

# EQUATION SHEET

## Circle Geometry

Diameter

$$d = 2r$$

Circumference

$$C = 2\pi r = \pi d$$

Area

$$A = \pi r^2$$

$$1 \text{ revolution} = 360^\circ = 2\pi \text{ radians}$$

## Triangle Geometry

Area

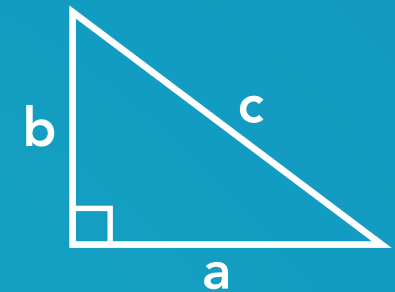
$$A = \frac{1}{2}bh$$

Angles

$$\theta_1 + \theta_2 + \theta_3 = 180^\circ$$

Pythagorean theorem

$$c^2 = a^2 + b^2$$



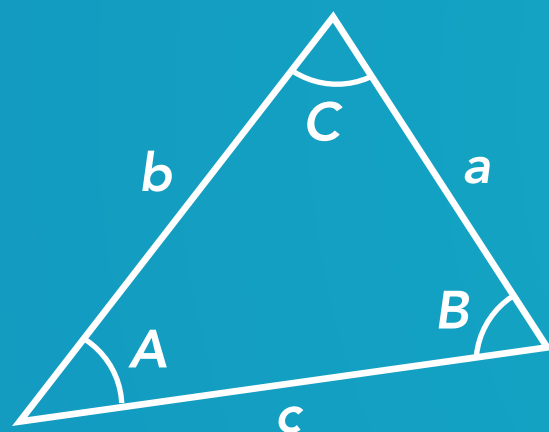
Trig identities:

$$\tan(\theta) = \frac{\sin(\theta)}{\cos(\theta)}$$

$$\sin^2(\theta) + \cos^2(\theta) = 1$$

$$\sin(2\theta) = 2\sin(\theta)\cos(\theta)$$

$$\cos(2\theta) = \cos^2(\theta) - \sin^2(\theta)$$

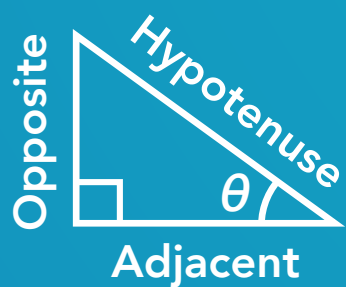


Law of sines

$$\frac{a}{\sin(A)} = \frac{b}{\sin(B)} = \frac{c}{\sin(C)}$$

Law of cosines

$$c^2 = a^2 + b^2 - 2ab\cos(C)$$



$$\sin(\theta) = \frac{\text{opposite}}{\text{hypotenuse}}$$

$$\cos(\theta) = \frac{\text{adjacent}}{\text{hypotenuse}}$$

$$\tan(\theta) = \frac{\text{opposite}}{\text{adjacent}}$$

$$\theta = \sin^{-1}\left(\frac{\text{opposite}}{\text{hypotenuse}}\right)$$

$$\theta = \cos^{-1}\left(\frac{\text{adjacent}}{\text{hypotenuse}}\right)$$

$$\theta = \tan^{-1}\left(\frac{\text{opposite}}{\text{adjacent}}\right)$$

## Quadratic Formula

Quadratic formula for

$$ax^2 + bx + c = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

# 1D and 2D Kinematics

Average speed

$$v_{\text{avg}} = \frac{\text{total distance}}{\text{total time}}$$

delta

$$\Delta = \text{final} - \text{initial}$$

$$\Delta x = x_f - x_i$$

or

$$\Delta x = x - x_0$$

Variables

Variables	SI Unit
$t$	time
$x$	horizontal position
$y$	vertical position
$v$	velocity
$a$	acceleration

$$\frac{\text{m}}{\text{s}}$$

$$\frac{\text{m}}{\text{s}^2}$$

Horizontal motion:

