PHY 131 Tables and Formulas

You may refer to this handout on quizzes and exams. Do not add additional information. j

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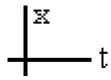
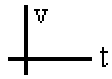
Sec. 1:

Velocity: $v = \frac{dx}{dt} =$ slope of  Average velocity: $v_{av} = \frac{\Delta x}{\Delta t}$

Acceleration: $a = \frac{dv}{dt} =$ slope of  Average acceleration: $a_{av} = \frac{\Delta v}{\Delta t}$

Motion with constant acceleration:

$$\Delta x = v_{av} t \qquad v_{av} = \frac{1}{2}(v_i + v_f) \qquad v_f = v_i + at$$

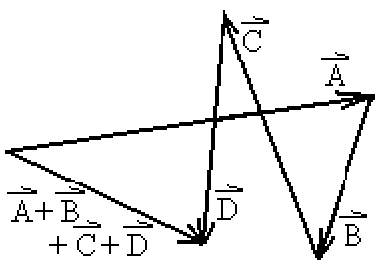
$$\Delta x = v_i t + \frac{1}{2} a t^2 \qquad v_f^2 = v_i^2 + 2\,a\,\Delta x$$

$g = 9.8\ m/s^2 = 32.2\ ft/s^2$

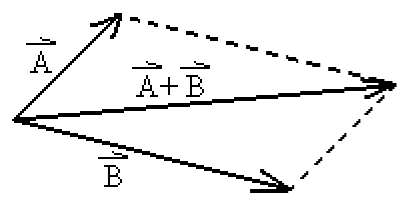
Sec. 2: Memorize: Definitions of trig functions, and Pythagorean theorem.

Graphical vector addition:

Head to tail method:

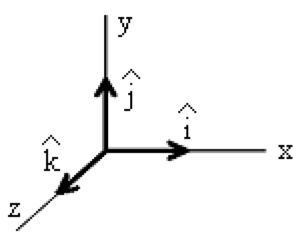


Parallelogram rule:



Unit vectors:

$$|\hat{i}| = |\hat{j}| = |\hat{k}| = 1$$



If $\vec{A} = A_x \hat{i} + A_y \hat{j} + A_z \hat{k}$ and $\vec{B} = B_x \hat{i} + B_y \hat{j} + B_z \hat{k}$ then

$$\vec{A} + \vec{B} = (A_x + B_x)\hat{i} + (A_y + B_y)\hat{j} + (A_z + B_z)\hat{k}$$

$$n\vec{A} = nA_x \hat{i} + n A_y \hat{j} + nA_z \hat{k} \quad (n = \text{some scalar})$$

$$\vec{A} - \vec{B} = \vec{A} + (-\vec{B})$$

$$|\vec{A}| = \sqrt{A_x^2 + A_y^2 + A_z^2}$$

Sec. 3:
Memorize: Newton's three laws, and relationship between weight and mass.

Static friction: $f_s \le \mu_s n$ Kinetic (sliding) friction: $f_k = \mu_k n$

f = force of friction, μ = coefficient of friction, n = normal force

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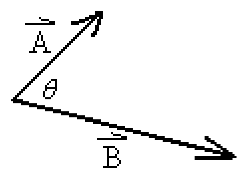
Sec. 4:
Projectiles: Treat each component like one dimensional motion.

Horizontal range: $$R = \frac{v_i^2 \sin(2\theta_i)}{g}$$

Centripetal force: $F = \frac{m v^2}{r}$ Centripetal acceleration: $a = \frac{v^2}{r}$

Sec. 5:
Memorize: Formulas for kinetic energy, gravitational potential energy and total energy. Understand conservation of energy.

Dot product: $\vec{A}\cdot\vec{B} = |\vec{A}||\vec{B}|\cos\theta = A_x B_x + A_y B_y + A_z B_z$



Work: $W = \vec{F}\cdot\vec{s}$ $\vec{F}$ = force, $\vec{s}$ = displacement ($W = \int \vec{F}\cdot d\vec{s}$ if force is not constant.)

