PHYS 2310 Engineering Physics I Formula Sheets

Chapters 1-18

Chapter 1/Important Numbers

Units for SI Base Quantities

Quantity	Unit Name	Unit Symbol
Length	Meter	M
Time	Second	s
Mass (not weight)	Kilogram	kg

Common Conversions

1 kg or 1 m	1000 g or m	1 m	$1 \times 10^6\ \mu m$
1 m	100 cm	1 inch	2.54 cm
1 m	1000 mm	1 day	86400 seconds
1 second	1000 milliseconds	1 hour	3600 seconds
1 m	3.281 ft	360°	2π rad

Important Constants/Measurements

Mass of Earth	5.98×10^{24} kg
Radius of Earth	6.38×10^{6} m
1 u (Atomic Mass Unit)	1.661×10^{-27} kg
Density of water	$1\ g/cm^3$ or $1000\ kg/m^3$
g (on earth)	$9.8\ \mathrm{m/s^2}$

Density

Common geometric Formulas

Circumference	$C = 2\pi r$	Area circle	$A = \pi r^2$
Surface area (sphere)	$SA = 4\pi r^2$	Volume (sphere)	$V = \frac{4}{3}\pi r^3$
Volume (rectangular solid)	$V = l \cdot w \cdot h$ $V = area \cdot thickness$		

Chapter 2

Velocity

Average Velocity	$V_{avg} = \frac{displacement}{time} = \frac{\Delta x}{\Delta t}$	2.2
Average Speed	$s_{avg} = \frac{total\ distance}{time}$	2.3
Instantaneous Velocity	$v = \lim_{\Delta t \to 0} \frac{\Delta \overline{x}}{\Delta t} = \frac{dx}{dt}$	2.4

Acceleration

Average Acceleration	$a_{avg} = \frac{\Delta v}{\Delta t}$	2.7
Instantaneous Acceleration	$a = \frac{dv}{dt} = \frac{d^2x}{dt^2}$	2.8 2.9

Motion of a particle with constant acceleration

$v = v_0 + at$	2.11
$\Delta x = \frac{1}{2}(v_0 + v)t$	2.17
$\Delta x = v_0 t + \frac{1}{2}at^2$	2.15
$v^2 = v_0^2 + 2a\Delta x$	2.16

Chapter 3

Adding Vectors Geometrically	$\vec{a}+\vec{b}=\vec{b}+\vec{a}$	3.2
Adding Vectors Geometrically (Associative Law)	$(\vec{a}+\vec{b})+\vec{c}=\vec{a}+(\vec{b}+\vec{c})$	3.3
Components of Vectors	$a_x = acos\theta$ $a_y = asin\theta$	3.5
Magnitude of vector	$\lvert a\rvert = a = \sqrt{a_x^2+a_y^2}$	3.6
Angle between x axis and vector	$tan\theta = \frac{a_y}{a_x}$	3.6
Unit vector notation	$\vec{a}=a_x\hat{\imath}+a_y\hat{\jmath}+a_z\hat{k}$	3.7
Adding vectors in Component Form	$r_x = a_x + b_x$ $r_y = a_y + b_y$ $r_z = a_z + b_z$	3.10 3.11 3.12
Scalar (dot product)	$\vec{a}\cdot\vec{b} = abcos\theta$	3.20
Scalar (dot product)	$\vec{a}\cdot\vec{b}=(a_x\hat{\imath}+a_y\hat{\jmath}+a_z\hat{k})\cdot(b_x\hat{\imath}+b_y\hat{\jmath}+b_z\hat{k})$ $\vec{a}\cdot\vec{b}=a_xb_x+a_yb_y+a_zb_z$	3.22
Projection of $\vec{a}$ on $\vec{b}$ or component of $\vec{a}$ on $\vec{b}$	$\frac{\vec{a}\cdot\vec{b}}{\lvert b\rvert}$	
Vector (cross) product magnitude	$c = absin\phi$	3.24
Vector (cross product)	$\vec{a}x\vec{b}=(a_x\hat{\imath}+a_y\hat{\jmath}+a_z\hat{k})x(b_x\hat{\imath}+b_y\hat{\jmath}+b_z\hat{k})$ $=(a_yb_z-b_ya_z)\hat{\imath}+(a_zb_x-b_za_x)\hat{\jmath}$ $+(a_xb_y-b_xa_y)\hat{k}$ ***or*** $\vec{a}x\vec{b}=det\begin{vmatrix}\hat{\imath} & j & \hat{k}\\ a_x & a_y & a_z\\ b_x & b_y & b_z\end{vmatrix}$	3.26