Displacement:

$$\Delta x = x_f - x_i$$

Velocity:

$$v_x = \frac{\Delta x}{\Delta t}$$

Velocity  
(rearranged):

$$x_f = x_i + v_x \Delta t$$

Acceleration:

$$a_x = \frac{\Delta v_x}{\Delta t}$$

Acceleration  
(rearranged):

$$v_{xf} = v_{xi} + a_x \Delta t$$

Kinematic equations for  
constant acceleration:

$$x_f = x_i + v_{xi} t + \frac{1}{2} a_x t^2$$

$$v_{xf}^2 = v_{xi}^2 + 2 a_x (x_f - x_i)$$

Vertical motion:

$$\Delta y = y_f - y_i$$

$$v_y = \frac{\Delta y}{\Delta t}$$

$$y_f = y_i + v_y \Delta t$$

$$a_y = \frac{\Delta v_y}{\Delta t}$$

$$v_{yf} = v_{yi} + a_y \Delta t$$

$$y_f = y_i + v_{yi} t + \frac{1}{2} a_y t^2$$

$$v_{yf}^2 = v_{yi}^2 + 2 a_y (y_f - y_i)$$

Subscripts

i	0	initial
f	-	final
x		horizontal
y		vertical

## Projectile Motion

Range

$$\Delta x = v_i \cos(\theta) \frac{v_i \sin(\theta) + \sqrt{(v_i \sin(\theta))^2 + 2 g y_i}}{g}$$

Range  
(if  $y_i = y_f$ )

$$\Delta x = \frac{v_i^2 \sin(2\theta)}{g}$$

Circular and Rotational Motion

Variables		SI Unit
$s$	tangential position	m
$\Delta s$	tangential displacement	m
$v_t$	tangential velocity	$\frac{m}{s}$
$a_t$	tangential acceleration	$\frac{m}{s^2}$

Variables		SI Unit
$\theta$	angular position	rad
$\Delta \theta$	angular displacement	rad
$\omega$	angular velocity	$\frac{rad}{s}$
$\alpha$	angular acceleration	$\frac{rad}{s^2}$

Conversion  
(Angular variable must use radians)



Circular motion  
(tangential description)

Rotational motion  
(angular description)

Position:

$$s \text{ m}$$

$$s = r \theta$$

$$\theta \text{ rad}$$

Displacement:

$$\Delta s = s_f - s_i \text{ m}$$

$$\Delta s = r \Delta \theta$$

$$\Delta \theta = \theta_f - \theta_i \text{ rad}$$

Velocity:

$$v_t = \frac{\Delta s}{\Delta t} \frac{m}{s}$$

$$v_t = r \omega$$

$$\omega = \frac{\Delta \theta}{\Delta t} \frac{rad}{s}$$

Acceleration:

$$a_t = \frac{\Delta v_t}{\Delta t} \frac{m}{s^2}$$

$$a_t = r \alpha$$

$$\alpha = \frac{\Delta \omega}{\Delta t} \frac{rad}{s^2}$$

Kinematic equations  
with acceleration:

$$s_f = s_i + v_{ti}t + \frac{1}{2}a_t t^2$$

$$\theta_f = \theta_i + \omega_i t + \frac{1}{2}\alpha t^2$$

$$v_{tf}^2 = v_{ti}^2 + 2a_t(s_f - s_i)$$

$$\omega_f^2 = \omega_i^2 + 2\alpha(\theta_f - \theta_i)$$

Newton's 2nd Law of Motion

Newton's 2nd law of motion

$$\vec{F}_{net} = m\vec{a}$$

or

$$\sum \vec{F} = m\vec{a}$$

$\Sigma$ : the sum of \_\_

Variables		SI Unit
$F$	force	$N = \frac{kg \cdot m}{s^2}$
$m$	mass	kg
$a$	acceleration	$\frac{m}{s^2}$
$v$	velocity	$\frac{m}{s}$

Gravitational Force & Weight

Newton’s Law of Universal Gravitation  
(gravitational force)

$$F_g = \frac{Gm_1m_2}{r^2} = F_{1\text{ on }2} = F_{2\text{ on }1}$$

Gravitational field strength  
or acceleration due to gravity

$$g = \frac{GM}{r^2}$$

Gravitational force on mass  
in gravitational field

$$F_g = mg = F_g = \frac{GMm}{r^2}$$

Constants	Unit	Name
G	$6.67 \times 10^{-11}$	$\frac{\text{m}^3}{\text{kg} \cdot \text{s}^2}$ gravitational constant

