TABLE OF INFORMATION FOR 2002

CONSTANTS AND CONVERSION FACTORS

1 unified atomic mass unit,	$1\ u = 1.66 \times 10^{-27}$ kg
	$= 931\ MeV/c^2$
Proton mass,	$m_p = 1.67 \times 10^{-27}$ kg
Neutron mass,	$m_n = 1.67 \times 10^{-27}$ kg
Electron mass,	$m_e = 9.11 \times 10^{-31}$ kg
Magnitude of the electron charge,	$e = 1.60 \times 10^{-19}$ C
Avogadro's number,	$N_0 = 6.02 \times 10^{23}\ mol^{-1}$
Universal gas constant,	$R = 8.31$ J/(mol · K)
Boltzmann's constant,	$k_B = 1.38 \times 10^{-23}$ J/K
Speed of light,	$c = 3.00 \times 10^8$ m/s
Planck's constant,	$h = 6.63 \times 10^{-34}$ J·s
	$= 4.14 \times 10^{-15}$ eV·s
	$hc = 1.99 \times 10^{-25}$ J·m
	$= 1.24 \times 10^3$ eV·nm
Vacuum permittivity,	$\epsilon_0 = 8.85 \times 10^{-12}\ C^2/N \cdot m^2$
Coulomb's law constant,	$k = 1/4\pi\epsilon_0 = 9.0 \times 10^9\ N \cdot m^2/C^2$
Vacuum permeability,	$\mu_0 = 4\pi \times 10^{-7}$ (T·m)/A
Magnetic constant,	$k' = \mu_0/4\pi = 10^{-7}$ (T·m)/A
Universal gravitational constant,	$G = 6.67 \times 10^{-11}\ m^3/kg \cdot s^2$
Acceleration due to gravity at the Earth's surface,	$g = 9.8\ m/s^2$
1 atmosphere pressure,	$1\ atm = 1.0 \times 10^5\ N/m^2$
	$= 1.0 \times 10^5$ Pa
1 electron volt,	$1\ eV = 1.60 \times 10^{-19}$ J

UNITS

Name	Symbol
meter	m
kilogram	kg
second	s
ampere	A
kelvin	K
mole	mol
hertz	Hz
newton	N
pascal	Pa
joule	J
watt	W
coulomb	C
volt	V
ohm	Ω
henry	H
farad	F
tesla	T
degree Celsius	°C
electron-volt	eV

PREFIXES

Factor	Prefix	Symbol
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES

θ	sin θ	cos θ	tan θ
0°	0	1	0
30°	1/2	$\sqrt{3}/2$	$\sqrt{3}/3$
37°	3/5	4/5	3/4
45°	$\sqrt{2}/2$	$\sqrt{2}/2$	1
53°	4/5	3/5	4/3
60°	$\sqrt{3}/2$	1/2	$\sqrt{3}$
90°	1	0	∞

The following conventions are used in this examination.

I. Unless otherwise stated, the frame of reference of any problem is assumed to be inertial.

II. The direction of any electric current is the direction of flow of positive charge (conventional current).

III. For any isolated electric charge, the electric potential is defined as zero at an infinite distance from the charge.

*IV. For mechanics and thermodynamics equations, *W* represents the work done <u>on</u> a system.

*Not on the Table of Information for Physics C, since Thermodynamics is not a Physics C topic.

ADVANCED PLACEMENT PHYSICS B EQUATIONS FOR 2002

NEWTONIAN MECHANICS

$v = v_0 + at$

$x = x_0 + v_0 t + \frac{1}{2} at^2$

$v^2 = v_0^2 + 2a(x - x_0)$

$\sum \mathbf{F} = \mathbf{F}_{net} = m\mathbf{a}$

$F_{fric} \le \mu N$

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

$\tau = rF \sin\theta$

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

$\mathbf{J} = \mathbf{F}\Delta t = \Delta\mathbf{p}$

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

$\Delta U_g = mgh$

$W = \mathbf{F} \cdot \Delta\mathbf{r} = F\Delta r \cos\theta$

$P_{avg} = \frac{W}{\Delta t}$

$P = \mathbf{F} \cdot \mathbf{v} = Fv \cos\theta$

$\mathbf{F}_s = -k\mathbf{x}$

$U_s = \frac{1}{2} kx^2$

$T_s = 2\pi\sqrt{\frac{m}{k}}$

$T_p = 2\pi\sqrt{\frac{\ell}{g}}$

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

$F_G = -\frac{Gm_1m_2}{r^2}$

$U_G = -\frac{Gm_1m_2}{r}$

a = acceleration
F = force
f = frequency
h = height
J = impulse
K = kinetic energy
k = spring constant
ℓ = length
m = mass
N = normal force
P = power
p = momentum
r = radius or distance
$\mathbf{r}$ = position vector
T = period
t = time
U = potential energy
v = velocity or speed
W = work done on a system
x = position
μ = coefficient of friction
θ = angle
τ = torque