Chapter 4

Position vector	$\vec{r}=x\hat{\imath}+y\hat{\jmath}+z\hat{k}$	4.4
displacement	$\Delta\vec{r}=\Delta x\hat{\imath}+\Delta y\hat{\jmath}+\Delta z\hat{k}$	4.4
Average Velocity	$\vec{V}_{avg}=\frac{\Delta x}{\Delta t}$	4.8
Instantaneous Velocity	$\vec{v}=\frac{d\vec{r}}{dt}=v_x\hat{\imath}+v_y\hat{\jmath}+v_z\hat{k}$	4.10 4.11
Average Acceleration	$\vec{a}_{avg}=\frac{\Delta\vec{v}}{\Delta t}$	4.15
Instantaneous Acceleration	$\vec{a}=\frac{d\vec{v}}{dt}$ $\vec{a}=a_x\hat{\imath}+a_y\hat{\jmath}+a_z\hat{k}$	4.16 4.17

Projectile Motion

	$v_y = v_0sin\theta_0 - gt$	4.23
	$\Delta x = v_0cos\theta t + \frac{1}{2}a_xt^2$ or $\Delta x = v_0cos\theta t$ if a_x=0	4.21
	$\Delta y = v_0sin\theta t - \frac{1}{2}gt^2$	4.22
	$v_y^2 = (v_0sin\theta_0)^2 - 2g\Delta y$	4.24
	$v_y = v_0sin\theta_0 - gt$	4.23
Trajectory	$y=(tan\theta_0)x-\frac{gx^2}{2(v_0cos\theta_0)^2}$	4.25
Range	$R=\frac{v_0^2}{g}\sin(2\theta_0)$	4.26

Relative Motion	$\overrightarrow{v_{AC}}=\overrightarrow{v_{AB}}+\overrightarrow{v_{BC}}$ $\overrightarrow{a_{AB}}=\overrightarrow{a_{BA}}$	4.44 4.45
Uniform Circular Motion	$a=\frac{v^2}{r}$ $T=\frac{2\pi r}{v}$	4.34 4.35

Chapter 5

Newton's Second Law

General	$\vec{F}_{net} = m\vec{a}$	5.1
Component form	$F_{net,x} = ma_x$ $F_{net,y} = ma_y$ $F_{net,z} = ma_y$	5.2

Gravitational Force

Gravitational Force	$F_g = mg$	5.8
Weight	$W = mg$	5.12

Chapter 6

Friction

Static Friction (maximum)	$\vec{f}_{s,max} = \mu_s F_N$	6.1
Kinetic Frictional	$\vec{f}_k = \mu_k F_N$	6.2

Drag Force	$D = \frac{1}{2} C\rho A v^2$	6.14
Terminal velocity	$v_t = \sqrt{\frac{2F_g}{C\rho A}}$	6.16

Centripetal acceleration	$a = \frac{v^2}{R}$	6.17
Centripetal Force	$F = \frac{mv^2}{R}$	6.18

Chapter 7

Kinetic Energy	$K = \frac{1}{2}mv^2$	7.1
Work done by constant Force	$W = Fdcos\theta = \vec{F} \cdot \vec{d}$	7.7 7.8
Work- Kinetic Energy Theorem	$\Delta K = K_f - K_0 = W$	7.10
Work done by gravity	$W_g = mgdcos\phi$	7.12
Work done by lifting/lowering object	$\Delta K = W_a + W_g$ $W_a = applied\ Force$	7.15
Spring Force (Hooke's law)	$\vec{F_s} = -k\vec{d}$ $F_x = -kx$ (along x-axis)	7.20 7.21
Work done by spring	$W_s = \frac{1}{2}kx_i^2 - \frac{1}{2}kx_f^2$	7.25
Work done by Variable Force	$W = \int_{x_i}^{x_f} F_x dx + \int_{y_i}^{y_f} F_y dy + \int_{z_i}^{z_f} F_z dz$	7.36
Average Power (rate at which that force does work on an object)	$P_{avg} = \frac{W}{\Delta t}$	7.42
Instantaneous Power	$P = \frac{dW}{dt} = FVcos\theta = \vec{F} \cdot \vec{v}$	7.43 7.47