Variables	SI Unit
$F_g$	gravitational force N
w	weight force N
m	mass kg
M	mass producing a field kg
r	distance between centers m
g	gravitational acceleration $\frac{\text{m}}{\text{s}^2}$

Weight force

$$F_g = mg \text{ or } w = mg$$

Friction

Maximum static friction force

$$f_{s\text{ max}} = \mu_s F_n$$

$\mu_s$  : coefficient of static friction

Kinetic friction force

$$f_k = \mu_k F_n$$

$\mu_k$  : coefficient of kinetic friction

Rolling friction force

$$f_r = \mu_r F_n$$

$\mu_r$  : coefficient of kinetic friction

Variables	SI Unit
$f_s$	static friction force N
$f_k$	kinetic friction force N
$f_r$	rolling friction force N
$\mu_s$	coefficient of static friction
$\mu_k$	coefficient of kinetic friction
$\mu_r$	coefficient of rolling friction
$F_n$	normal force N

Spring Force

Spring force  
(Hooke's Law)

$$F_{\text{sp}} = k \Delta x$$

Equivalent spring constant  
for springs in series

$$\frac{1}{k_{\text{eq}}} = \frac{1}{k_1} + \frac{1}{k_2} + \dots$$

Equivalent spring constant  
for springs in parallel

$$k_{\text{eq}} = k_1 + k_2 + \dots$$

Variables		SI Unit
$F_{\text{sp}}$	spring force	N
$\Delta x$	displacement	m
$k$	spring constant	$\frac{\text{N}}{\text{m}}$

Elasticity of Materials

"Spring constant"  
for a material

$$k = \frac{YA}{L}$$

Elastic Force

$$F = \frac{YA}{L} \Delta L$$

Stress

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

Variables		SI Unit
$F$	force	N
$k$	spring constant	$\frac{\text{N}}{\text{m}}$
$Y, E$	Young's modulus	$\frac{\text{N}}{\text{m}^2}$
$A$	cross-sectional area	$\text{m}^2$
$L$	length	m

Torque

Torque

$$\tau = r F_{\perp}$$

or

$$\tau = r_{\perp} F$$



CW



CCW

Variables		SI Unit
$\tau$	torque	$\text{N} \cdot \text{m}$
$F$	force	N
$r$	distance from rotation axis	m

Rotational Dynamics

Newton's 2nd law of motion  
applied to rotation

$$\tau_{\text{net}} = I \alpha$$

or

$$\sum \tau = I \alpha$$

$\Sigma$ : the sum of \_\_

Rotational inertia for a system of masses

$$I = \sum m_i r_i^2 = m_1 r_1^2 + m_2 r_2^2 + m_3 r_3^2 + \dots$$

Variables		SI Unit
$\tau$	torque	$\text{N} \cdot \text{m}$
$I$	rotational inertia	$\text{kg} \cdot \text{m}^2$
$\alpha$	angular acceleration	$\frac{\text{rad}}{\text{s}^2}$
$m$	mass	kg
$r$	distance from rotation axis	m

Rotational inertia for common shapes:

Solid sphere  
(center)

$$I = \frac{2}{5} m R^2$$

Sphere shell  
(center)

$$I = \frac{2}{3} m R^2$$

Solid cylinder  
(center)

$$I = \frac{1}{2} m R^2$$

Cylinder shell  
(center)

$$I = m R^2$$

Solid rod  
(center)

$$I = \frac{1}{12} m L^2$$

Solid rod  
(end)

$$I = \frac{1}{3} m L^2$$



## Center of Mass

x coordinate of center of mass  
of a system

$$x_{\text{COM}} = \frac{m_1 x_1 + m_2 x_2 + \dots}{m_1 + m_2 + \dots}$$

y coordinate of center of mass  
of a system

$$y_{\text{COM}} = \frac{m_1 y_1 + m_2 y_2 + \dots}{m_1 + m_2 + \dots}$$

Variables		SI Unit
$x$	x position	m
$y$	y position	m
$m$	mass	kg

## Uniform Circular Motion

Frequency

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

Tangential velocity

$$v = \frac{2\pi r}{T}$$

$$v = 2\pi r f$$

Variables		SI Unit
$v$	velocity	$\frac{\text{m}}{\text{s}}$
$r$	radius	m
$T$	period	s
$f$	frequency	$\text{Hz} = \frac{\text{cycles}}{\text{s}}$
$\omega$	angular velocity	$\frac{\text{rad}}{\text{s}}$

