ADVANCED PLACEMENT PHYSICS 2 TABLE OF INFORMATION

CONSTANTS AND CONVERSION FACTORS	
Avogadro's number,	$N_0 = 6.02 \times 10^{23}\ \text{mol}^{-1}$
Universal gas constant,	$R = 8.31\ \text{J}/(\text{mol} \cdot \text{K})$
Boltzmann's constant,	$k_B = 1.38 \times 10^{-23}\ \text{J/K}$
1 atmosphere of pressure,	$1\ \text{atm} = 1.0 \times 10^5\ \text{N/m}^2 = 1.0 \times 10^5\ \text{Pa}$
Coulomb constant,	$k = \dfrac{1}{4\pi\varepsilon_0} = 9.0 \times 10^9\ \dfrac{\text{N} \cdot \text{m}^2}{\text{C}^2}$
Proton mass,	$m_p = 1.67 \times 10^{-27}\ \text{kg}$
Neutron mass,	$m_n = 1.67 \times 10^{-27}\ \text{kg}$
Electron mass,	$m_e = 9.11 \times 10^{-31}\ \text{kg}$
Elementary charge,	$e = 1.60 \times 10^{-19}\ \text{C}$
Vacuum permittivity,	$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2/(\text{N} \cdot \text{m}^2)$
Vacuum permeability,	$\mu_0 = 4\pi \times 10^{-7}\ (\text{T} \cdot \text{m})/\text{A}$
1 electron volt,	$1\ \text{eV} = 1.60 \times 10^{-19}\ \text{J}$
Planck's constant,	$h = 6.63 \times 10^{-34}\ \text{J} \cdot \text{s} = 4.14 \times 10^{-15}\ \text{eV} \cdot \text{s}$
	$hc = 1.99 \times 10^{-25}\ \text{J} \cdot \text{m} = 1240\ \text{eV} \cdot \text{nm}$
Speed of light,	$c = 3.00 \times 10^8\ \text{m/s}$
Wien's constant,	$b = 2.90 \times 10^{-3}\ \text{m} \cdot \text{K}$
Stefan-Boltzmann constant,	$\sigma = 5.67 \times 10^{-8}\ \text{W}/(\text{m}^2 \cdot \text{K}^4)$
1 unified atomic mass unit,	$1\ \text{u} = 1.66 \times 10^{-27}\ \text{kg} = 931\ \text{MeV}/c^2$

Universal gravitational constant, $G = 6.67 \times 10^{-11}\ \text{m}^3/(\text{kg} \cdot \text{s}^2) = 6.67 \times 10^{-11}\ \text{N} \cdot \text{m}^2/\text{kg}^2$

Magnitude of the acceleration due to gravity at Earth's surface, $g = 9.8\ \text{m/s}^2$

Magnitude of the gravitational field strength at the Earth's surface, $g = 9.8\ \text{N/kg}$

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

PREFIXES

Factor	Prefix	Symbol
10^{12}	tera	T
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	0°	30°	37°	45°	53°	60°	90°
$\sin\theta$	0	$1/2$	$3/5$	$\sqrt{2}/2$	$4/5$	$\sqrt{3}/2$	1
$\cos\theta$	1	$\sqrt{3}/2$	$4/5$	$\sqrt{2}/2$	$3/5$	$1/2$	0
$\tan\theta$	0	$\sqrt{3}/3$	$3/4$	1	$4/3$	$\sqrt{3}$	∞

The following conventions are used in this exam:

- The frame of reference of any problem is assumed to be inertial unless otherwise stated.
- Air resistance is assumed to be negligible unless otherwise stated.
- In all situations, positive work is defined as work done **ON** a system
- Springs and strings are assumed to be ideal unless otherwise stated.
- The electric potential is zero at an infinite distance from an isolated point charge.
- The direction of current is the direction in which positive charges would drift.
- All batteries and meters are assumed to be ideal unless otherwise stated.