Chapter 8

Potential Energy	$\Delta U = -W = -\int_{xi}^{xf} F(x)dx$	8.1 8.6
Gravitational Potential Energy	$\Delta U = mg\Delta y$	8.7
Elastic Potential Energy	$U(x) = \frac{1}{2}kx^2$	8.11
Mechanical Energy	$E_{mec} = K + U$	8.12
Principle of conservation of mechanical energy	$K_1 + U_1 = K_2 + U_2$ $E_{mec} = \Delta K + \Delta U = 0$	8.18 8.17
Force acting on particle	$F(x) = -\frac{dU(x)}{dx}$	8.22
Work on System by external force With no friction	$W = \Delta E_{mec} = \Delta K + \Delta U$	8.25 8.26
Work on System by external force With friction	$W = \Delta E_{mec} + \Delta E_{th}$	8.33
Change in thermal energy	$\Delta E_{th} = f_k dcos\theta$	8.31
Conservation of Energy *if isolated W=0	$W = \Delta E = \Delta E_{mec} + \Delta E_{th} + \Delta E_{int}$	8.35
Average Power	$P_{avg} = \frac{\Delta E}{\Delta t}$	8.40
Instantaneous Power	$P = \frac{dE}{dt}$	8.41

*****In General Physics, Kinetic Energy is abbreviated to KE and Potential Energy is PE***

Chapter 9

Impulse and Momentum

Impulse	$\vec{J} = \int_{t_i}^{t_f} \vec{F}(t)dt$ $J = F_{net}\Delta t$	9.30 9.35
Linear Momentum	$\vec{p} = m\vec{v}$	9.22
Impulse-Momentum Theorem	$\vec{J} = \Delta\vec{p} = \vec{p}_f - \vec{p}_i$	9.31 9.32
Newton's 2nd law	$\vec{F}_{net} = \frac{d\vec{p}}{dt}$	9.22
System of Particles	$\vec{F}_{net} = m\vec{a}_{com}$ $\vec{P} = M\vec{v}_{com}$ $\vec{F}_{net} = \frac{d\vec{P}}{dt}$	9.14 9.25 9.27

Collision

Final Velocity of 2 objects in a head-on collision where one object is initially at rest 1: moving object 2: object at rest	$v_{1f} = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) v_{1i}$ $v_{2f} = \left(\frac{2m_1}{m_1 + m_2}\right) v_{1i}$	9.67 9.68
Conservation of Linear Momentum (in 1D)	$\vec{P} = constant$ $\vec{P}_i = \vec{P}_f$	9.42 9.43
Elastic Collision	$\vec{p}_{1i} + \vec{p}_{2i} = \vec{p}_{1f} + \vec{p}_{2f}$ $m_1 v_{i1} + m_2 v_{12} = m_1 v_{f1} + m_2 v_{f2}$ $K_{1i} + K_{2i} = K_{1f} + K_{2f}$	9.50 9.51 9.78

Collision continued…

Inelastic Collision	$m_1 v_{01} + m_2 v_{02} = (m_1 + m_2) v_f$	
Conservation of Linear Momentum (in 2D)	$\vec{P}_{1i} + \vec{P}_{2i} = \vec{P}_{1f} + \vec{P}_{2f}$	9.77
Average force	$F_{avg} = -\frac{n}{\Delta t}\Delta p = -\frac{n}{\Delta t} m\Delta v$ $F_{avg} = -\frac{\Delta m}{\Delta t}\Delta v$	9.37 9.40

Center of Mass

Center of mass location	$\vec{r}_{com} = \frac{1}{M}\sum_{i=1}^{n} m_i \vec{r}_i$	9.8
Center of mass velocity	$\vec{v}_{com} = \frac{1}{M}\sum_{i=1}^{n} m_i \vec{v}_i$	

Rocket Equations

Thrust (Rv_{rel})	$Rv_{rel} = Ma$	9.88
Change in velocity	$\Delta v = v_{rel} ln \frac{M_i}{M_f}$	9.88

Chapter 10

Angular displacement (in radians	$\theta = \frac{s}{r}$ $\Delta\theta = \theta_2 - \theta_1$	10.1 10.4
Average angular velocity	$\omega_{avg} = \frac{\Delta\theta}{\Delta t}$	10.5
Instantaneous Velocity	$\omega = \frac{d\theta}{dt}$	10.6
Average angular acceleration	$\alpha_{avg} = \frac{\Delta\omega}{\Delta t}$	10.7
Instantaneous angular acceleration	$\alpha = \frac{d\omega}{dt}$	10.8

