Kinematics

$d = \frac{1}{2}(V_0 + V_f)t$

$d = V_0 t + \frac{1}{2}at^2$

$V_f = V_0 + at$

$V_f^2 = V_0^2 + 2ad$

$V_{0,x} = V_0\cos\theta$
$V_{0,y} = V_0\sin\theta$

$v_{0,y}$ = Initial velocity in y direction (m/s)
$v_{0,x}$ = Initial velocity in x direction (m/s)
v_0 = Initial velocity (m/s)
θ = Launch angle

Force, etc

Force
$F = ma$
$F_x = F\cos\theta$
$F_y = F\sin\theta$

Friction
$F_f = \mu_k F_N$
$F_{f\,max} = \mu_s F_N$

Pressure
$P = \frac{F_\perp}{A}$

Center of Mass
$x_{CM} = \frac{m_1x_1 + m_2x_2 + m_3x_3 + \dots}{m_1 + m_2 + m_3 + \dots}$

$F_{grav} = \frac{GMm}{r^2}$

Forces on an Inclined Plane
$F_N = mg\cos\theta$
$F_{g,\ acting\ parallel} = mg\sin\theta$

Torque
$\tau = rF\sin\theta = \ell F$

Centripetal Force
$F_c = \frac{mv^2}{r}$

F_c = Centripetal force (N)
m = Mass (kg)
v = Velocity (m/s)
r = Radius (m)

Centripetal Acceleration
$a_c = \frac{v^2}{r}$

a_c = Centripetal acceleration (m/s²)
v = Velocity (m/s)
r = Radius (m)

Charges and Electric Fields

Coulomb's Law
$F_E = \frac{k|q_1 q_2|}{r^2}$

Electric Potential Energy Between Two Charges
$PE_{Elec} = \frac{kq_1 q_2}{r}$

Magnitude of Electric Field
$E_{by\,Q} = \frac{k|Q|}{r^2}$

Force of Electric Field on a Charge
$F_{on\,q} = qE$

Strength of Electric Field Between Parallel Plate Capacitor
$V = Ed$

Electric Potential Created by a Charge
$\Phi = \frac{kQ}{r}$

Change in Electric Potential Energy
$\Delta PE_{Elec} = qV$

Force on a Charge by a Magnetic Field
$F_B = |q|vB\sin\theta$

F_B = Magnetic field force (N)
q = Charge (C)
v = Speed of charge (m/s)
B = Magnetic field strength (T)
θ = Angle between velocity and magnetic field

Work Done by Electric Field
$W = -\Delta PE_{Elec}$

W = Work (J)
ΔPE_{Elec} = Electric Potential Energy (J)

Light, Optics, and Quantum Physics

Index of Refraction
$n = \frac{c}{v}$

Photon Energy
$E = hf = \frac{hc}{\lambda}$

Energy Level of a Hydrogen Atom
$E_n = \frac{-13.6\ eV}{n^2}$

Snells Law
$n_1\sin\theta_1 = n_2\sin\theta_2$

Energy of a Photon Emitted or Absorbed Under the Bohr Model
$E_{photon} = hf = |\Delta E_{atom}| = 13.6\ eV\left(\frac{1}{n_{final}^2} - \frac{1}{n_{initial}^2}\right)$

Critical Angle for Total Internal Reflection
$\sin\theta_{crit} = \frac{n_2}{n_1}$

Kinetic Energy of a Photoelectron
$KE_{max} = hf - \Phi$

Mirror and Lens Equation
$\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$

o = Objects distance from the mirror
i = Images distance from the mirror
f = Focal length of the mirror

Lens Power
$P = \frac{1}{f}$

Heisenberg Uncertainty Relation
$\Delta x\Delta p \geq \frac{h}{2\pi}$

Δx = Change in position (m)
Δp = Change in momentum (kg•m/s)
h = Plancks constant
= 6.6 x 10⁻³⁴ J•s

Magnification Equation
$m = -\frac{i}{o}$

Multiply the height of the object by m to get the height of the image. If m is positive the image is upright. If m is negative the image is inverted.