## Centripetal Acceleration and Force

Centripetal acceleration

$$\vec{a}_c = \frac{v^2}{r} \text{ (towards center of circle)}$$

$v$  : tangential speed (m/s)

$r$  : radius of circular path (m)

Centripetal acceleration  
(other variables substituted for speed)

$$a_c = \frac{v^2}{r} = \omega^2 r = (2\pi f)^2 r = \left(\frac{2\pi}{T}\right)^2 r$$

$\omega$  : angular speed (rad/s)

$f$  : frequency (Hz = rev/s)

$T$  : period (s)

Variables		SI Unit
$a_c$	centripetal acceleration	$\frac{\text{m}}{\text{s}^2}$
$a$	acceleration	$\frac{\text{m}}{\text{s}^2}$
$v$	velocity	$\frac{\text{m}}{\text{s}}$
$r$	radius	m
$t$	time	s

Centripetal force

$$\vec{F}_c = m \frac{v^2}{r} \text{ (towards center of circle)}$$

Orbital Motion

Constants		Unit	Name
$G$	$6.67 \times 10^{-11}$	$\frac{\text{m}^3}{\text{kg} \cdot \text{s}^2}$	gravitational constant

Orbital speed

$$v = \sqrt{\frac{GM}{r}}$$

Orbital period

$$T = 2\pi \sqrt{\frac{r^3}{GM}}$$

Orbital period for elliptical orbit

$$T = 2\pi \sqrt{\frac{a^3}{G(M + m)}}$$

Orbital period for elliptical orbit  
(assuming  $M$  is much larger than  $m$ )

$$T = 2\pi \sqrt{\frac{a^3}{GM}}$$

Kinetic energy of object  
in a circular orbit

$$K = \frac{1}{2}mv^2 = \frac{GMm}{2r}$$

Gravitational potential  
energy of two-mass system

$$U_g = -\frac{GMm}{r}$$

Total energy of object  
in a circular orbit

$$E = K + U_g = -\frac{GMm}{2r}$$

Variables		SI Unit
$M$	planet mass	kg
$m$	object mass	kg
$R$	planet radius	m
$r$	orbital radius	m
$v$	orbital speed	$\frac{\text{m}}{\text{s}}$
$T$	orbital period	s
$F_g$	gravitational force	N
$F_c$	centripetal force	N

Variables		SI Unit
$E$	total energy	J
$K$	kinetic energy	J
$U_g$	potential energy	J

Kinetic Energy

Kinetic energy

$$K = \frac{1}{2}mv^2$$

Rotational  
kinetic energy

$$K_{\text{rot}} = \frac{1}{2}I\omega^2$$

Variables		SI Unit
$K$	kinetic energy	J
$m$	mass	kg
$v$	speed	$\frac{\text{m}}{\text{s}}$

Variables		SI Unit
$K_{\text{rot}}$	rotational kinetic energy	J
$I$	rotational inertia	$\text{kg} \cdot \text{m}^2$
$\omega$	angular speed	$\frac{\text{rad}}{\text{s}}$

Gravitational Potential Energy

Gravitational potential energy  
of a two-mass system

$$U_g = - \frac{GMm}{r}$$

$$U_g = 0 \text{ at } r = \infty$$

Change in gravitational  
potential energy of an  
object-earth system

$$\Delta U_g = mg\Delta y$$

Gravitational potential energy  
of an object-earth system  
\*relative to a reference point

$$U_g = mgy \quad U_g = 0 \text{ at } y = 0$$

Constants		Unit	Name
$G$	$6.67 \times 10^{-11}$	$\frac{\text{m}^3}{\text{kg} \cdot \text{s}^2}$	gravitational constant

Variables		SI Unit
$U_g$	gravitational potential energy	J
$M$	planet mass	kg
$m$	object mass	kg
$r$	distance between centers	m
$y$	height	m
$g$	gravitational acceleration	$\frac{\text{m}}{\text{s}^2}$

Spring Potential Energy

Spring potential  
energy

$$U_{\text{sp}} = \frac{1}{2}k\Delta x^2$$

$$\Delta x \text{ or } \Delta y$$

Variables		SI Unit
$U_{\text{sp}}$	spring potential energy	J
$k$	spring constant	$\frac{\text{N}}{\text{m}}$
$\Delta x$	displacement	m