Rotational Kinematics

$\omega = \omega_0 + \alpha t$	10.12
$\Delta\theta = \omega_0 t + \frac{1}{2}\alpha t^2$	10.13
$\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$	10.14
$\Delta\theta = \frac{1}{2}(\omega + \omega_0)t$	10.15
$\Delta\theta = \omega t - \frac{1}{2}\alpha t^2$	10.16

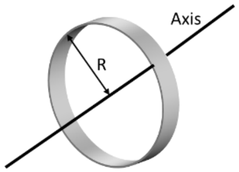
Relationship Between Angular and Linear Variables

Velocity	$v = \omega r$	10.18
Tangential Acceleration	$a_t = \alpha r$	10.19
Radical component of $\vec{a}$	$a_r = \frac{v^2}{r} = \omega^2 r$	10.23
Period	$T = \frac{2\pi r}{v} = \frac{2\pi}{\omega}$	10.19 10.20

Rotation inertia	$I = \sum m_i r_i^2$	10.34
Rotation inertia (discrete particle system)	$I = \int r^2 dm$	10.35
Parallel Axis Theorem h=perpendicular distance between two axes	$I = I_{com} + Mh^2$	10.36
Torque	$\tau = rF_t = r_\perp F = rFsin\theta$	10.39-10.41
Newton's Second Law	$\tau_{net} = I\alpha$	10.45
Rotational work done by a toque	$W = \int_{\theta_i}^{\theta_f} \tau d\theta$ $W = \tau\Delta\theta$ (τ constant)	10.53 10.54
Power in rotational motion	$P = \frac{dW}{dt} = \tau\omega$	10.55
Rotational Kinetic Energy	$K = \frac{1}{2}I\omega^2$	10.34
Work-kinetic energy theorem	$\Delta K = K_f - K_i = \frac{1}{2}I\omega_f^2 - \frac{1}{2}I\omega_i^2 = W$	10.52

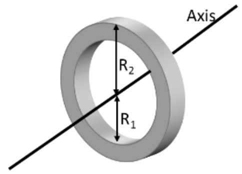
Moments of Inertia I for various rigid objects of Mass M

Thin walled hollow cylinder or hoop about central axis



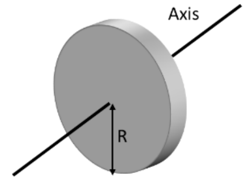
$$I = MR^2$$

Annular cylinder (or ring) about central axis



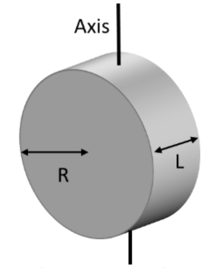
$$I = \frac{1}{2}M(R_1^2 + R_2^2)$$

Solid cylinder or disk about central axis



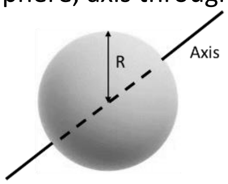
$$I = \frac{1}{2}MR^2$$

Solid cylinder or disk about central diameter



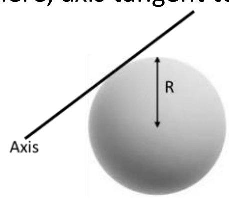
$$I = \frac{1}{4}MR^2 + \frac{1}{12}ML^2$$

Solid Sphere, axis through center



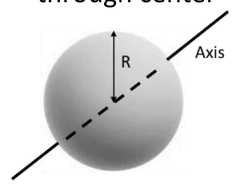
$$I = \frac{2}{5}MR^2$$

Solid Sphere, axis tangent to surface



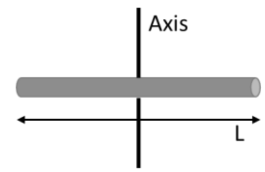
$$I = \frac{7}{5}MR^2$$

Thin Walled spherical shell, axis through center



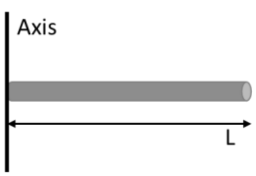
$$I = \frac{2}{3}MR^2$$

Thin rod, axis perpendicular to rod and passing though center



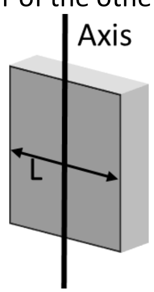
$$I = \frac{1}{12}ML^2$$

Thin rod, axis perpendicular to rod and passing though end



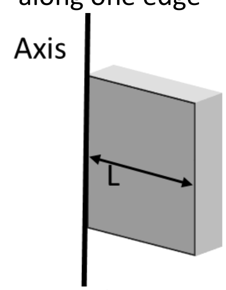
$$I = \frac{1}{3}ML^2$$

Thin Rectangular sheet (slab), axis parallel to sheet and passing though center of the other edge



