LINEAR MOTION

velocity, $\vec{v} = \frac{\Delta \vec{x}}{t}$

acceleration, $\vec{a} = \frac{\Delta \vec{v}}{t}$

Newton's 2^{nd} Law,
$\vec{F}_{NET} = m \cdot \vec{a}$

Constant Acceleration

$v_f = v_i + at$

$\Delta x = v_i t + \frac{1}{2} a t^2$

$v_f^2 = v_i^2 + 2a\Delta x$

Work, $W = |F| \cdot |d| \cdot \cos\theta$

Power, $P = \frac{W}{t}$

Kinetic Energy, $K = \frac{1}{2} m v^2$

Potential Energy (Gravitational), $U = mgh$

Momentum, $p = mv$

Impulse, $\Delta p = F_{AVG} \cdot t$

ROTATIONAL MOTION

angular velocity, $\omega = \frac{\Delta \theta}{t}$

angular acceleration, $\alpha = \frac{\Delta \omega}{t}$

torque, $T = F \cdot l \sin\theta$

rotational inertia, I

Newton's 2^{nd} Law

$T_{NET} = I \cdot \alpha$

constant angular acceleration

$\omega_f = \omega_i + \alpha t$

$\Delta\theta = \omega_i t + \frac{1}{2} \alpha t^2$

$\omega_f^2 = \omega_i^2 + 2\alpha\Delta\theta$

Angular Momentum, $L = I \cdot \omega$

Tangential velocity to angular velocity

$V = \omega \cdot r$

Rotations sign convention

counterclockwise $\rightarrow$ (+)

clockwise $\rightarrow$ (−)

MISCELLANEOUS

weight, $F_g = mg$

friction, $f = \mu N$

centripetal acceleration / centripetal force

$a_c = \frac{v^2}{r} = \omega^2 r \rightarrow F_c = \frac{mv^2}{r}$ or $F_c = m\omega^2 r$

arc length, $s = \theta \cdot r$ (θ in radians)

Hooke's Law, $F = -kx$

Spring Potential Energy, $U_s = \frac{1}{2} k x^2$

height - length - angle of a pendulum

$h = l(1 - \cos\theta)$

Elastic collision w/ one object initially at rest

$v_{1f} = v_{1i} \cdot \frac{(m_1 - m_2)}{(m_1 + m_2)}$ $\quad v_{2f} = v_{1i} \cdot \frac{2m_1}{(m_1 + m_2)}$

Vector Addition

Vector Addition, $\vec{R} = \vec{A} + \vec{B} + \vec{C} + \ldots$

$R_x = A_x + B_x + C_x + \ldots$

$R_y = A_y + B_y + C_y + \ldots$

$|\vec{R}| = \sqrt{R_x^2 + R_y^2}$

$\theta = \tan^{-1}\left(\left|\frac{R_y}{R_x}\right|\right)$

ELASTICITY

stress $= \frac{F}{\text{Area}}$

strain $= \frac{\Delta L}{L}$

stress $\propto$ strain

$\frac{F}{A} = Y \frac{\Delta L}{L}$

Y = Young's modulus

SIMPLE HARMONIC MOTION

$\omega = \sqrt{\frac{k}{m}}$ $\quad \omega = 2\pi f$ $\quad f = \frac{1}{T}$

$x_{max} = A$ $\quad x(t) = A\cos(\omega t)$

$v_{max} = \omega A$ $\quad v(t) = -\omega A \sin(\omega t)$

$a_{max} = \omega^2 A$ $\quad a(t) = -\omega^2 A \cos(\omega t)$

THERMODYNAMICS

C° to F°

$T_F = \frac{9}{5} T_C + 32°F$

C° to K

$T_K = T_C + 273.15$

Linear Expansion

$\frac{\Delta L}{L} = \alpha \Delta T$

Ideal Gas Law

$PV = N k_B T$

$k_B = 1.38 \cdot 10^{-23}$ J/K

$N_A = 6.022 \cdot 10^{23}$ things/mole

Heat to change temperature

$Q = m \cdot c \cdot \Delta T$

Heat to change phase

$Q = m \cdot L_f$

$C_{water} = 4.186\ \text{kJ/kg°C}$ $\quad C_{ice} = 2.1\ \text{kJ/kg°C}$ $\quad L_f(ice) = 333.7\ \text{kJ/kg}$