m = Magnification factor
i = Images distance from the mirror
o = Objects distance from the mirror

Work, Energy, and Power

Work
$W = Fd\cos\theta$

W = Work (J)
F = Force (N)
d = Distance (m)
θ = Angle between force vector and displacement

$W = \Delta KE = KE_f - KE_i$

W = Work (J)
ΔKE = Change in kinetic energy (J)
KE_f = Final kinetic energy (J)
KE_i = Initial kinetic energy (J)

Kinetic Energy
$KE = \frac{1}{2}mv^2$

KE = Kinetic energy (J)
m = Mass (kg)
v = Velocity (m/s)

Gravitational Potential Energy
$\Delta PE_{grav} = -W_{by\ gravity} = mg\Delta h$

ΔPE_{grav} = Change in gravitational potential energy (J)
$W_{by\ gravity}$ = Work done by the force of gravity (J)
m = Mass (kg)
g = Acceleration due to gravity (m/s²)
Δh = Change in height (m)

Conduction
$P_{cond} = \frac{\Delta Q}{\Delta t} = -kA\frac{\Delta T}{\Delta x} = kA\frac{T_i - T_f}{L}$

P_{cond} = Rate of thermal energy transfer (J)
ΔQ = Change in heat (J)
Δt = Change in time (s)
ΔT = Change in temperature
Δx = Change in length (m)
k = Thermal conductivity constant (W/mK)
A = Area (m²)
T_i = Initial Temperature
T_f = Final Temperature
L = Length (m)

Total Mechanical Energy
$E = KE + PE$

E = Total mechanical energy (J)
KE = Kinetic energy (J)
PE = Potential energy (J)

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

P = Power (W)
W = Work (J)
t = Time (s)

$P = Fv\cos\theta$

P = Power (W)
F = Force (N)
v = Velocity (m/s)
θ = Angle between force vector and displacement

Conservation of Total Mechanical Energy
$E_i = E_f$
$KE_i + PE_i + W_{by\,F} = KE_f + PE_f$
$\Delta KE + \Delta PE = 0$

E_i = Initial mechanical energy (J)
E_f = Final mechanical energy (J)
KE_i = Initial kinetic energy (J)
KE_f = Final kinetic energy (J)
PE_i = Initial potential energy (J)
PE_f = Final potential energy (J)
ΔKE = Change kinetic energy (J)
ΔPE = Change potential energy (J)
$W_{by\,F}$ = Work by outside forces (J)

First Law of Thermodynamics
$\Delta E = Q - W$

ΔE = Change in energy (J)
Q = Heat (J)
W = Work (J)

Linear Thermal Expansion
$\Delta L = \alpha L_0\Delta T$

ΔL = Change in length (m)
α = Coefficient of linear expansion (1/ C)
L_0 = Initial length (m)
ΔT = Change in temperature

Momentum
$\rho = mv$

ρ = Momentum (kgm/s)
m = Mass (kg)
v = Velocity (m/s)

Thermodynamic Work
$W = P\Delta V$

W = Work (J)
P = Pressure (Pa)
ΔV = Change in volume (m³)

Impulse
$J = \Delta\rho = \Delta(mv) = F\Delta t$

J = Impulse (kgm/s)
Δρ = Change in momentum (kgm/s)
Δ(mv) = Change in mass x velocity (kgm/s)
F = Force (N)
Δt = Change in time (s)

Mechanical Advantage
$MA = \frac{F_{resistance}}{F_{effort}}$

MA = Mechanical advantage
$F_{resistance}$ = Force that would be applied if no machine were used (N)
F_{effort} = Force applied with the machine (N)

Efficiency
$Eff\ (\%) = \frac{W_{output}}{Energy_{input}}$

Eff (%) = Efficiency
W_{output} = Work output (J)
$Energy_{input}$ = Supplied energy (J)

Elastic Collision
$v_{I,0} + v_{I,f} = v_{II,0} + v_{II,f}$

$v_{I,0}$ = Initial velocity I (m/s)
$v_{I,f}$ = Final velocity I (m/s)
$v_{II,0}$ = Initial velocity II (m/s)
$v_{II,f}$ = Final velocity II (m/s)