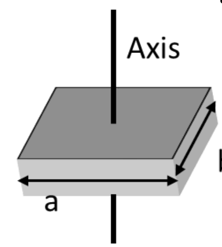
$$I = \frac{1}{12}ML^2$$

Thin Rectangular sheet (slab_, axis along one edge



$$I = \frac{1}{3}ML^2$$

Thin rectangular sheet (slab) about perpendicular axis through center



$$I = \frac{1}{12}M(a^2 + b^2)$$

Chapter 11

Rolling Bodies (wheel)

Speed of rolling wheel	$v_{com} = \omega R$	11.2
Kinetic Energy of Rolling Wheel	$K = \frac{1}{2} I_{com}\omega^2 + \frac{1}{2} M v_{com}^2$	11.5
Acceleration of rolling wheel	$a_{com} = \alpha R$	11.6
Acceleration along x-axis extending up the ramp	$a_{com,x} = -\frac{g sin\theta}{1 + \frac{I_{com}}{MR^2}}$	11.10

Torque as a vector

Torque	$\vec{\tau} = \vec{r} \times \vec{F}$	11.14
Magnitude of torque	$\tau = rF_{\perp} = r_{\perp}F = rF sin\phi$	11.15-11.17
Newton's 2nd Law	$\vec{\tau}_{net} = \frac{d\vec{\ell}}{dt}$	11.23

Angular Momentum

Angular Momentum	$v\vec{\ell} = \vec{r} \times \vec{p} = m(\vec{r} \times \vec{v})$	11.18
Magnitude of Angular Momentum	$\ell = rmv sin\phi$ $\ell = rp_{\perp} = rmv_{\perp}$	11.19-11.21
Angular momentum of a system of particles	$\vec{L} = \sum_{i=1}^{n} \vec{\ell}_i$ $\vec{\tau}_{net} = \frac{d\vec{L}}{dt}$	11.26 11.29

Angular Momentum continued

Angular Momentum of a rotating rigid body	$L = I\omega$	11.31
Conservation of angular momentum	$\vec{L} = constant$ $\vec{L}_i = \vec{L}_f$	11.32 11.33

Precession of a Gyroscope

Precession rate	$\Omega = \frac{Mgr}{I\omega}$	11.31

Chapter 12

Static Equilibrium

	$\vec{F}_{net} = 0$	12.3
	$\vec{\tau}_{net} = 0$	12.5
If forces lie on the xy-plane	$\vec{F}_{net,x} = 0,\ \vec{F}_{net,y} = 0$	12.7 12.8
	$\vec{\tau}_{net,z} = 0$	12.9

Stress (force per unit area) Strain (fractional change in length)	$stress = modulus \times strain$	12.22
Stress (pressure)	$P = \frac{F}{A}$	
Tension/Compression E: Young's modulus	$\frac{F}{A} = E\frac{\Delta L}{L}$	12.23
Shearing Stress G: Shear modulus	$\frac{F}{A} = G\frac{\Delta x}{L}$	12.24
Hydraulic Stress B: Bulk modulus	$p = B\frac{\Delta V}{V}$	

Chapter 13

Gravitational Force (Newton's law of gravitation)	$F = G\frac{m_1 m_2}{r^2}$	13.1
Principle of Superposition	$\vec{F}_{1,net} = \sum_{i=2}^{n} \vec{F}_{1i}$	13.5
Gravitational Force acting on a particle from an extended body	$\vec{F}_1 = \int d\vec{F}$	13.6
Gravitational acceleration	$a_g = \frac{GM}{r^2}$	13.11
Gravitation within a spherical Shell	$F = \frac{GmM}{R^3} r$	13.19
Gravitational Potential Energy	$U = -\frac{GMm}{r}$	13.21
Potential energy on a system (3 particles)	$U = -\left(\frac{Gm_1m_2}{r_{12}} + \frac{Gm_1m_3}{r_{13}} + \frac{Gm_2m_3}{r_{23}}\right)$	13.22
Escape Speed	$v = \sqrt{\frac{2GM}{R}}$	13.28
Kepler's 3rd Law (law of periods)	$T^2 = \left(\frac{4\pi^2}{GM}\right) r^3$	13.34
Energy for bject in circular orbit	$U = -\frac{GMm}{r}\ \ K = \frac{GMm}{2r}$	13.21 13.38
Mechanical Energy (circular orbit)	$E = -\frac{GMm}{2r}$	13.40
Mechanical Energy (elliptical orbit)	$E = -\frac{GMm}{2a}$	13.42