DOPPLER EFFECT

FOR SOUND

$f_{obs} = \frac{(V_{sound} - V_{obs})}{(V_{sound} - V_{source})} \cdot f_{source}$

V_{obs} and V_{source} are positive if moving in direction of wave propogation, negative if moving in opposite direction to wave propogation

WAVE MOTION

wavenumber, $k = \frac{2\pi}{\lambda}$

periodic wave relation

$V = f\lambda$

velocity on a string

$V = \sqrt{\frac{F}{\mu}}$ $\quad \mu = \frac{m}{L}$

standing waves

- string

$f_n = \frac{nV}{2L}$ $\quad n = 1, 2, 3, \ldots$

- pipe open on both ends

$f_n = \frac{nv}{2L}$ $\quad n = 1, 2, 3, \ldots$

- pipe open on one end

$f_n = \frac{nv}{4L}$ $\quad n = 1, 3, 5, 7, \ldots$

SOUND

$V_{sound} \propto \sqrt{T_K}$

$V = 331$ m/s at 0°C (273°K)

intensity, $I = \frac{\text{Power}}{\text{Area}}$

loudness (intensity level)

$\beta = 10\text{dB} \log_{10}\left(\frac{I}{I_0}\right)$

Threshold of Hearing $\rightarrow I_0 = 10^{-12}\ \text{W/m}^2$

Beat frequency

$f_{beat} = f_2 - f_1 = \Delta f$

FACTORS AND PERCENT CHANGE

$\frac{X_2}{X_1} = k$ $\quad \frac{X_2 - X_1}{X_1} = \frac{n\%}{100}$

$k = 1 \pm \frac{n\%}{100}$

ELECTRIC FORCE

Coulomb's Law

$$|F| = \frac{k|q_1||q_2|}{r^2}$$

$$k = 9 \cdot 10^9 \frac{Nm^2}{C^2} = \frac{1}{4\pi\epsilon_0}$$

$$\epsilon_0 = 8.85 \cdot 10^{-12} \frac{C^2}{Nm^2}$$

$$e = 1.6 \cdot 10^{-19} C$$

$$m_e = 9.109 \cdot 10^{-31} kg$$

$$m_p = 1.673 \cdot 10^{-27} kg$$

Electric Field, $\vec{E} = \frac{\vec{F}}{q}$

Electric Field from a point charge

$$E = \frac{kq}{r^2}$$

Electric Field inside a parallel plate capacitor

$$E = \frac{\sigma}{\epsilon_0} = \frac{\Delta V}{d}$$

Potential Energy for two point charges from infinity

$$U_E = \frac{kq_1q_2}{r}$$

Electric Potential, $V = \frac{U_E}{q}$

Electric Potential for a point charge referenced from infinity

$$V = \frac{kq_0}{r}$$

Electric Flux, $\Phi_E = E \cdot A \cdot \cos\theta$

Gauss's Law

$$\Phi = \frac{q_{encl}}{\epsilon_0}$$

INTERFERENCE + DIFFRACTION

Constructive Interference

$\Delta l = m\lambda \quad (m = 0, \pm 1, \pm 2, \ldots)$

Destructive Interference

$\Delta l = (m + \frac{1}{2})\lambda \quad (m = 0, \pm 1, \pm 2, \ldots)$

Thin Film Interference

Constructive: $2nt = (m + \frac{1}{2})\lambda_0$

Destructive: $2nt = m\lambda_0$

Double Slit: $d\sin\theta = m\lambda$

Single Slit: $a\sin\theta = m\lambda$

small angle approx: $\sin\theta \approx \frac{x}{D}$

diffraction grating: $d\sin\theta = \frac{dx}{\sqrt{x^2 + D^2}} = m\lambda$

CIRCUITS

Ohm's Law, $V = IR$

Resistance in a wire

$$R = \rho\frac{l}{A}$$

resistivity change w/ temperature

$$\rho = \rho_0(1 + \alpha \cdot \Delta T)$$

$$\Delta T = T - T_0$$

current from drift velocity