Work-energy theorem:

$W = \Delta KE$ (W = work done by any kinds of forces)

or

$E_i + W_{nc} = E_f$ (W_{nc} = work done by non-conservative forces.)

Sec. 6:
Memorize: Formula for momentum. Understand conservation of momentum.

Power: $P = \frac{dE}{dt}$ Average power: $P_{av} = \frac{W}{t} = \frac{\Delta E}{\Delta t}$ also, $P = \vec{F}\cdot\vec{v}$

Impulse-momentum theorem: $\vec{I} = \Delta\vec{p}$ where $\vec{I} = \vec{F}\,\Delta t$ and $\vec{p}$ = momentum, not power.

Elastic collision: one where mechanical energy is conserved.

Sec. 7: REMEMBER: Some equations require use of radians.

Angular velocity: $\omega = \frac{d\theta}{dt}$ Average angular velocity: $\omega_{av} = \frac{\Delta\theta}{\Delta t}$

Angular acceleration: $\alpha = \frac{d\omega}{dt}$ Average angular acceleration: $\alpha_{av} = \frac{\Delta\omega}{\Delta t}$

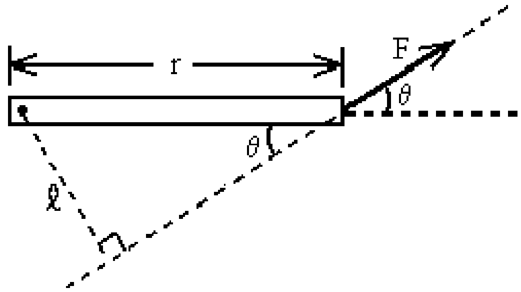
Tangential displacement, velocity, and acceleration: $s = r\theta$ $v_T = r\omega$ $a_T = r\alpha$

Motion with constant angular acceleration:

$\Delta\theta = \omega_{av} t$ $\omega_{av} = \frac{1}{2}(\omega_i + \omega_f)$ $\omega_f = \omega_i + \alpha t$

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

Torque:



$\tau = \ell F = r \sin\theta \, F$

(+ if CCW, - if CW)

Moments of inertia:

Particle of mass m, following orbit of radius r: $I = mr^2$. System of such particles: $I = \Sigma m_i r_i^2$

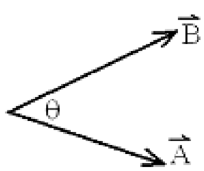
Rigid bodies, total mass = M, outside radius = R
- Hoop or tube, rotating about center: $I = MR^2$
- Solid cylinder or disk, rotating about center: $I = (½)MR^2$
- Solid sphere, rotating about center: $I = (2/5)MR^2$
- Thin spherical shell, rotating about center: $I = (2/3)MR^2$
- Thin rod, length L, rotating about center: $I = (1/12)ML^2$
- Thin rod, length L, rotating about one end: $I = (1/3)ML^2$

Rotational version of Newton's 2nd law: $\Sigma \vec{\tau} = I\vec{\alpha}$

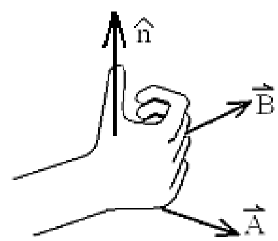
Rotational kinetic energy: $KE_R = \frac{1}{2} I \omega^2$

Sec. 8:

Cross product:



$\vec{A} \times \vec{B} = |\vec{A}||\vec{B}| \sin\theta \, \hat{n}$



Torque: $\vec{\tau} = \vec{r} \times \vec{F}$ ($\vec{\tau}$ points along thumb if fingers point in direction of rotation.)

First & second conditions of equilibrium: 1. $\Sigma \vec{F} = 0$ 2. $\Sigma \vec{\tau} = 0$

Sec. 9:

Total kinetic energy: $KE = \frac{1}{2} m v^2 + \frac{1}{2} I \omega^2$

Work done by a torque: $W = \tau\theta$ ($W = \int \vec{\tau} \cdot d\vec{\theta}$ if $\vec{\tau}$ is not constant.)