Circuits

Ohm's Law
$V = IR$

V = Voltage (V)
I = Current (A)
R = Resistance (Ω)

Power (Power dissipated by a resistor or supplied by a battery)
$P = IV = I^2R$

P = Power (W)
V = Voltage (V)
I = Current (A)
R = Resistance (Ω)

Energy Stored in a Capacitor
$PE = 1/2\ QV$

PE = Potential energy (J)
Q = Charge (C)
V = Voltage (V)

Resistance
$R = \rho\frac{L}{A}$

R = Resistance (Ω)
ρ = Resistivity (Ωm)
L = Length (m)
A = Area (m²)

Equivalent Resistance
Series
$R_{eq} = R_1 + R_2 + \dots$

Parallel
$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$

R = Resistance (Ω)

AC Voltage
$V_{rms} = \frac{V_{max}}{\sqrt{2}}$

V_{rms} = Root mean squared voltage (V)
V_{max} = Max voltage (V)

AC Current
$I_{rms} = \frac{I_{max}}{\sqrt{2}}$

I_{rms} = Root mean squared current (A)
I_{max} = Max current (A)

AC Average Power Supplied
$\bar{P} = I_{rms}V_{rms}$

Average power supplied by a voltage source

$\bar{P}$ = Average power (W)
I_{rms} = Root mean squared current (A)
V_{rms} = Root mean squared voltage (V)

Capacitance
$C = \frac{Q}{V} = K\varepsilon_0\frac{A}{d}$

C = Capacitance (F)
Q = Charge (C)
V = Voltage (V)
K = Dielectric constant
= 1 for air, otherwise specific to material
ε_0 = Permittivity of free space
= 8.85 x 10⁻¹² (F/m)
A = Area (m²)
d = Distance (m)

Total Capacitance
Series
$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$

For capacitors in series, the charge (Q) stored on each capacitor is the same as the equivalent capacitor

For capacitors in parallel, the voltage is the same across each, and the charge (Q) stored on each capacitor will add up to the total charge of the equivalent capacitor

Parallel
$C_{eq} = C_1 + C_2 + \dots$

C = Capacitance (F)

AC Average Power Dissipated
$\bar{P} = I_{rms}^2 R$

Average power dissipated by a resistor

$\bar{P}$ = Average power (W)
I_{rms} = Root mean squared current (A)
R = Resistance (Ω)

Fluids

Specific Gravity
$sp.\ gr. = \frac{\rho}{\rho_{H_2O}}$

sp. gr. = Specific gravity
ρ = Density (kg/m³)
ρ_{H_2O} = Density of water
= 1000 kg/m³

Flow Rate
$f = Av$

f = Flow rate (m³/s)
A = Cross sectional area (m²)
v = Flow speed (m/s)

Pascals Law
$F_2 d_2 = \left(\frac{A_2}{A_1}F_1\right)\left(\frac{A_1}{A_2}d_1\right) = F_1 d_1$

F_1 = Force 1 (N)
F_2 = Force 2 (N)
A_1 = Area 1 (m²)
A_2 = Area 2 (m²)
d_1 = Distance 1 (m)
d_2 = Distance 2 (m)

Continuity Equation
$A_1v_1 = A_2v_2$

A_1 = Area 1 (m²)
A_2 = Area 2 (m²)
v_1 = Flow speed 1 (m/s)
v_2 = Flow speed 2 (m/s)

Force of Gravity
$F_{grav} = \rho Vg$

F_{grav} = Force of gravity
ρ = Density (kg/m³)
V = Volume (m³)
g = Acceleration due to gravity (N/kg)

Torricelli's Result
$v_{efflux} = \sqrt{2gD}$

v_{efflux} = Efflux speed (m/s)
g = Acceleration due to gravity (m/s²)
D = Depth (m)

Hydrostatic Gauge Pressure
$P_{gauge} = \rho_{fluid}gD$

Fluid must be at rest, and it does not take pressure due to the atmosphere into account