ELECTRICITY AND MAGNETISM

$F = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r^2}$

$\mathbf{E} = \frac{\mathbf{F}}{q}$

$U_E = qV = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r}$

$E_{avg} = -\frac{V}{d}$

$V = \frac{1}{4\pi\epsilon_0}\sum_i \frac{q_i}{r_i}$

$C = \frac{Q}{V}$

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

$U_c = \frac{1}{2}QV = \frac{1}{2}CV^2$

$I_{avg} = \frac{\Delta Q}{\Delta t}$

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

$V = IR$

$P = IV$

$C_p = \sum_i C_i$

$\frac{1}{C_s} = \sum_i \frac{1}{C_i}$

$R_s = \sum_i R_i$

$\frac{1}{R_p} = \sum_i \frac{1}{R_i}$

$F_B = qvB\sin\theta$

$F_B = BI\ell\sin\theta$

$B = \frac{\mu_0}{2\pi}\frac{I}{r}$

$\phi_m = \mathbf{B} \cdot \mathbf{A} = BA\cos\theta$

$\mathcal{E}_{avg} = -\frac{\Delta\phi_m}{\Delta t}$

$\mathcal{E} = B\ell v$

A = area
B = magnetic field
C = capacitance
d = distance
E = electric field
$\mathcal{E}$ = emf
F = force
I = current
ℓ = length
P = power
Q = charge
q = point charge
R = resistance
r = distance
t = time
U = potential (stored) energy
V = electric potential or potential difference
v = velocity or speed
ρ = resistivity
ϕ_m = magnetic flux

ADVANCED PLACEMENT PHYSICS B EQUATIONS FOR 2002

FLUID MECHANICS AND THERMAL PHYSICS

$p = p_0 + \rho g h$

$F_{buoy} = \rho V g$

$A_1 v_1 = A_2 v_2$

$p + \rho g y + \frac{1}{2}\rho v^2 = \text{const.}$

$\Delta \ell = \alpha \ell_0 \Delta T$

$Q = mL$

$Q = mc\Delta T$

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

$pV = nRT$

$K_{avg} = \frac{3}{2} k_B T$

$v_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3k_B T}{\mu}}$

$W = -p\Delta V$

$Q = nc\Delta T$

$\Delta U = Q + W$

$\Delta U = nc_V \Delta T$

$e = \left|\frac{W}{Q_H}\right|$

$e_c = \frac{T_H - T_C}{T_H}$

- A = area
- c = specific heat or molar specific heat
- e = efficiency
- F = force
- h = depth
- K_{avg} = average molecular kinetic energy
- L = heat of transformation
- ℓ = length
- M = molecular mass
- m = mass of sample
- n = number of moles
- p = pressure
- Q = heat transferred to a system
- T = temperature
- U = internal energy
- V = volume
- v = velocity or speed
- v_{rms} = root-mean-square velocity
- W = work done on a system
- y = height
- α = coefficient of linear expansion
- μ = mass of molecule
- ρ = density

ATOMIC AND NUCLEAR PHYSICS

$E = hf = pc$

$K_{max} = hf - \phi$

$\lambda = \frac{h}{p}$

$\Delta E = (\Delta m)c^2$

- E = energy
- f = frequency
- K = kinetic energy
- m = mass
- p = momentum
- λ = wavelength
- ϕ = work function

WAVES AND OPTICS

$v = f\lambda$

$n = \frac{c}{v}$

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

$\sin\theta_c = \frac{n_2}{n_1}$

$\frac{1}{s_i} + \frac{1}{s_0} = \frac{1}{f}$

$M = \frac{h_i}{h_0} = -\frac{s_i}{s_0}$

$f = \frac{R}{2}$

$d \sin\theta = m\lambda$

$x_m \approx \frac{m\lambda L}{d}$

- d = separation
- f = frequency or focal length
- h = height
- L = distance
- M = magnification
- m = an integer
- n = index of refraction
- R = radius of curvature
- s = distance
- v = speed
- x = position
- λ = wavelength
- θ = angle

GEOMETRY AND TRIGONOMETRY

Rectangle
$A = bh$

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

Circle
$A = \pi r^2$
$C = 2\pi r$

Parallelepiped
$V = \ell w h$

Cylinder
$V = \pi r^2 \ell$
$S = 2\pi r \ell + 2\pi r^2$

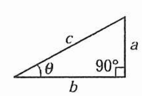
Sphere
$V = \frac{4}{3}\pi r^3$
$S = 4\pi r^2$

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

$\sin\theta = \frac{a}{c}$

$\cos\theta = \frac{b}{c}$

$\tan\theta = \frac{a}{b}$



- A = area
- C = circumference
- V = volume
- S = surface area
- b = base
- h = height
- ℓ = length
- w = width
- r = radius