Angular momentum: $\vec{L} = \vec{r} \times \vec{p}$, or $L = I\vec{\omega}$

Understand conservation of angular momentum.

Sec. 10: Memorize: Relationship between frequency and period.

Hooke's law: $\vec{F} = -k\,\vec{x}$ (F = force, k = spring constant, x = displacement from equilibrium.)

Harmonic oscillator:

Displacement: $x = A\cos(\omega t + \phi)$ where $\omega = 2\pi f = \sqrt{\frac{k}{m}}$ (f = frequency.)

Velocity: $v = -v_{max}\sin(\omega t + \phi)$ where $v_{max} = \omega A$

Acceleration: $a = -a_{max}\cos(\omega t + \phi)$ where $a_{max} = \omega^2 A$

Elastic potential energy: $U_s = ½\,k\,x^2$

Pendulum: $\omega = \sqrt{\frac{g}{L}}$ ($\omega = 2\pi f$)

Sec. 11: Memorize: Relationship between wavelength, speed and frequency.

Harmonic wave traveling to the right: $y = A\sin(kx - \omega t + \phi)$

Harmonic wave traveling to the left: $y = A\sin(kx + \omega t + \phi)$

Angular wave number: $k = \frac{2\pi}{\lambda}$ Angular frequency: $\omega = 2\pi f$

Speed of string waves: $v = \sqrt{\frac{F}{\mu}}$ F = string tension (force), μ = mass per unit length

Speed of sound in air: $v = \sqrt{402T}$ T = kelvin temperature (Celsius + 273)

Intensity: $I = \frac{\text{power}}{\text{area}}$

Intensity vs. distance: $\frac{I_1}{I_2} = \frac{r_2^2}{r_1^2}$

Sound level in decibels: $\beta = 10\log\left(\frac{I}{10^{-12}\,W/m^2}\right)$

Doppler effect: $f' = f\,\frac{(v \pm v_o)}{(v \mp v_s)}$ Top: toward Bottom: away

v = speed of waves, v_o = observer's speed, v_s = source's speed

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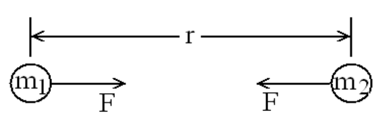
Sec. 12: Memorize: Ideal gas law.

Law of universal gravitation:

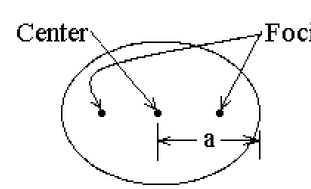


$F = \frac{G\,m_1\,m_2}{r^2}$

$G = 6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2$

Kepler's laws:

1. Orbits are elliptical, with sun at one focus.
2. Line from sun to planet sweeps through equal areas in equal times.
3. $T^2 = \frac{4\pi^2}{G(m_1 + m_2)}a^3$ T = period, a = semi-major axis



Sec. 13: Change in length: $\Delta L = L_0 \alpha \Delta T$

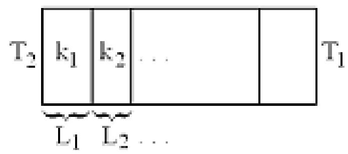
Change in volume: $\Delta V = V_0 \beta \Delta T$ $\beta \approx 3\alpha$

Heat flow due to a change of temperature: $Q = m\, c\, \Delta T$ c = specific heat

Heat flow due to a change of state $Q = mL_f$ or $Q = mL_v$ L=heat of fusion or vaporization

Conduction:

$$\frac{dQ}{dt} = -kA\frac{dT}{dx}$$



$$\frac{\Delta Q}{\Delta t} = -\frac{A(T_2 - T_1)}{\sum_i (L_i / k_i)}$$

dQ/dt = Rate of heat flow

k = Thermal conductivity

A = Area dT/dx = Temp. gradient

L/k = "R-VALUE"

Stefan's Law: $P = \sigma A e T^4$

P = Power Radiated, $\sigma = 5.67 \times 10^{-8}$ W/m^2 K^4, A = Area, e = Emissivity (0 to 1) T = Temp.