$$I = neAv_D$$

resistors in series

$$R_{Eq} = R_1 + R_2 + \ldots + R_N$$

resistors in parallel

$$\frac{1}{R_{Eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_N}$$

power supplied by emf

$$P = I\mathcal{E}$$

power dissipated by resistor

$$P = I\Delta V = I^2R = \frac{\Delta V^2}{R}$$

capacitance, $C = \frac{Q}{\Delta V}$

parallel plate capacitance

$$C = \frac{\epsilon_0 A}{d}$$

energy stored in a capacitor

$$U = \frac{1}{2}Q\Delta V = \frac{1}{2}C\Delta V^2 = \frac{Q^2}{2C}$$

capacitors in series

$$\frac{1}{C_{Eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots + \frac{1}{C_N}$$

$$Q_1 = Q_2 = \ldots = Q_N$$

capacitors in parallel

$$C_{Eq} = C_1 + C_2 + \ldots + C_N$$

$$Q = Q_1 + Q_2 + \ldots + Q_N$$

charging an RC circuit

$$V_c(t) = \mathcal{E}(1 - e^{-t/\tau})$$

$$I(t) = \frac{\mathcal{E}}{R}e^{-t/\tau}$$

$$\tau = RC$$

discharging an RC circuit

$$V_c(t) = \mathcal{E}e^{-t/\tau}$$

MAGNETIC FORCE

Force on a charged particle

$$\vec{F} = q\vec{v} \times \vec{B} = qvB\sin\theta$$

Force on a current

$$\vec{F} = l\vec{I} \times \vec{B} = lIB\sin\theta$$

Torque on a current loop

$$\tau = NIAB\sin\theta$$

Magnetic Field due to a current

- r distance away from a long straight wire $\Big\}\ B(r) = \frac{\mu_0 I}{2\pi r}$
- at the center of a coil with N turns and radius R $\Big\}\ B = \frac{\mu_0 NI}{2R}$
- at the center of a solenoid w/ n turns per unit length $\Big\}\ B = \mu_0 nI$

$$\mu_0 = 4\pi \cdot 10^{-7} \frac{Tm}{A}$$

Motional emf, $\mathcal{E} = vlB$

Magnetic flux, $\Phi_B = B \cdot A$

Faraday's Law, $\mathcal{E} = -\frac{\Delta\Phi}{\Delta t}$

LIGHT AND OPTICS

index of refraction, $n = \frac{c}{v}$

wavelength and frequency relation, $v = \lambda \cdot f$

wavenumber, $k = \frac{2\pi}{\lambda}$

intensity, $I = \frac{P}{A}$. $I \propto 1/r^2$ for a point source

Doppler effect for light

$$f_o = f_s\left(\frac{\sqrt{1 + v_{rel}/c}}{\sqrt{1 - v_{rel}/c}}\right) \approx f_s(1 + v_{rel}/c) \text{ for } v_{rel} << c$$

$v_{rel} > 0$, objects are approaching

$v_{rel} < 0$, objects are receding

incident light unpolarized through ideal polarizer

$$I_t = \frac{1}{2}I_i$$

incident light polarized through ideal polarizer (Malus's Law)

$$I_t = I_i\cos^2\theta$$

θ → angle between polarizations

Snell's Law

$$n_i\sin\theta_i = n_t\sin\theta_t$$

Apparent depth/actual depth $\Rightarrow \frac{d'}{d} = \frac{n_T}{n_i} = \frac{n_{air}}{n_{water}}$

Critical angle $\theta_c = \sin^{-1}\left(\frac{n_t}{n_i}\right)$

mirror/thin lens equation

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

focal length from mirror curvature, $f = \frac{R}{2}$

magnification $m = \frac{h'}{h} = -\frac{q}{p}$