ADVANCED PLACEMENT PHYSICS C EQUATIONS FOR 2002

MECHANICS

$v = v_0 + at$

$x = x_0 + v_0 t + \frac{1}{2}at^2$

$v^2 = v_0^2 + 2a(x - x_0)$

$\sum \mathbf{F} = \mathbf{F}_{net} = m\mathbf{a}$

$\mathbf{F} = \frac{d\mathbf{p}}{dt}$

$\mathbf{J} = \int \mathbf{F}\, dt = \Delta\mathbf{p}$

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

$F_{fric} \le \mu N$

$W = \int \mathbf{F} \cdot d\mathbf{r}$

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

$P = \frac{dW}{dt}$

$P = \mathbf{F} \cdot \mathbf{v}$

$\Delta U_g = mgh$

$a_c = \frac{v^2}{r} = \omega^2 r$

$\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F}$

$\sum \boldsymbol{\tau} = \boldsymbol{\tau}_{net} = I\boldsymbol{\alpha}$

$I = \int r^2\, dm = \sum mr^2$

$\mathbf{r}_{cm} = \sum m\mathbf{r} / \sum m$

$v = r\omega$

$\mathbf{L} = \mathbf{r} \times \mathbf{p} = I\boldsymbol{\omega}$

$K = \frac{1}{2}I\omega^2$

$\omega = \omega_0 + \alpha t$

$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$

$\mathbf{F}_s = -k\mathbf{x}$

$U_s = \frac{1}{2}kx^2$

$T = \frac{2\pi}{\omega} = \frac{1}{f}$

$T_s = 2\pi\sqrt{\frac{m}{k}}$

$T_p = 2\pi\sqrt{\frac{\ell}{g}}$

$\mathbf{F}_G = -\frac{Gm_1 m_2}{r^2}\hat{\mathbf{r}}$

$U_G = -\frac{Gm_1 m_2}{r}$

- a = acceleration
- F = force
- f = frequency
- h = height
- I = rotational inertia
- J = impulse
- K = kinetic energy
- k = spring constant
- ℓ = length
- L = angular momentum
- m = mass
- N = normal force
- P = power
- p = momentum
- r = radius or distance
- $\mathbf{r}$ = position vector
- T = period
- t = time
- U = potential energy
- v = velocity or speed
- W = work done on a system
- x = position
- μ = coefficient of friction
- θ = angle
- τ = torque
- ω = angular speed
- α = angular acceleration

ELECTRICITY AND MAGNETISM

$F = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$

$\mathbf{E} = \frac{\mathbf{F}}{q}$

$\oint \mathbf{E} \cdot d\mathbf{A} = \frac{Q}{\epsilon_0}$

$E = -\frac{dV}{dr}$

$V = \frac{1}{4\pi\epsilon_0}\sum_i \frac{q_i}{r_i}$

$U_E = qV = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r}$

$C = \frac{Q}{V}$

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

$C_p = \sum_i C_i$

$\frac{1}{C_s} = \sum_i \frac{1}{C_i}$

$I = \frac{dQ}{dt}$

$U_c = \frac{1}{2}QV = \frac{1}{2}CV^2$

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

$V = IR$

$R_s = \sum_i R_i$

$\frac{1}{R_p} = \sum_i \frac{1}{R_i}$

$P = IV$

$\mathbf{F}_M = q\mathbf{v} \times \mathbf{B}$

$\oint \mathbf{B} \cdot d\boldsymbol{\ell} = \mu_0 I$

$\mathbf{F} = \int I\, d\boldsymbol{\ell} \times \mathbf{B}$

$B_s = \mu_0 nI$

$\phi_m = \int \mathbf{B} \cdot d\mathbf{A}$

$\mathcal{E} = -\frac{d\phi_m}{dt}$

$\mathcal{E} = -L\frac{dI}{dt}$

$U_L = \frac{1}{2}LI^2$

- A = area
- B = magnetic field
- C = capacitance
- d = distance
- E = electric field
- $\mathcal{E}$ = emf
- F = force
- I = current
- L = inductance
- ℓ = length
- n = number of loops of wire per unit length
- P = power
- Q = charge
- q = point charge
- R = resistance
- r = distance
- t = time
- U = potential or stored energy
- V = electric potential
- v = velocity or speed
- ρ = resistivity
- ϕ_m = magnetic flux
- κ = dielectric constant

ADVANCED PLACEMENT PHYSICS C EQUATIONS FOR 2002

GEOMETRY AND TRIGONOMETRY

Rectangle
$A = bh$

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

Circle
$A = \pi r^2$
$C = 2\pi r$

Parallelepiped
$V = \ell wh$

Cylinder
$V = \pi r^2 \ell$
$S = 2\pi r\ell + 2\pi r^2$

Sphere
$V = \frac{4}{3}\pi r^3$
$S = 4\pi r^2$

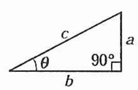
Right Triangle
$a^2 + b^2 = c^2$

$\sin\theta = \frac{a}{c}$

$\cos\theta = \frac{b}{c}$

$\tan\theta = \frac{a}{b}$

A = area
C = circumference
V = volume
S = surface area
b = base
h = height
ℓ = length
w = width
r = radius



CALCULUS

$\frac{df}{dx} = \frac{df}{du}\frac{du}{dx}$

$\frac{d}{dx}\left(x^n\right) = nx^{n-1}$

$\frac{d}{dx}\left(e^x\right) = e^x$

$\frac{d}{dx}(\ln x) = \frac{1}{x}$

$\frac{d}{dx}(\sin x) = \cos x$

$\frac{d}{dx}(\cos x) = -\sin x$

$\int x^n\,dx = \frac{1}{n+1}x^{n+1},\ n \neq -1$

$\int e^x\,dx = e^x$

$\int \frac{dx}{x} = \ln|x|$

$\int \cos x\,dx = \sin x$

$\int \sin x\,dx = -\cos x$

Reference Guide & Formula Sheet for Physics

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#3 Components of a Vector

if $V = 34$ m/sec $\angle 48°$

then

$V_x = 34$ m/sec•(cos 48°); and $V_y = 34$ m/sec•(sin 48°)