ELECTRICITY		MAGNETISM	
$\left\|\vec{F}_E\right\| = \frac{1}{4\pi\varepsilon_0}\frac{\left\|q_1 q_2\right\|}{r^2} = k\frac{\left\|q_1 q_2\right\|}{r^2}$ $\vec{E} = \frac{\vec{F}_E}{q}$ $\left\|\vec{E}\right\| = \frac{1}{4\pi\varepsilon_0}\frac{\left\|q\right\|}{r^2} = k\frac{\left\|q\right\|}{r^2}$ $U_E = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r} = k\frac{q_1 q_2}{r}$ $\Delta V = \frac{\Delta U_E}{q}$ $V = \frac{1}{4\pi\varepsilon_0}\sum_i \frac{q_i}{r_i}$ $\left\|\vec{E}\right\| = \left\|\frac{\Delta V}{\Delta r}\right\|$ $C = \frac{Q}{\Delta V}$ $C = \kappa\varepsilon_0 \frac{A}{d}$ $E_C = \frac{Q}{\kappa\varepsilon_0 A}$ $U_C = \frac{1}{2}Q\Delta V$ $I = \frac{\Delta Q}{\Delta t}$ $R = \frac{\rho\ell}{A}$ $P = I\Delta V$ $I = \frac{\Delta V}{R}$ $R_{\text{eq},s} = \sum_i R_i$ $\frac{1}{R_{\text{eq},p}} = \sum_i \frac{1}{R_i}$ $\frac{1}{C_{\text{eq},s}} = \sum_i \frac{1}{C_i}$ $C_{\text{eq},p} = \sum_i C_i$ $\tau = R_{\text{eq}} C_{\text{eq}}$	A = area C = capacitance d = distance E = electric field F = force I = current ℓ = length P = power q = charge Q = charge r = distance, radius, or position R = resistance t = time U = potential energy V = electric potential κ = dielectric constant ρ = resistivity τ = time constant	$F_B = qvB\sin\theta$ $B = \frac{\mu_0 I}{2\pi r}$ $F_B = I\ell B\sin\theta$ $\Phi_B = \vec{B}\cdot\vec{A}$ $\Phi_B = \left\|\vec{B}\right\|\cos\theta\left\|\vec{A}\right\|$ $\left\|\mathcal{E}\right\| = \left\|\frac{\Delta\Phi_B}{\Delta t}\right\|$ $\mathcal{E} = B\ell v$	A = area B = magnetic field F = force I = current ℓ = length q = charge r = distance, radius, or position t = time v = velocity or speed $\mathcal{E}$ = emf θ = angle Φ = flux

THERMAL PHYSICS	
$P = \frac{F_\perp}{A}$ $K_{\text{avg}} = \frac{3}{2}k_B T = \frac{1}{2}mv_{\text{rms}}^2$ $\frac{Q}{\Delta t} = \frac{kA\Delta T}{L}$ $PV = nRT = Nk_B T$ $U = \frac{3}{2}nRT = \frac{3}{2}Nk_B T$ $W = -P\Delta V$ $\Delta U = Q + W$ $Q = mc\Delta T$	A = area c = specific heat F = force k = thermal conductivity K = kinetic energy L = length m = mass n = number of moles N = number of atoms P = pressure Q = energy transferred to a system by heating t = time T = temperature U = internal energy v = velocity or speed V = volume W = work done on a system

WAVES, SOUND, AND OPTICS

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

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

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

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

$$|M| = \left|\frac{h_i}{h_o}\right| = \left|\frac{s_i}{s_o}\right|$$

$$\Delta D = m\lambda$$

$$\Delta D = a\sin\theta$$

$$a\left(\frac{y_{\text{min}}}{L}\right) \approx m\lambda$$

$$\Delta D = d\sin\theta$$

$$d\left(\frac{y_{\text{max}}}{L}\right) \approx m\lambda$$

$$v_{\text{string}} = \sqrt{\frac{F_T}{m/\ell}}$$

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

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

$$y(x) = A\cos\left(2\pi\frac{x}{\lambda}\right)$$

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

a = width
A = amplitude
d = separation
D = path length
f = frequency or focal length
F = force
h = height
ℓ = length
L = distance
m = order or mass
M = magnification
n = index of refraction
s = position
t = time
T = period
v = speed
x = position
y = position
λ = wavelength
θ = angle
ω = angular frequency

MODERN PHYSICS

$$E = hf$$

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

$$\lambda = \frac{c}{f}$$

$$\lambda_{\text{max}} = \frac{b}{T}$$

$$P = A\sigma T^4$$

$$K_{\text{max}} = hf - \phi$$

$$\Delta\lambda = \frac{h}{m_e c}(1 - \cos\theta)$$

$$E = mc^2$$

$$N = N_0 e^{-\lambda t}$$

$$\lambda = \frac{\ln 2}{t_{1/2}}$$

A = area
b = constant
E = energy
f = frequency
K = kinetic energy
m = mass
N = number of particles
p = momentum
P = power
t = time
T = absolute temperature
θ = angle
λ = wavelength or decay constant
σ = constant
ϕ = work function