Conservation of Energy

Conservation of energy  
(universe and isolated systems)

$$\Delta E_{\text{total}} = 0 \quad , \quad E_{\text{total i}} = E_{\text{total f}}$$

Variables		SI Unit
$E$	energy	J
$K$	kinetic energy	J
$U_g$	gravitational potential energy	J
$U_{\text{sp}}$	spring potential energy	J

Work

Work

$$\Delta E_{\text{system}} = W$$

Work

$$W = F_{\parallel} d$$

$F_{\parallel}$  : component of force parallel to  $d$   
\*F is an external force  
 $d$  : displacement of the system

Variables		SI Unit
$W$	work	$\text{J} = \text{N} \cdot \text{m}$
$E$	energy	J
$F$	force	N
$d$	displacement	m



# Power

Power

$$P = \frac{\Delta E}{\Delta t}$$

Power

$$P = \frac{W}{\Delta t} = F_{\parallel} v$$

$F_{\parallel}$  : component of force parallel to  $v$   
\*F is an external force  
 $v$  : velocity of the system

Variables		SI Unit
$P$	power	$W = \frac{J}{s}$
$E$	energy	J
$W$	work	J
$F$	force	N
$v$	velocity	$\frac{m}{s}$

# Momentum

Momentum

$$\vec{p} = m\vec{v}$$

Momentum vector components

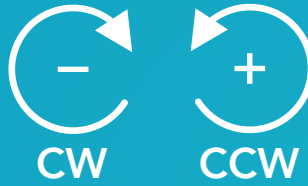
$$p_x = mv_x$$

$$p_y = mv_y$$

Variables		SI Unit
$p$	momentum	$\frac{kg \cdot m}{s}$
$m$	mass	kg
$v$	velocity	$\frac{m}{s}$

Angular momentum

$$L = I\omega$$



Variables		SI Unit
$L$	angular momentum	$\frac{kg \cdot m^2}{s}$
$I$	rotational inertia	$kg \cdot m^2$
$\omega$	angular velocity	$\frac{rad}{s}$

# Impulse

Impulse

$$\vec{J} = \Delta \vec{p} = \vec{F}_{avg} \Delta t$$

$F_{avg}$  : average force over time

Variables		SI Unit
$J$	impulse	$\frac{kg \cdot m}{s} = N \cdot s$
$p$	momentum	$\frac{kg \cdot m}{s}$
$F$	force	N
$t$	time	s

Rotational impulse

$$\Delta L = \tau_{avg} \Delta t$$

$\tau_{avg}$  : average torque over time

Variables		SI Unit
$\tau$	torque	$N \cdot m$
$L$	angular momentum	$\frac{kg \cdot m^2}{s}$
$I$	rotational inertia	$kg \cdot m^2$
$\omega$	angular velocity	$\frac{rad}{s}$

# Conservation of Momentum

Law of conservation of momentum  
(universe and isolated systems)

$$\Delta \vec{p}_{\text{total}} = 0 \quad , \quad \vec{p}_{\text{total i}} = \vec{p}_{\text{total f}}$$

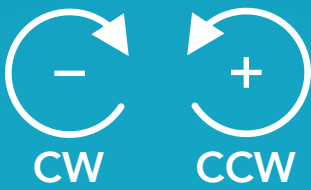
$$\Delta p_{x \text{ total}} = 0 \quad , \quad p_{xi \text{ total}} = p_{xf \text{ total}}$$

$$\Delta p_{y \text{ total}} = 0 \quad , \quad p_{yi \text{ total}} = p_{yf \text{ total}}$$

Variables		SI Unit
$p$	momentum	$\frac{\text{kg} \cdot \text{m}}{\text{s}}$
$m$	mass	kg
$v$	velocity	$\frac{\text{m}}{\text{s}}$
$J$	impulse	$\frac{\text{kg} \cdot \text{m}}{\text{s}}$
$F$	force	N
$t$	time	s

Law of conservation of angular momentum  
(universe and isolated systems)

$$\Delta \vec{L}_{\text{total}} = 0 \quad , \quad \vec{L}_{\text{total i}} = \vec{L}_{\text{total f}}$$