#4 Weight = m•g

g = 9.81 m/sec² near the surface of the Earth

= 9.795 m/sec² in Fort Worth, TX

Density = mass / volume

$$\rho = \frac{m}{V}\left(unit : kg / m^3\right)$$

#7 Ave speed = distance / time = v = d/t

Ave velocity = displacement / time = v = d/t

Ave acceleration = change in velocity / time

#8 Friction Force

$F_F = \mu \cdot F_N$

If the object is not moving, you are dealing with static friction and it can have any value from zero up to $\mu_s F_N$

If the object is sliding, then you are dealing with kinetic friction and it will be constant and equal to $\mu_K F_N$

#9 Torque $\tau = RF_\perp$

$\tau = F \cdot L \cdot \sin\theta$

Where θ is the angle between F and L; unit: Nm

#11 Newton's Second Law

$F_{net} = \Sigma F_{Ext} = m \cdot a$

#12 Work = F•D•cos θ

Where D is the distance moved and θ is the angle between **F** and the direction of motion, unit : J

#16 Power = rate of work done

$$Power = \frac{Work}{time}$$ unit : watt

Efficiency = $Work_{out}$ / $Energy_{in}$

Mechanical Advantage = force out / force in

M.A. = F_{out} / F_{in}

#19 Constant-Acceleration Linear Motion

$v = v_o + a \cdot t$	x
$(x-x_o) = v_o \cdot t + ½ \cdot a \cdot t^2$	v
$v^2 = v_o^2 + 2 \cdot a \cdot (x - x_o)$	t
$(x-x_o) = ½ \cdot (v_o + v) \cdot t$	a
$(x-x_o) = v \cdot t - ½ \cdot a \cdot t^2$	v_o

#20 Heating a Solid, Liquid or Gas

$Q = m \cdot c \cdot \Delta T$ (no phase changes!)

Q = the heat added

c = specific heat.

ΔT = temperature change, K

#21 Linear Momentum

momentum = **p** = m•v = mass • velocity

momentum is conserved in collisions

#23 Center of Mass – point masses on a line

$x_{cm} = \Sigma(mx) / M_{total}$

#25 Angular Speed vs. Linear Speed

Linear speed = v = r•ω = r • angular speed

#26 Pressure under Water

$P = \rho \cdot g \cdot h$

h = depth of water

ρ = density of water

#28 Universal Gravitation

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

G = 6.67 E-11 N m² / kg²

#29 Mechanical Energy

$PE_{Grav} = P = m \cdot g \cdot h$

$KE_{Linear} = K = ½ \cdot m \cdot v^2$

#30 Impulse = Change in Momentum

$F \cdot \Delta t = \Delta(m \cdot v)$

#31 Snell's Law

$n_1 \cdot \sin\theta_1 = n_2 \cdot \sin\theta_2$

Index of Refraction

n = c / v

c = speed of light = 3 E+8 m/s

#32 Ideal Gas Law

$P \cdot V = n \cdot R \cdot T$

n = # of moles of gas

R = gas law constant

= 8.31 J / K mole.

#34 Periodic Waves

$v = f \cdot \lambda$

$f = 1 / T$ T = period of wave

#35 Constant-Acceleration Circular Motion

$\omega = \omega_o + \alpha \cdot t$	θ
$\theta - \theta_o = \omega_o \cdot t + ½ \cdot \alpha \cdot t^2$	ω
$\omega^2 = \omega_o^2 + 2 \cdot \alpha \cdot (\theta - \theta_o)$	t
$\theta - \theta_o = ½ \cdot (\omega_o + \omega) \cdot t$	α
$\theta - \theta_o = \omega \cdot t - ½ \cdot \alpha \cdot t^2$	ω_o

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#36 Buoyant Force - Buoyancy

$F_B = \rho \cdot V \cdot g = m_{Displaced\ fluid} \cdot g = weight_{Displaced\ fluid}$

ρ = density of the fluid

V = volume of fluid displaced

#37 Ohm's Law

$V = I \cdot R$

V = voltage applied

I = current

R = resistance

Resistance of a Wire

$R = \rho \cdot L / A_x$

ρ = resistivity of wire material

L = length of the wire

A_x = cross-sectional area of the wire

#39 Heat of a Phase Change

$Q = m \cdot L$

L = Latent Heat of phase change

#41 Hooke's Law

$F = k \cdot x$

Potential Energy of a spring

$W = ½ \cdot k \cdot x^2$ = Work done on spring

#42 Electric Power

$P = I^2 \cdot R = V^2 / R = I \cdot V$

#44 Speed of a Wave on a String

$$T = \frac{mv^2}{L}$$

T = tension in string

m = mass of string

L = length of string

#45 Projectile Motion

Horizontal: $x - x_o = v_o \cdot t + 0$

Vertical: $y - y_o = v_o \cdot t + ½ \cdot a \cdot t^2$

#46 Centripetal Force

$$F = \frac{mv^2}{r} = m\omega^2 r$$

#47 Kirchhoff's Laws

Loop Rule: $\Sigma_{Around\ any\ loop} \Delta V_i = 0$

Node Rule: $\Sigma_{at\ any\ node} I_i = 0$

#51 Minimum Speed at the top of a Vertical Circular Loop

$$v = \sqrt{rg}$$

#53 Resistor Combinations

SERIES

$R_{eq} = R_1 + R_2 + R_3 + \ldots$

PARALLEL

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n} = \sum_{i=1}^{n} \frac{1}{R_i}$$

#54 Newton's Second Law and Rotational Inertia

τ = torque = $I \cdot \alpha$

I = moment of inertia = $m \cdot r^2$ (for a point mass)

(See table in Lesson 58 for I of 3D shapes.)