Sec. 14: Memorize: Definitions of P = pressure and ρ = density.

Variation of pressure with depth: $\Delta P = -\rho g \Delta h$

Pascal's Principle: P increase at one point in an enclosed fluid = P increase at any other point.

Archimedes' Principle: Buoyant force = weight of displaced fluid = $(\rho V)g$

Equation of continuity: Av = constant (v = speed)

Bernoulli's equation: $P + \frac{1}{2}\rho v^2 + \rho g h = \text{constant}$

MATHEMATICAL BACKGROUND:

Geometric Formulas (r = radius, h = height):

Circumference of a circle or sphere:	$2\pi r$
Area of a circle:	πr^2
Area of a circular cylinder (excluding ends):	$2\pi r h$
Area of a sphere:	$4\pi r^2$
Volume of a circular cylinder:	$\pi r^2 h$
Volume of a sphere	$\frac{4}{3}\pi r^3$

Quadratic Formula: If $ax^2 + bx + c = 0$ then

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

Logarithms: if $x = b^y$ then $\log_b(x) = y$ (b = base)

$\log(xy) = \log x + \log y$ $\log(x/y) = \log x - \log y$

$\log(x^a) = a \log x$ $\log_b(b^x) = x$

Derivatives:

If $y = ax^n$ then $\frac{dy}{dx} = a(nx^{n-1})$ where a & n are constants $\neq 0$

If y = a constant, then $\frac{dy}{dx} = 0$

Example: If $y = 7x^3 + 4x + 8$, then $dy/dx = 21x^2 + 4 + 0$

Product rule: If y = f(x)g(x), then $\frac{dy}{dx} = f\frac{dg}{dx} + g\frac{df}{dx}$ (First times the derivative of the second + second times the derivative of the first.)

Chain rule: If y = f(g(x)), then $\frac{dy}{dx} = \frac{df}{dg}\frac{dg}{dx}$ (Derivative of what's outside the parentheses times derivative of what's inside the parentheses. Example: If $y = (7x)^3$ then $dy/dx = [3(7x)^2][7]$.)

Some Fundamental Constants:

Gravitational constant:	$G = 6.672 \times 10^{-11}\ N \cdot m^2 / kg^2$
Speed of light:	$c = 2.998 \times 10^8$ m / s
Electron rest mass:	$m_e = 9.110 \times 10^{-31}$ kg
Proton rest mass:	$m_p = 1.673 \times 10^{-27}$ kg
Neutron rest mass:	$m_n = 1.675 \times 10^{-27}$ kg
Universal gas constant:	R = 8.314 J/mole·K
Avogadro's Number:	$N_0 = 6.022 \times 10^{23}$ molecules / mole
Boltzmann's constant:	$k = 1.381 \times 10^{-23}$ J / K

Some Physical Properties:

Density of air at 20°C and 1 atmosphere ____1.29 kg / m^3

Speed of sound in air at 20°C and 1 atm. ____343 m/s

Density of water at 20°C ________________ 1000 kg / m^3 (=1.0 gram / cm^3)

Mass of earth __________________________ 5.99×10^{24} kg

Radius of earth _________________________ 6.37×10^6 m

Standard atmospheric pressure ___________ 1.013×10^5 Pa

Approximate Coefficients of Friction:

	μ_S	μ_k
wood on wood	0.5	0.3
steel on steel	0.74	0.57
teflon on teflon	0.04	0.04
glass on glass	0.94	0.40

	μ_S	μ_k
rubber on dry concrete	1.0	0.8
rubber on wet concrete	0.7	0.5
metal on ice	0.03	0.01