*Note: $G = 6.6704 \times 10^{-11}\ N \cdot m^2/kg^2$

Chapter 14

Density	$\rho = \frac{\Delta m}{\Delta V}$ $\rho = \frac{m}{V}$	14.1 14.2
Pressure	$p = \frac{\Delta F}{\Delta A}$ $p = \frac{F}{A}$	14.3 14.4
Pressure and depth in a static Fluid P1 is higher than P2	$p_2 = p_1 + \rho g(y_1 - y_2)$ $p = p_0 + \rho gh$	14.7 14.8
Gauge Pressure	ρgh	
Archimedes' principle	$F_b = m_f g$	14.16
Mass Flow Rate	$R_m = \rho R_V = \rho Av$	14.25
Volume flow rate	$R_V = Av$	14.24
Bernoulli's Equation	$p + \frac{1}{2}\rho v^2 + \rho gy = constant$	14.29
Equation of continuity	$R_m = \rho R_V = \rho Av = constant$	14.25
Equation of continuity when $\rho_1 = \rho_2$	$R_V = Av = constant$	14.24

Chapter 15

Frequency cycles per time	$f = \frac{1}{T}$	15.2
displacement	$x = x_m \cos(\omega t + \phi)$	15.3
Angular frequency	$\omega = \frac{2\pi}{T} = 2\pi f$	15.5
Velocity	$v = -\omega x_m \sin(\omega t + \phi)$	15.6
Acceleration	$a = -\omega^2 x_m \cos(\omega t + \phi)$	15.7
Kinetic and Potential Energy	$K = \frac{1}{2}mv^2 \quad U = \frac{1}{2}kx^2$	
Angular frequency	$\omega = \sqrt{\frac{k}{m}}$	15.12
Period	$T = 2\pi\sqrt{\frac{m}{k}}$	15.13
Torsion pendulum	$T = 2\pi\sqrt{\frac{I}{k}}$	15.23
Simple Pendulum	$T = 2\pi\sqrt{\frac{L}{g}}$	15.28
Physical Pendulum	$T = 2\pi\sqrt{\frac{I}{mgL}}$	15.29
Damping force	$\vec{F}_d = -b\vec{v}$	
displacement	$x(t) = x_m e^{-\frac{bt}{2m}} \cos(\omega' t + \phi)$	15.42
Angular frequency	$\omega' = \sqrt{\frac{k}{m} - \frac{b^2}{4m^2}}$	15.43
Mechanical Energy	$E(t) \approx \frac{1}{2}kx_m^2 e^{-\frac{bt}{m}}$	15.44

Chapter 16

Sinusoidal Waves

Mathematical form (positive direction)	$y(x,t) = y_m \sin(kx - \omega t)$	16.2
Angular wave number	$k = \frac{2\pi}{\lambda}$	16.5
Angular frequency	$\omega = \frac{2\pi}{T} = 2\pi f$	16.9
Wave speed	$v = \frac{\omega}{k} = \frac{\lambda}{T} = \lambda f$	16.13
Average Power	$P_{avg} = \frac{1}{2}\mu v \omega^2 y_m^2$	16.33

Traveling Wave Form	$y(x,t) = h(kx \pm \omega t)$	16.17
Wave speed on stretched string	$v = \sqrt{\frac{\tau}{\mu}}$	16.26
Resulting wave when 2 waves only differ by phase constant	$y'(x,t) = \left[2y_m \cos\left(\frac{1}{2}\phi\right)\right] \sin\left(kx - \omega t + \frac{1}{2}\phi\right)$	16.51
Standing wave	$y'(x,t) = [2y_m \sin(kx)]\cos(\omega t)$	16.60
Resonant frequency	$f = \frac{v}{\lambda} = n\frac{v}{2L}$ for n=1,2,…	16.66