#55 Circular Unbanked Tracks

$$\frac{mv^2}{r} = \mu mg$$

#56 Continuity of Fluid Flow

$A_{in} \cdot v_{in} = A_{out} \cdot v_{out}$ A= Area, v = velocity

#58 Moment of Inertia - I

cylindrical hoop	$m \cdot r^2$
solid cylinder or disk	$½\ m \cdot r^2$
solid sphere	$^2/_5\ m \cdot r^2$
hollow sphere	$⅔\ m \cdot r^2$
thin rod (center)	$^1/_{12}\ m \cdot L^2$
thin rod (end)	$⅓\ m \cdot L^2$

#59 Capacitors $Q = C \cdot V$

Q = charge on the capacitor

C = capacitance of the capacitor

V = voltage applied to the capacitor

RC Circuits (Discharging)

$V_c = V_o \cdot e^{-t/RC}$

$V_c - I \cdot R = 0$

#60 Thermal Expansion

Linear: $\Delta L = L_o \cdot \alpha \cdot \Delta T$

Volume: $\Delta V = V_o \cdot \beta \cdot \Delta T$

#61 Bernoulli's Equation

$P + \rho \cdot g \cdot h + ½ \cdot \rho \cdot v^2$ = constant

$Q_{Volume\ Flow\ Rate} = A_1 \cdot v_1 = A_2 \cdot v_2$ = constant

#62 Rotational Kinetic Energy (See LEM, pg 8)

$KE_{rotational} = ½ \cdot I \cdot \omega^2 = ½ \cdot I \cdot (v / r)^2$

$KE_{rolling\ w/o\ slipping} = ½ \cdot m \cdot v^2 + ½ \cdot I \cdot \omega^2$

Angular Momentum = L = I•ω = m•v•r•sin θ

Angular Impulse equals

CHANGE IN Angular Momentum

$\Delta L = \tau_{torque} \cdot \Delta t = \Delta(I \cdot \omega)$

Reference Guide & Formula Sheet for Physics

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#63 Period of Simple Harmonic Motion

$T = 2\pi\sqrt{\frac{m}{k}}$ where k = spring constant

$f = 1 / T = 1$ / period

#64 Banked Circular Tracks

$v^2 = r \cdot g \cdot \tan\theta$

#66 First Law of Thermodynamics

$\Delta U = Q_{Net} + W_{Net}$

Change in Internal Energy of a system =
+Net Heat added to the system
+Net Work done on the system

Flow of Heat through a Solid

$\Delta Q / \Delta t = k \cdot A \cdot \Delta T / L$

k = thermal conductivity
A = area of solid
L = thickness of solid

#68 Potential Energy stored in a Capacitor

$P = \frac{1}{2} \cdot C \cdot V^2$

RC Circuit formula (Charging)

$V_c = V_{cell} \cdot (1 - e^{-t/RC})$

$R \cdot C = \tau$ = time constant

$V_{cell} - V_{capacitor} - I \cdot R = 0$

#71 Simple Pendulum

$T = 2\pi\sqrt{\frac{L}{g}}$ and $f = 1/T$

#72 Sinusoidal motion

$x = A \cdot \cos(\omega \cdot t) = A \cdot \cos(2 \cdot \pi \cdot f \cdot t)$

ω = angular frequency
f = frequency

#73 Doppler Effect

$f' = f \dfrac{343 \pm^{Toward}_{Away} v_o}{343 \mp^{Toward}_{Away} v_s}$

v_o = velocity of observer: v_s = velocity of source

#74 2nd Law of Thermodynamics

The change in internal energy of a system is

$\Delta U = Q_{Added} + W_{Done\ On} - Q_{lost} - W_{Done\ By}$

Maximum Efficiency of a Heat Engine (Carnot Cycle) (Temperatures in Kelvin)

$\%Eff = (1 - \frac{T_c}{T_h}) \cdot 100\%$

#75 Thin Lens Equation

$\frac{1}{f} = \frac{1}{D_o} + \frac{1}{D_i} = \frac{1}{o} + \frac{1}{i}$

f = focal length
i = image distance
o = object distance

Magnification

$M = -D_i / D_o = -i / o = H_i / H_o$

Helpful reminders for mirrors and lenses

Focal Length of:	positive	negative
mirror	concave	convex
lens	converging	diverging
Object distance = o	all objects	
Object height = H_o	all objects	
Image distance = i	real	virtual
Image height = H_i	virtual, upright	real, inverted
Magnification	virtual, upright	real, inverted

#76 Coulomb's Law

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

$k = \frac{1}{4\pi\varepsilon_o} = 9E9\frac{N \cdot m^2}{C^2}$

#77 Capacitor Combinations

PARALLEL

$C_{eq} = C_1 + C_2 + C_3 + \ldots$

SERIES

$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots + \frac{1}{C_n} = \sum_{i=1}^{n}\frac{1}{C_i}$

#78 Work done on a gas or by a gas

$W = P \cdot \Delta V$

#80 Electric Field around a point charge

$E = k\frac{q}{r^2}$

$k = \frac{1}{4\pi\varepsilon_o} = 9E9\frac{N \cdot m^2}{C^2}$

#82 Magnetic Field around a wire

$B = \frac{\mu_o I}{2\pi r}$

Magnetic Flux

$\Phi = B \cdot A \cdot \cos\theta$

Force caused by a magnetic field on a moving charge

$F = q \cdot v \cdot B \cdot \sin\theta$

#83 Entropy change at constant T

$\Delta S = Q / T$

(Phase changes only: melting, boiling, freezing, etc)