P_{gauge} = Hydrostatic gauge pressure (Pa)
ρ_{fluid} = Density of fluid
g = Acceleration due to gravity (N/kg)
D = Depth (m)

Bernoullis Equation
$P_1 + \frac{1}{2}\rho v_1^2 + \rho gy_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho gy_2$

P_1 = Pressure 1 (Pa)
P_2 = Pressure 2 (Pa)
v_1 = Flow speed 1 (m/s)
v_2 = Flow speed 2 (m/s)
y_1 = Height 1 (m)
y_2 = Height 2 (m)
ρ = Density (kg/m³)
g = Acceleration due to gravity (m/s²)

Archimedes Principle
$F_{buoy} = \rho_{fluid}V_{sub}g$

F_{buoy} = Buoyant force (N)
ρ_{fluid} = Density of fluid
V_{sub} = Volume submerged (m³)
g = Acceleration due to gravity (N/kg)

Poiseuilles Law Volume Flow Rate
$\frac{V}{t} = \frac{\Delta P\pi R^4}{8\eta L}$

V = Volume (m³)
t = Time (s)
ΔP = Change in pressure (Pa)
R = Radius (m)
η = Coefficient of viscosity (Pa•s)
L = Length (m)

Viscous Force
$F_v = \eta A\frac{v}{d}$

F_v = Viscous force (N)
η = Coefficient of viscosity (Pa•s)
A = Area in contact with liquid (m²)
v = Pulling speed (m/s)
d = Depth of the fluid (m)

Floating Object in Equilibrium at Surface
$w_{object} = F_{buoy}$

If the object is fully submerged, then apparent weight = weight - buoyant force

$\frac{V_{sub}}{V} = \frac{\rho_{object}}{\rho_{fluid}}$

Example: If the object's density is 3/4 the density of the fluid, then 3/4 of the object will be submerged (and vice versa)

Oscillations, Waves, and Sound

Frequency
$f = \frac{1}{T}$

Period
$T = \frac{1}{f}$

f = Frequency (Hz)
T = Period (s)

Wave Speed
$v = \lambda f$

v = Speed (m/s)
λ = Wavelength (m)
f = Frequency (Hz)

Elastic Potential Energy
$PE_{elastic} = \frac{1}{2}kx^2$

$PE_{elastic}$ = Elastic potential energy (J)
k = Spring constant (N/m)
x = Displacement from equilibrium position (m)

Doppler Effect
$f_O = f_S\frac{v \pm v_O}{v \mp v_S}$

Choose the top sign if that object is moving towards the other

f_O = Frequency observed (Hz)
f_S = Source frequency (Hz)
v = Speed of the wave (m/s)
v_O = Observer velocity (m/s)
v_S = Source velocity (m/s)

Simple Harmonic Motion of Spring
Frequency
$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

Period
$T = 2\pi\sqrt{\frac{m}{k}}$

f = Frequency (Hz)
T = Period (s)
k = Spring constant (N/m)
m = mass (kg)

Work (Spring)
$W_{by\ spring} = -\Delta PE_{elastic}$
$W_{against\ spring} = \Delta PE_{elastic}$

$\Delta PE_{elastic}$ = Elastic potential energy (J)
$W_{by\ spring}$ = Work done by spring (J)
$W_{against\ spring}$ = Work done on spring (J)

Intensity Level
$\beta = 10\log_{10}\frac{I}{I_0}$

β = Intensity level (dB)
I = Intensity (W/m²)
I_0 = Threshold of hearing
= 10⁻¹² (W/m²)

Beat Frequency
$f_{beat} = |f_1 - f_2|$

f_{beat} = Beat frequency (Hz)
f_1 = Frequency 1
f_2 = Frequency 2

Force Exerted by Spring
$F = -kx$

F = Force (N)
k = Spring constant (N/m)
x = Displacement from equilibrium position (m)

Simple Harmonic Motion of Pendulum
Frequency
$f = \frac{1}{2\pi}\sqrt{\frac{g}{l}}$

