}{r}$	Total Energy of Orbital System	Identifies the (constant) total energy of a two-object orbital system as the sum of the kinetic energy of the satellite and the gravitational potential energy of the two-body system.	p. 375
$E = -\frac{GMm}{2a}$	Energy for Elliptical Orbits	Identifies the total energy of a two-object orbital system for the case of an elliptical orbit ($a = r$ for circular orbit).	p. 376

Equation	Name	What it does	Serway
$v_{\text{esc}} = \sqrt{\frac{2GM_E}{R_E}}$	Escape Speed	Identifies the speed required to "break free" from Earth's gravitational field.	p. 377
$P \equiv \frac{F}{A}$	Pressure	Defines pressure as the ratio of an applied force to its area of application.	p. 390
$P = P_0 + \rho g h$	Variation of Pressure With Depth	Gives the pressure at any depth in a fluid relative to a reference pressure.	p. 392
$B = \rho_{\text{fluid}} g V$	Buoyant Force	Identifies the force suspending a submerged object as the weight of the fluid the object displaces.	p. 396
$A_1 v_1 = A_2 v_2$	Continuity Equation (fluids)	Expresses the unchanging product of area and speed for an ideal fluid.	p. 400
$P + \frac{1}{2}\rho v^2 + \rho g y = \text{constant}$	Bernoulli's Equation	Expresses the unchanging sum of pressure, kinetic energy density, and potential energy density for an ideal fluid.	p. 403
$x(t) = A\cos(\omega t + \phi)$	Simple Harmonic Motion	Gives position as a function of time for an object in simple harmonic motion.	p. 420
$\omega = 2\pi f = \frac{2\pi}{T} = \sqrt{\frac{k}{m}}$	Angular Frequency (H.O.)	Identifies the angular frequency of a particle in simple harmonic motion.	p. 421
$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{k}}$	Period (H.O.)	Expressions for the period of simple harmonic motion.	p. 422

Equation	Name	What it does	Serway
$f = \frac{1}{T} = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$	Frequency (H.O.)	Expressions for the frequency of simple harmonic motion.	p. 422
$E = \frac{1}{2}mv^2 + \frac{1}{2}kx^2 = \frac{1}{2}kA^2$	Energy of Harmonic Oscillator	Identifies the total energy of a harmonic oscillator as the sum of its periodically varying kinetic and potential energies. Also expressed in terms of amplitude.	p. 427
$\omega = \sqrt{\frac{g}{L}}$	Angular Frequency (simple pendulum)	Gives the angular frequency of a simple pendulum in terms of its length.	p. 432
$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{L}{g}}$	Period (simple pendulum)	Expressions for the period of a simple pendulum.	p. 433
$T = 2\pi\sqrt{\frac{I}{mgd}}$	Period (physical pendulum)	Gives the period of a physical pendulum in terms of its moment of inertia about a pivot a distance d from the pendulum's center of mass.	p. 434
$x = Ae^{-bt/2m}\cos(\omega t + \phi)$	Damped Harmonic Oscillator	Equation of motion for an harmonic oscillator damped by a resistive force $\mathbf{R} = -b\mathbf{v}$.	p. 436
$\omega = \sqrt{\frac{k}{m} - \left(\frac{b}{2m}\right)^2}$	Angular Frequency (damped H.O.)	Gives the angular frequency of a damped harmonic oscillator whose angular frequency is $\omega = \sqrt{k/m}$ when undamped.	p. 436
$A = \frac{F_0/m}{\sqrt{(\omega^2 - \omega_0^2)^2 - \left(\frac{b\omega}{m}\right)^2}}$	Amplitude (driven H.O.)	Gives the amplitude of an harmonic oscillator driven by a force $\mathbf{F}$.	p. 437

Equation	Name	What it does	Serway
$y(x,t) = A\sin(kx - \omega t)$	Wave Function (sinusoidal wave)	Sinusoidal solution to the wave equation that relates the transverse displacement y of each point along the wave to its longitudinal position x and time t.	p. 455
$k \equiv \frac{2\pi}{\lambda}$	Angular Wave Number	Defines the angular wave number as inversely proportional to wavelength.	p. 455
$\omega \equiv \frac{2\pi}{T} = 2\pi f$	Angular Frequency (wave)	Defines the angular frequency of a wave.	p. 456
$v = \frac{\omega}{k} = \lambda f$	Speed of Propagation (wave)	Identifies the speed of a wave in terms of other wave quantities.	p. 456
$v = \sqrt{\frac{T}{\mu}}$	Speed of Propagation (wave on string)	Identifies the speed of a wave on a string of linear mass density μ.	p. 458
$\mathscr{P} = \frac{1}{2}\mu\omega^2 A^2 v$	Power (wave)	Gives the power of a wave propagating through a medium with linear mass density μ.	p. 464
$\Delta P = \Delta P_{\text{max}} \sin(kx - \omega t)$	Pressure (sound wave)	Gives variation in air pressure due to a periodic sound wave.	p. 476
$I \equiv \frac{\mathscr{P}}{A} = \frac{1}{2}\rho v(\omega s_{\text{max}})^2$	Intensity (sound wave)	Defines the intensity of a periodic sound wave as the ratio of its power to the area affected.	p. 478
$\beta \equiv 10\log\left(\frac{I}{I_0}\right)$	Sound Level in Decibels	Converts intensity units (W/m^2) to dB. $I_0 = 1.0 \times 10^{-12}$ W/m^2.	p. 480
$f' = f\left(\frac{v + v_O}{v - v_S}\right)$	Doppler Shift	Gives the Doppler-shifted frequency in terms of the speeds of the source and observer.	p. 485

Equation	Name	What it does	Serway
$\sin\theta = \dfrac{v}{v_S}$	Mach Angle	Identifies the angle the shock-wavefront makes with the trajectory of a sound source causing the shock wave.	p. 488
$y = (2A\sin kx)\cos\omega t$	Standing Wave	A standing wave function representing two identical waves traveling in opposite directions.	p. 505
$f_n = n\dfrac{v}{2L},\ n = 1, 2, 3, \ldots$	Natural Frequencies (both ends antinodes)	Gives the natural frequencies of a rod free at both ends or standing wave in a pipe open at both ends.	p. 513
$f_n = n\dfrac{v}{4L},\ n = 1, 3, 5, \ldots$	Natural Frequencies (one end node, one antinode)	Gives the natural frequencies of a rod fixed at one end or standing wave in a pipe closed at one end.	p. 514
$f_{\text{beat}} = \lvert f_1 - f_2 \rvert$	Beat Frequency	Identifies the frequency of "beats" between two close frequencies.	p. 518