Variables		SI Unit
$L$	angular momentum	$\frac{\text{kg} \cdot \text{m}^2}{\text{s}}$
$I$	rotational inertia	$\text{kg} \cdot \text{m}^2$
$\omega$	angular velocity	$\frac{\text{rad}}{\text{s}}$

# Simple Harmonic Motion

Period of a  
mass-spring oscillation

$$T_{\text{sp}} = 2\pi \sqrt{\frac{m}{k}}$$

Frequency of a  
mass-spring oscillation

$$f_{\text{sp}} = \frac{1}{2\pi} \sqrt{\frac{k}{m}}$$

Maximum velocity of a  
mass-spring oscillation

$$v_{\text{max}} = A \sqrt{\frac{k}{m}}$$

Period of a  
pendulum oscillation

$$T_{\text{p}} = 2\pi \sqrt{\frac{L}{g}}$$

Frequency of a  
pendulum oscillation

$$f_{\text{p}} = \frac{1}{2\pi} \sqrt{\frac{g}{L}}$$

Maximum velocity of a  
pendulum oscillation

$$v_{\text{max}} = \theta_{\text{max}} \sqrt{gL}$$

Variables		SI Unit
$T$	period	s
$f$	frequency	$\text{Hz} = \frac{\text{cycles}}{\text{s}}$
$A$	amplitude	m
$m$	mass	kg
$k$	spring constant	$\frac{\text{N}}{\text{s}}$
$U_{\text{sp}}$	spring potential energy	J
$K$	kinetic energy	J

Variables		SI Unit
$T$	period	s
$f$	frequency	$\text{Hz} = \frac{\text{cycles}}{\text{s}}$
$\theta$	angle	rad
$L$	length	m
$g$	grav. acceleration	$\frac{\text{m}}{\text{s}^2}$
$U_{\text{g}}$	grav. potential energy	J
$K$	kinetic energy	J

Waves

Wave speed

$$v = \lambda f = \frac{\lambda}{T}$$

Linear density

$$\mu = \frac{m}{L}$$

Speed of a wave  
in a string

$$v_{\text{string}} = \sqrt{\frac{T_s}{\mu}}$$

Variables		SI Unit
$\lambda$	wavelength	m
$T$	period	s
$f$	frequency	Hz = $\frac{\text{cycles}}{\text{s}}$
$A$	amplitude	m, ...
$v$	velocity	$\frac{\text{m}}{\text{s}}$

Sound

Constants	Unit	Name
$I_0$	$1 \times 10^{-12}$	$\frac{\text{W}}{\text{m}^2}$ threshold of hearing

Constants	Unit	Name
$R$	8.3145	$\frac{\text{J}}{\text{mol} \cdot \text{K}}$ ideal gas constant

Speed of sound in a gas

$$v_{\text{sound}} = \sqrt{\frac{\gamma RT}{M}}$$

Variables		SI Unit
$v$	velocity	$\frac{\text{m}}{\text{s}}$
$\gamma$	adiabatic index	
$T$	temperature	K
$M$	molar mass	$\frac{\text{kg}}{\text{mol}}$

Sound intensity

$$I = \frac{P_{\text{source}}}{4\pi r^2}$$

Sound intensity level

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

Variables		SI Unit
$I$	sound intensity	$\frac{\text{W}}{\text{m}^2}$
$P$	power	$\frac{\text{J}}{\text{s}}$
$r$	distance from source	m
$\beta$	sound intensity level	dB

Observed frequency,  
receding sound source

$$f_o = \frac{f_s}{1 + (v_s/v)}$$

Observed frequency,  
approaching sound source

$$f_o = \frac{f_s}{1 - (v_s/v)}$$

Observed frequency,  
receding observer

$$f_o = \left( 1 - \frac{v_o}{v} \right) f_s$$

Observed frequency,  
approaching observer

$$f_o = \left( 1 + \frac{v_o}{v} \right) f_s$$

Variables		SI Unit
$f_s$	source frequency	Hz
$f_o$	observed frequency	Hz
$v_s$	source speed	$\frac{\text{m}}{\text{s}}$
$v_o$	observer speed	$\frac{\text{m}}{\text{s}}$
$v$	speed of sound	$\frac{\text{m}}{\text{s}}$