GEOMETRY AND TRIGONOMETRY

Rectangle
$A = bh$

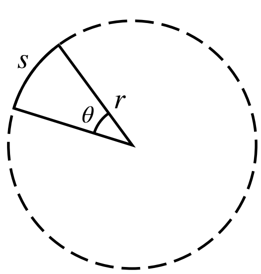
Triangle
$A = \frac{1}{2}bh$

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

Rectangular Solid
$V = \ell wh$

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

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



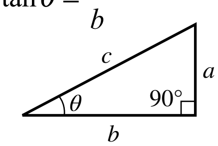
A = area
b = base
C = circumference
h = height
ℓ = length
r = radius
s = arc length
S = surface area
V = volume
w = width
θ = angle

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

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

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

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



MECHANICS AND FLUIDS

$v_x = v_{x0} + a_x t$

$x = x_0 + v_{x0}t + \frac{1}{2}a_x t^2$

$v_x^2 = v_{x0}^2 + 2a_x\left(x - x_0\right)$

$\vec{x}_{cm} = \frac{\sum m_i \vec{x}_i}{\sum m_i}$

$\vec{a}_{sys} = \frac{\sum \vec{F}}{m_{sys}} = \frac{\vec{F}_{net}}{m_{sys}}$

$\left|\vec{F}_g\right| = G\frac{m_1 m_2}{r^2}$

$\left|\vec{F}_f\right| \le \left|\mu \vec{F}_n\right|$

$\vec{F}_s = -k\Delta\vec{x}$

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

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

$W = F_{\parallel}d = Fd\cos\theta$

$\Delta K = \sum W_i = \sum F_{\parallel,i}d_i$

$\Delta U_s = \frac{1}{2}k(\Delta x)^2$

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

$\Delta U_g = mg\Delta y$

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

$P_{inst} = F_{\parallel}v = Fv\cos\theta$

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

$\vec{F}_{net} = \frac{\Delta\vec{p}}{\Delta t} = m\frac{\Delta\vec{v}}{\Delta t} = m\vec{a}$

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

$\vec{v}_{cm} = \frac{\sum \vec{p}_i}{\sum m_i} = \frac{\sum m_i \vec{v}_i}{\sum m_i}$

a = acceleration
d = distance
E = energy
F = force
J = impulse
k = spring constant
K = kinetic energy
m = mass
p = momentum
P = power
r = radius, distance, or position
t = time
U = potential energy
v = velocity or speed
W = work
x = position
y = height
θ = angle
μ = coefficient of friction

$\omega = \omega_0 + \alpha t$

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

$\omega^2 = \omega_0^2 + 2\alpha\left(\theta - \theta_0\right)$

$v = r\omega$

$a_T = r\alpha$

$\tau = r_{\perp}F = rF\sin\theta$

$I = \sum m_i r_i^2$

$I' = I_{cm} + Md^2$

$\alpha_{sys} = \frac{\Sigma\tau}{I_{sys}} = \frac{\tau_{net}}{I_{sys}}$

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

$W = \tau\Delta\theta$

$L = I\omega$

$L = rmv\sin\theta$

$\Delta L = \tau\Delta t$

$\Delta x_{cm} = r\Delta\theta$

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

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

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

$x = A\cos(2\pi ft)$

$x = A\sin(2\pi ft)$

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

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

$P = P_0 + \rho gh$

$P_{gauge} = \rho gh$

$F_b = \rho Vg$

$A_1 v_1 = A_2 v_2$

$P_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g y_2 + \frac{1}{2}\rho v_2^2$

a = acceleration
A = amplitude or area
d = distance
f = frequency
F = force
h = height
I = rotational inertia
k = spring constant
K = kinetic energy
ℓ = length
L = angular momentum
m = mass
M = mass
P = pressure
r = radius, distance, or position
t = time
T = period
v = velocity or speed
V = volume
W = work
x = position
y = vertical position
α = angular acceleration
θ = angle
ρ = density
τ = torque
ω = angular speed