Reference Guide & Formula Sheet for Physics

Dr. Hoselton & Mr. Price

#84 Capacitance of a Capacitor

$C = \kappa \cdot \varepsilon_o \cdot A / d$

κ = dielectric constant
A = area of plates
d = distance between plates
ε_o = 8.85 E(-12) F/m

#85 Induced Voltage N = # of loops

$Emf = N\frac{\Delta\Phi}{\Delta t}$

Lenz's Law – induced current flows to create a B-field opposing the change in magnetic flux.

#86 Inductors during an increase in current

$V_L = V_{cell} \cdot e^{-t/(L/R)}$

$I = (V_{cell}/R) \cdot [1 - e^{-t/(L/R)}]$

$L / R = \tau$ = time constant

#88 Transformers

$N_1 / N_2 = V_1 / V_2$

$I_1 \cdot V_1 = I_2 \cdot V_2$

#89 Decibel Scale

B (Decibel level of sound) = 10 log (I / I_o)

I = intensity of sound
I_o = intensity of softest audible sound

#92 Poiseuille's Law

$\Delta P = 8 \cdot \eta \cdot L \cdot Q / (\pi \cdot r^4)$

η = coefficient of viscosity
L = length of pipe
r = radius of pipe
Q = flow rate of fluid

Stress and Strain

Y or S or B = stress / strain

stress = F/A

Three kinds of strain: unit-less ratios

I. Linear: strain = ΔL / L
II. Shear: strain = Δx / L
III. Volume: strain = ΔV / V

#93 Postulates of Special Relativity

1. Absolute, uniform motion cannot be detected.
2. No energy or mass transfer can occur at speeds faster than the speed of light.

#94 Lorentz Transformation Factor

$\beta = \sqrt{1 - \frac{v^2}{c^2}}$

#95 Relativistic Time Dilation

$\Delta t = \Delta t_o / \beta$

#96 Relativistic Length Contraction

$\Delta x = \beta \cdot \Delta x_o$

Relativistic Mass Increase

$m = m_o / \beta$

#97 Energy of a Photon or a Particle

$E = h \cdot f = m \cdot c^2$

h = Planck's constant = 6.63 E(-34) J sec
f = frequency of the photon

#98 Radioactive Decay Rate Law

$A = A_o \cdot e^{-kt} = (1/2^n) \cdot A_0$ (after n half-lives)

Where k = (ln 2) / half-life

#99 Blackbody Radiation and the Photoelectric Effect

$E = n \cdot h \cdot f$ where h = Planck's constant

#100 Early Quantum Physics
Rutherford-Bohr Hydrogen-like Atoms

$\frac{1}{\lambda} = R \cdot \left(\frac{1}{n_s^2} - \frac{1}{n^2}\right) meters^{-1}$

or

$f = \frac{c}{\lambda} = cR\left(\frac{1}{n_s^2} - \frac{1}{n^2}\right) Hz$

R = Rydberg's Constant
= 1.097373143 E7 m^{-1}
n_s = series integer (2 = Balmer)
n = an integer > n_s

Mass-Energy Equivalence

$m_v = m_o / \beta$

Total Energy = KE + $m_o c^2 = m_o c^2 / \beta$

Usually written simply as $E = m c^2$

de Broglie Matter Waves

For light: $E_p = h \cdot f = h \cdot c / \lambda = p \cdot c$

Therefore, momentum: $p = h / \lambda$

Similarly for particles, $p = m \cdot v = h / \lambda$, so the matter wave's wavelength must be

$\lambda = h / m v$

Energy Released by Nuclear Fission or Fusion Reaction

$E = \Delta m_o \cdot c^2$

MISCELLANEOUS FORMULAS

Quadratic Formula
if $a x^2 + b x + c = 0$
then

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

Trigonometric Definitions
sin θ = opposite / hypotenuse
cos θ = adjacent / hypotenuse
tan θ = opposite / adjacent

sec θ = 1 / cos θ = hyp / adj
csc θ = 1 / sin θ = hyp / opp
cot θ = 1 / tan θ = adj / opp

Inverse Trigonometric Definitions
$\theta = \sin^{-1}$ (opp / hyp)
$\theta = \cos^{-1}$ (adj / hyp)
$\theta = \tan^{-1}$ (opp / adj)

Law of Sines
a / sin A = b / sin B = c / sin C
or
sin A / a = sin B / b = sin C / c

Law of Cosines
$a^2 = b^2 + c^2 - 2 b c \cos A$
$b^2 = c^2 + a^2 - 2 c a \cos B$
$c^2 = a^2 + b^2 - 2 a b \cos C$

T-Pots
For the functional form

$$\frac{1}{A} = \frac{1}{B} + \frac{1}{C}$$

You may use "The Product over the Sum" rule.

$$A = \frac{B \cdot C}{B + C}$$

For the Alternate Functional form

$$\frac{1}{A} = \frac{1}{B} - \frac{1}{C}$$

You may substitute T-Pot-d

$$A = \frac{B \cdot C}{C - B} = -\frac{B \cdot C}{B - C}$$

Fundamental SI Units

Unit	Base Unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric Current	ampere	A
Thermodynamic Temperature	kelvin	K
Luminous Intensity	candela	cd
Quantity of Substance	moles	mol
Plane Angle	radian	rad
Solid Angle	steradian	sr or str