Period
$T = 2\pi\sqrt{\frac{l}{g}}$

f = Frequency (Hz)
T = Period (s)
g = Acceleration due to gravity (m/s²)
l = Length of the pendulum (m)

Standing Wave (Closed Pipe)
$\lambda_n = \frac{4L}{n}$

λ_n = Harmonic frequency (Hz)
n = Harmonic number (odd number)
L = Length (m)

$f_n = \frac{nv}{4L}$

f_n = Harmonic frequency (Hz)
n = Harmonic number (odd number)
v = Speed (m/s)
L = Length (m)

Standing Wave (Fixed Ends and Open Pipe)
$\lambda_n = \frac{2L}{n}$

λ_n = Harmonic frequency (Hz)
n = Harmonic number (1, 2, 3, ...)
L = Length (m)

$f_n = \frac{nv}{2L}$

f_n = Harmonic frequency (Hz)
n = Harmonic number (1, 2, 3, ...)
v = Speed (m/s)
L = Length (m)

Angular Motion

Angular Velocity
$\omega = \frac{\Delta\theta}{\Delta t}$

ω = Angular velocity (rad/s)
Δθ = Angular displacement (rad)
Δt = Change in time (s)

Arc Length
$S = R\Delta\theta$

S = Arc length (m)
R = Radius (m)
Δθ = Angular displacement (rad)

Speed
$v = R\omega$

v = Speed (m/s)
R = Radius (m)
ω = Angular velocity (rad/s)

Angular Velocity
$\alpha = \frac{\Delta\omega}{\Delta t} = \frac{\tau}{I}$

α = Angular acceleration (rad/s²)
Δω = Change in angular velocity (rad/s)
Δt = Change in time (s)

Magnitude of Acceleration
$a_{tan} = R\alpha$

a_{tan} = Magnitude of the tangential acceleration (m/s²)
R = Radius (m)
α = Angular acceleration (rad/s²)

Velocity of Center of Mass Rolling Without Slipping
$v_{CM} = r\omega$

v_{CM} = Center of mass velocity (m/s)
r = Radius (m)
ω = Angular velocity (rad/s)

Moment of Inertia
Point Mass
$I = mr^2$

Cylinder
$I = \frac{1}{2}mr^2$

Sphere
$I = \frac{2}{5}mr^2$

Rod with Axis at Center
$I = \frac{1}{12}mL^2$

Rod with Axis at End
$I = \frac{1}{3}mL^2$

I = Moment of inertia (kgm²)
m = Mass (kg)
r = Radius (m)
L = Length (m)

Angular Momentum
$L = mvr\sin\theta = m\omega r^2 = I\omega$

L = Angular momentum (kgm²/s)
m = Mass (kg)
v = Velocity (m/s)
r = Radius (m)
I = Moment of inertia (kgm²)
ω = Angular velocity (rad/s)
θ = Angle between the radius and velocity

Rotational Kinetic Energy
$KE_{rot} = \frac{1}{2}I\omega^2$

KE_{rot} = Rotational kinetic energy (J)
I = Moment of inertia (kgm²)
ω = Angular velocity (rad/s)

Stress and Strain

Hookes Law
stress = modulus x strain

$Stress = \frac{F}{A}$

F = Force (N)
A = Area (m²)

Tensile and Compression
$Strain = \frac{\Delta L}{L_0}$

ΔL = Change in length
L_0 = Original length

$\Delta L = \frac{FL_0}{EA}$

ΔL = Change in length (m)
F = Force (N)
L_0 = Original length
E = Youngs modulus (Pa)
A = Area (m²)

Shear
$Strain = \frac{X}{L_0}$

X = Distance of shear
L_0 = Original length

$X = \frac{FL_0}{AG}$

X = Distance of shear (m)
F = Force (N)
L_0 = Original length
A = Area (m²)
G = Shear modulus (Pa)

Units

Watt = W = J/s

Newton = N = kgm/s²

Ampere = A = C/s

Ohm = Ω = V/A

Tesla = T = N/Am

Farad = F = C/V

Joule = J = Nm

Volt = V = J/C

Hertz = Hz = Cycles/Second

Pascal = Pa = N/m²