Chapter 17

Sound Waves

Speed of sound wave	$v = \sqrt{\frac{B}{\rho}}$	17.3
displacement	$s = s_m \cos(kx - \omega t)$	17.12
Change in pressure	$\Delta p = \Delta p_m \sin(kx - \omega t)$	17.13
Pressure amplitude	$\Delta p_m = (v\rho\omega) s_m$	17.14

Interference

Phase difference	$\phi = \frac{\Delta L}{\lambda} 2\pi$	17.21
Fully Constructive Interference	$\phi = m(2\pi)$ for m=0,1,2… $\frac{\Delta L}{\lambda} = 0,1,2$	17.22 17.23
Full Destructive interference	$\phi = (2m + 1)\pi$ for m=0,12 $\frac{\Delta L}{\lambda} = .5, 1.5, 2.5 \ldots$	17.24 17.25
Mechanical Energy	$E(t) \approx \frac{1}{2} k x_m^2 e^{-\frac{bt}{m}}$	15.44

Sound Intensity

Intensity	$I = \frac{P}{A}$ $I = \frac{1}{2} \rho v \omega^2 s_m^2$	17.26 17.27
Intensity -uniform in all directions	$I = \frac{P_s}{4\pi r^2}$	17.29
Intensity level in decibels	$\beta = (10dB) \log\left(\frac{I}{I_o}\right)$	17.29
Mechanical Energy	$E(t) \approx \frac{1}{2} k x_m^2 e^{-\frac{bt}{m}}$	15.44

Standing Waves Patterns in Pipes

Standing wave frequency (open at both ends)	$f = \frac{v}{\lambda} = \frac{nv}{2L}$ for n=1,2,3	17.39
Standing wave frequency (open at one end)	$f = \frac{v}{\lambda} = \frac{nv}{4L}$ for n=1,3,5	17.41

beats	$f_{beat} = f_1 - f_2$	17.46

Doppler Effect

Source Moving *toward* stationary observer	$f' = f \frac{v}{v - v_s}$	17.53
Source Moving *away* from stationary observer	$f' = f \frac{v}{v + v_s}$	17.54
Observer moving *toward* stationary source	$f' = f \frac{v + v_D}{v}$	17.49
Observer moving *away* from stationary source	$f' = f \frac{v - v_D}{v}$	17.51

Shockwave

Half-angle θ of Mach cone	$sin\theta = \frac{v}{v_s}$	17.57

Chapter 18

Temperature Scales

Fahrenheit to Celsius	$T_C = \frac{5}{9}(T_F - 32)$	18.8
Celsius to Fahrenheit	$T_F = \frac{9}{5}T_C + 32$	18.8
Celsius to Kelvin	$T = T_C + 273.15$	18.7

Thermal Expansion

Linear Thermal Expansion	$\Delta L = L\alpha\Delta T$	18.9
Volume Thermal Expansion	$\Delta V = V\beta\Delta T$	18.10

Heat

Heat and temperature change	$Q = C(T_f - T_i)$ $Q = cm(T_f - T_i)$	18.13 18.14
Heat and phase change	$Q = Lm$	18.16
Power	P=Q/t	
Power (Conducted)	$P_{cond} = \frac{Q}{t} = kA\frac{T_H - T_C}{L}$	18.32
Rate objects absorbs energy	$P_{abs} = \sigma\epsilon A T_{env}^4$	18.39
Power from radiation	$P_{rad} = \sigma\epsilon A T^4$	18.38

$$\sigma = 5.6704 \times 10^{-8}\ W/m^2 \cdot K^4$$

First Law of Thermodynamics

First Law of Thermodynamics	$\Delta E_{int} = E_{int,f} - E_{int,i} = Q - W$ $dE_{int} = dQ - dW$	18.26 18.27

Note:
ΔE_{int} Change in Internal Energy
Q (heat) is positive when the system absorbs heat and negative when it loses heat. **W** (work) is work done by system. W is positive when expanding and negative contracts because of an external force

Applications of First Law

Adiabatic (no heat flow)	Q=0 $\Delta E_{int} = -W$
(constant volume)	W=0 $\Delta E_{int} = Q$
Cyclical process	$\Delta E_{int} = 0$ Q=W
Free expansions	$Q = W = \Delta E_{int} = 0$

Misc.

Work Associated with Volume Change	$W = \int dW = \int_{V_i}^{V_f} p\,dV$ $W = p\Delta v$	18.25