Some Derived SI Units

Symbol/Unit	Quantity	Base Units
C coulomb	Electric Charge	A•s
F farad	Capacitance	A^2•s4/(kg•m^2)
H henry	Inductance	kg•m^2/(A^2•s^2)
Hz hertz	Frequency	s^{-1}
J joule	Energy & Work	kg•m^2/s^2 = N•m
N newton	Force	kg•m/s^2
Ω ohm	Elec Resistance	kg•m^2/(A^2•s^2)
Pa pascal	Pressure	kg/(m•s^2)
T tesla	Magnetic Field	kg/(A•s^2)
V volt	Elec Potential	kg•m^2/(A•s^3)
W watt	Power	kg•m^2/s^3

Non-SI Units

°C	degrees Celsius	Temperature
eV	electron-volt	Energy, Work

Aa acceleration, Area, A_x=Cross-sectional Area, Amperes, Amplitude of a Wave, Angle,
Bb Magnetic Field, Decibel Level of Sound, Angle,
Cc specific heat, speed of light, Capacitance, Angle, Coulombs, °Celsius, Celsius Degrees, candela,
Dd displacement, differential change in a variable, Distance, Distance Moved, distance,
Ee base of the natural logarithms, charge on the electron, Energy,
Ff Force, *frequency of a wave or periodic motion*, Farads,
Gg Universal Gravitational Constant, acceleration due to gravity, Gauss, grams, Giga-,
Hh depth of a fluid, height, vertical distance, Henrys, Hz=Hertz,
Ii Current, Moment of Inertia, image distance, Intensity of Sound,
Jj Joules,
Kk K or KE = Kinetic Energy, force constant of a spring, thermal conductivity, coulomb's law constant, kg=kilograms, Kelvins, kilo-, rate constant for Radioactive decay =1/τ=ln2 / half-life,
Ll Length, Length of a wire, Latent Heat of Fusion or Vaporization, Angular Momentum, Thickness, Inductance,
Mm mass, Total Mass, meters, milli-, Mega-, m_o=rest mass, mol=moles,
Nn index of refraction, moles of a gas, Newtons, Number of Loops, nano-,
Oo
Pp Power, Pressure of a Gas or Fluid, Potential Energy, momentum, Power, Pa=Pascal,
Qq Heat gained or lost, Maximum Charge on a Capacitor, object distance, Flow Rate,
Rr radius, Ideal Gas Law Constant, Resistance, magnitude or length of a vector, rad=radians
Ss speed, seconds, Entropy, length along an arc,
Tt time, Temperature, Period of a Wave, Tension, Teslas, $t_{1/2}$=half-life,
Uu Potential Energy, Internal Energy,
Vv velocity, Velocity, Volume of a Gas, velocity of wave, Volume of Fluid Displaced, Voltage, Volts,
Ww weight, Work, Watts, Wb=Weber,
Xx distance, horizontal distance, x-coordinate east-and-west coordinate,
Yy vertical distance, y-coordinate, north-and-south coordinate,
Zz z-coordinate, up-and-down coordinate,

Αα Alpha angular acceleration, coefficient of linear expansion,
Ββ Beta coefficient of volume expansion, Lorentz transformation factor,
Χχ Chi

Δδ Delta Δ=change in a variable,

Εε Epsilon ε_o = permittivity of free space,

Φϕ Phi Magnetic Flux, angle,

Γγ Gamma surface tension = F / L, 1 / γ = Lorentz transformation factor,
Ηη Eta

Ιι Iota

ϑφ Theta and **Phi** lower case alternates.
Κκ Kappa dielectric constant,

Λλ Lambda wavelength of a wave, rate constant for Radioactive decay =1/τ=ln2/half-life,

Μμ Mu friction, μ_o = permeability of free space, micro-,
Νν Nu alternate symbol for frequency,

Οο Omicron
Ππ Pi 3.1425926536…,

Θθ Theta angle between two vectors,

Ρρ Rho density of a solid or liquid, resistivity,

Σσ Sigma Summation, standard deviation,
Ττ Tau torque, time constant for a exponential processes; eg τ=RC or τ=L/R or τ=1/k=1/λ,
Υυ Upsilon
ςϖ Zeta and **Omega** lower case alternates
Ωω Omega angular speed or angular velocity, Ohms
Ξξ Xi

Ψψ Psi

Ζζ Zeta

Values of Trigonometric Functions for 1st Quadrant Angles

(simple mostly-rational approximations)

θ	sin θ	cos θ	tan θ
0°	**0**	**1**	**0**
10°	*1/6*	*65/66*	*11/65*
15°	*1/4*	*28/29*	*29/108*
20°	*1/3*	*16/17*	*17/47*
29°	*$15^{1/2}/8$*	*7/8*	*$15^{1/2}/7$*
30°	**1/2**	**$3^{1/2}/2$**	**$1/3^{1/2}$**
37°	**3/5**	**4/5**	**3/4**
42°	*2/3*	*3/4*	*8/9*
45°	**$2^{1/2}/2$**	**$2^{1/2}/2$**	**1**
49°	*3/4*	*2/3*	*9/8*
53°	**4/5**	**3/5**	**4/3**
60	**$3^{1/2}/2$**	**1/2**	**$3^{1/2}$**
61°	*7/8*	*$15^{1/2}/8$*	*$7/15^{1/2}$*
70°	*16/17*	*1/3*	*47/17*
75°	*28/29*	*1/4*	*108/29*
80°	*65/66*	*1/6*	*65/11*
90°	**1**	**0**	**∞**