# Wave Interference

Beat frequency

$$f_{\text{beat}} = |f_1 - f_2|$$

Variables		SI Unit
$d$	in-line path length	m
$r$	radial path length	m
$\lambda$	wavelength	m
$m$	number of wavelengths	

In-line interference:

Constructive interference

$$\Delta d = m\lambda \quad m = 0, 1, 2, \dots$$

Destructive interference

$$\Delta d = \left(m + \frac{1}{2}\right)\lambda \quad m = 0, 1, 2, \dots$$

Radial interference:

Constructive interference (point C)

$$\Delta r = m\lambda \quad m = 0, 1, 2, \dots$$

Destructive interference (point D)

$$\Delta r = \left(m + \frac{1}{2}\right)\lambda \quad m = 0, 1, 2, \dots$$

# Standing Waves

Both ends are either nodes or antinodes:

Wavelengths

$$\lambda_m = \frac{2L}{m} \quad m = 1, 2, 3, \dots$$

Frequencies

$$f_m = \frac{v}{\lambda_m} = m\left(\frac{v}{2L}\right) \quad m = 1, 2, 3, \dots$$

One end is a node, one end is an antinode:

Wavelengths

$$\lambda_m = \frac{4L}{m} \quad m = 1, 3, 5, \dots$$

Frequencies

$$f_m = \frac{v}{\lambda_m} = m\left(\frac{v}{4L}\right) \quad m = 1, 3, 5, \dots$$

Variables		SI Unit
$\lambda$	wavelength	m
$f$	frequency	Hz
$L$	length	m
$v$	velocity	$\frac{\text{m}}{\text{s}}$
$m$	mode	

Fluids

Pressure unit conversions:  
1 bar = 100,000 Pa  
1 atm = 101,325 Pa  
1 psi ≈ 6,894.757 Pa  
1 torr = 1 mmHg = 1/760 atm ≈ 133.322 Pa  
1 inHg = 25.4 mmHg ≈ 3,386.38 Pa  
1 inH<sub>2</sub>O = 2.54 cmH<sub>2</sub>O ≈ 249.082 Pa

Values		Unit	Name
$\rho_{\text{water}}$	1,000	$\frac{\text{kg}}{\text{m}^3}$	density of water (4°C)
$\rho_{\text{ice}}$	916	$\frac{\text{kg}}{\text{m}^3}$	density of ice (0°C)
$\rho_{\text{merc}}$	13,600	$\frac{\text{kg}}{\text{m}^3}$	density of mercury (0°C)
$P_{\text{atm}}$	101,325	Pa	standard atmospheric pressure
$g$	9.8	$\frac{\text{m}}{\text{s}^2}$	gravitational acceleration

Density

$$\rho = \frac{m}{V}$$

Pressure

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

Variables

SI Unit

$P_{\text{abs}}$	absolute pressure	Pa
$P_{\text{gauge}}$	gauge pressure	Pa
$P_0$	reference pressure	Pa
$P_{\text{atm}}$	atmospheric pressure	Pa

Absolute pressure vs gauge pressure

$$P_{\text{abs}} = P_{\text{gauge}} + P_0$$

$$P_{\text{gauge}} = P_{\text{abs}} - P_0$$

$P_0$  is usually  $P_{\text{atm}}$  (1 atm)

Variables

SI Unit

$\rho$	density	$\frac{\text{kg}}{\text{m}^3}$
$m$	mass	kg
$V$	volume	m <sup>3</sup>
$P$	pressure	Pa = $\frac{\text{N}}{\text{m}^2}$
$F$	force	N
$A$	area	m <sup>2</sup>
$h$	depth	m
$v$	velocity	$\frac{\text{m}}{\text{s}}$
$t$	time	s
$y$	height	m

Absolute pressure at depth below surface

$$P_{\text{abs}} = \rho gh + P_0$$

Gauge pressure at depth below surface

$$P_{\text{gauge}} = \rho gh$$

Pressure difference between two depths

$$\Delta P = \rho g \Delta h$$

Buoyant force on object from fluid

$$F_B = \rho_f V_f g$$

Flow rate

$$\frac{V}{\Delta t} = Av$$

Conservation of flow rate

$$A_1 v_1 = A_2 v_2$$

Bernoulli's equation

$$P + \rho gy + \frac{1}{2} \rho v^2 = \text{constant}$$

Torricelli's theorem

$$v = \sqrt{2g\Delta y}$$

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