Expansion Coefficients (near room temperature):

	α (°C^{-1})
Aluminum	24×10^{-6}
Brass & bronze	19×10^{-6}
Copper	17×10^{-6}
Glass (ordinary)	9×10^{-6}
Glass (pyrex)	3.2×10^{-6}
Lead	29×10^{-6}
Steel	11×10^{-6}
Concrete	12×10^{-6}
Vinyl siding	150×10^{-6}

	β (°C^{-1})
Ethyl alcohol	1.12×10^{-4}
Benzene	1.24×10^{-4}
Acetone	1.5×10^{-4}
Glycerin	4.85×10^{-4}
Mercury	1.82×10^{-4}
Gasoline	9.6×10^{-4}

Specific heats (at 25°C):

Substance	cal/g·°C	J/kg·°C
Aluminum	0.215	900
Concrete	0.2	840
Copper	0.0924	387
Gold	0.0308	129
Ice(at -5°C)	0.50	2090
Iron & Steel	0.107	448
Lead	0.0305	128

Substance	cal/g·°C	J/kg·°C
Silver	0.056	234
Tin	0.054	226
Zinc	0.092	385
Ethyl alcohol	0.58	2400
Mercury	0.033	140
Water	1.00	4186
Steam (1atm) &100°	0.48	2010

Heat of Fusion of water = 79.6 cal/g = 3.34×10^5 J/kg

Heat of Vaporization of water = 539 cal/g = 2.26×10^6 J/kg

Thermal Conductivities, in W/m·°C (solids at 25°C, gases at 20°C):

Aluminum	238
Copper	397
Gold	314
Iron	79.5
Lead	34.7
Silver	427
Wood	0.08

Asbestos	0.08
Concrete	0.8
Diamond	2300
Glass	0.8
Ice	2
Rubber	0.2
Water	0.6

Air	0.0234
Helium	0.138
Hydrogen	0.172
Nitrogen	0.0234
Oxygen	0.0238

Units:

	Standard SI Unit:	Conversion Factors:
LENGTH	meter = m	1 m = 3.281 ft, 1 mile = 1609 m = 5280 ft, 1 inch = 2.54 cm
TIME	second = s	1 hour = 3600 s, 1 solar day = 86,400 s, 1 solar year = 3.156 x 10^7 s
MASS	kilogram = kg	1 kg weighs 2.203 lb if g = 9.80 m/s^2, 1 kg = .06852 slug
VOLUME	m^3	1 Liter = 10^{-3} m^3 = 10^{+3} cm^3
SPEED	m/s	1 mi/hr = 0.4470 m/s = 1.467 ft/sec
FORCE	newton = N	1 N = 0.2248 pound
ENERGY& WORK	joule = J	1 calorie = 4.186 J. 1 J = 0.7376 ft·lb, 1 BTU = 252 cal
POWER	watt = W	1 horsepower = 745.7 W = 550 ft·lb/sec
ANGLE	radian = rad	1 revolution = 360° = 2π rad
FREQUENCY	hertz = Hz	1 Hz = 60 rev/min = 1 cycle/sec
IMPULSE & MOMENTUM	kg·m/s = N·S	
TEMPERATURE	kelvin = k	T (in kelvins) = T (in Celsius) + 273.15
PRESSURE	pascal = N/m^2	1 atmosphere = 1.013 x 10^5 Pa = 14.70 lb/in^2

SI prefixes:

Power:	Prefix:	Abbreviation:
10^{-24}	yocto	y
10^{-21}	zepto	z
10^{-18}	atto	a
10^{-15}	femto	f
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m
10^{-2}	centi	c
10^{-1}	deci	d

Power:	Prefix:	Abbreviation:
10^1	deka	da
10^2	hecto	h
10^3	kilo	k
10^6	mega	M
10^9	giga	G
10^{12}	tera	T
10^{15}	peta	P
10^{18}	exa	E
10^{21}	zetta	Z
10^{24}	yotta	Y