(Memorize the **Bold** *rows for future reference.)*

Derivatives of Polynomials

For polynomials, with individual terms of the form Ax^n, we define the derivative of each term as

$$\frac{d}{dx}\left(Ax^n\right) = nAx^{n-1}$$

To find the derivative of the polynomial, simply add the derivatives for the individual terms:

$$\frac{d}{dx}\left(3x^2 + 6x - 3\right) = 6x + 6$$

Integrals of Polynomials

For polynomials, with individual terms of the form Ax^n, we define the indefinite integral of each term as

$$\int \left(Ax^n\right)dx = \frac{1}{n+1}Ax^{n+1}$$

To find the indefinite integral of the polynomial, simply add the integrals for the individual terms and the constant of integration, C.

$$\int (6x+6)dx = \left[3x^2 + 6x + C\right]$$

Prefixes

Factor	Prefix	Symbol	Example
10^{18}	exa-	E	**38 Es** (Age of the Universe in Seconds)
10^{15}	peta-	P	
10^{12}	tera-	T	**0.3 TW** (Peak power of a 1 ps pulse from a typical Nd-glass laser)
10^{9}	giga-	G	**22 G$** (Size of Bill & Melissa Gates' Trust)
10^{6}	mega-	M	**6.37 Mm** (The radius of the Earth)
10^{3}	kilo-	k	**1 kg** (SI unit of mass)
10^{-1}	deci-	d	**10 cm**
10^{-2}	centi-	c	**2.54 cm** (=1 in)
10^{-3}	milli-	m	**1 mm** (The smallest division on a meter stick)
10^{-6}	micro-	μ	
10^{-9}	nano-	n	**510 nm** (Wave-length of green light)
10^{-12}	pico-	p	**1 pg** (Typical mass of a DNA sample used in genome studies)
10^{-15}	femto-	f	
10^{-18}	atto-	a	**600 as** (Time duration of the shortest laser pulses)

Linear Equivalent Mass

Rotating systems can be handled using the linear forms of the equations of motion. To do so, however, you must use a mass equivalent to the mass of a non-rotating object. We call this the Linear Equivalent Mass (LEM). *(See Example I)*

For objects that are both rotating and moving linearly, you must include them twice; once as a linearly moving object (using m) and once more as a rotating object (using LEM). *(See Example II)*

The LEM of a rotating mass is easily defined in terms of its moment of inertia, I.

$$LEM = I/r^2$$

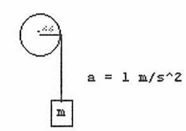
For example, using a standard table of Moments of Inertia, we can calculate the LEM of simple objects rotating on axes through their centers of mass:

	I	LEM
Cylindrical hoop	mr^2	m
Solid disk	$½mr^2$	½m
Hollow sphere	$⅔mr^2$	⅔m
Solid sphere	$⅖mr^2$	⅖m

Example I

A flywheel, M = 4.80 kg and r = 0.44 m, is wrapped with a string. A hanging mass, m, is attached to the end of the string.

When the hanging mass is released, it accelerates downward at 1.00 m/s². Find the hanging mass.



To handle this problem using the linear form of Newton's Second Law of Motion, all we have to do is use the LEM of the flywheel. We will assume, here, that it can be treated as a uniform solid disk.

The only external force on this system is the weight of the hanging mass. The mass of the system consists of the hanging mass plus the linear equivalent mass of the fly-wheel. From Newton's 2nd Law we have

F = ma, therefore, mg = [m + (LEM=½M)]a

mg = [m + ½M] a

(mg – ma) = ½M a

m(g – a) = ½Ma

m = ½•M•a / (g – a)

m = ½• 4.8 • 1.00 / (9.81 – 1)

m = 0.27 kg

If a = g/2 = 4.905 m/s², m = 2.4 kg

If a = ¾g = 7.3575 m/s², m = 7.2 kg

Note, too, that we do not need to know the radius unless the angular acceleration of the fly-wheel is requested. If you need α, and you have r, then α = a/r.

Example II

Find the kinetic energy of a disk, m = 6.7 kg, that is moving at 3.2 m/s while rolling without slipping along a flat, horizontal surface. ($I_{DISK} = ½mr^2$; LEM = ½m)

The total kinetic energy consists of the linear kinetic energy, $K_L = ½mv^2$, plus the rotational kinetic energy, $K_R = ½(I)(\omega)^2 = ½(I)(v/r)^2 = ½(I/r^2)v^2 = ½(LEM)v^2$.

KE = ½mv² + ½•(LEM=½m)•v²

KE = ½•6.7•3.2² + ½•(½•6.7)•3.2²

KE = 34.304 + 17.152 = 51 J

Final Note:

This method of incorporating rotating objects into the linear equations of motion works in every situation I've tried; even very complex problems. Work your problem the classic way and this way to compare the two. Once you've verified that the LEM method works for a particular type of problem, you can confidently use it for solving any other problem of the same type.