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,	$R = 8.31\ \text{J/(mol} \cdot \text{K)}$
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,	$k = \frac{1}{4\pi\varepsilon_0} = 9.0 \times 10^9\ \frac{\text{N} \cdot \text{m}^2}{\text{C}^2}$
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 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.
- 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, wires, and meters are assumed to be ideal unless otherwise stated.

ELECTRICITY

$$\left|\vec{F}_E\right| = \frac{1}{4\pi\varepsilon_0}\frac{\left|q_1 q_2\right|}{r^2} = k\frac{\left|q_1 q_2\right|}{r^2}$$

$$\vec{E} = \frac{\vec{F}_E}{q}$$

$$\left|\vec{E}\right| = \frac{1}{4\pi\varepsilon_0}\frac{\left|q\right|}{r^2} = k\frac{\left|q\right|}{r^2}$$

$$U_E = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r} = k\frac{q_1 q_2}{r}$$

$$\Delta V = \frac{\Delta U_E}{q}$$

$$V = \frac{1}{4\pi\varepsilon_0}\sum_i \frac{q_i}{r_i}$$

$$\left|\vec{E}\right| = \left|\frac{\Delta V}{\Delta r}\right|$$

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

$$C = \kappa\varepsilon_0\frac{A}{d}$$

$$E_C = \frac{Q}{\kappa\varepsilon_0 A}$$

$$U_C = \frac{1}{2}Q\Delta V$$

$$I = \frac{\Delta Q}{\Delta t}$$

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

$$P = I\Delta V$$

$$I = \frac{\Delta V}{R}$$

$$R_{\text{eq},s} = \sum_i R_i$$

$$\frac{1}{R_{\text{eq},p}} = \sum_i \frac{1}{R_i}$$

$$\frac{1}{C_{\text{eq},s}} = \sum_i \frac{1}{C_i}$$

$$C_{\text{eq},p} = \sum_i C_i$$

$$\tau = R_{\text{eq}} C_{\text{eq}}$$

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

MAGNETISM

$$F_B = qvB\sin\theta$$

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

$$F_B = I\ell B\sin\theta$$

$$\Phi_B = \vec{B}\cdot\vec{A}$$

$$\Phi_B = \left|\vec{B}\right|\cos\theta\left|\vec{A}\right|$$

$$\left|\mathcal{E}\right| = \left|\frac{\Delta\Phi_B}{\Delta t}\right|$$

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

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

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

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

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

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

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

$\Delta D = m\lambda$

$\Delta D = a\sin\theta$

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

$\Delta D = d\sin\theta$

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

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

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

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

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

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

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

$E = hf$

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

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

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

$P = A\sigma T^4$

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

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

$E = mc^2$

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

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

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
$A = bh$

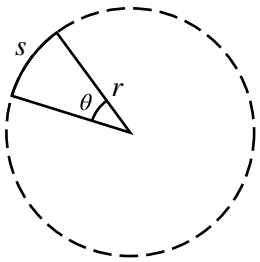
Triangle
$A = \frac{1}{2}bh$

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



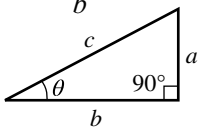
A = area
b = base
C = circumference
h = height
ℓ = length
r = radius
s = arc length
S = surface area
V = volume
w = width
θ = angle

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

$v_x = v_{x0} + a_x t$

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

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

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

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

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

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

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

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

$K = \frac{1}{2} m v^2$

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

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

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

$U_G = -\frac{G m_1 m_2}{r}$

$\Delta U_g = mg\Delta y$

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

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

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

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

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

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

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

$\omega = \omega_0 + \alpha t$

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

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

$v = r\omega$

$a_T = r\alpha$

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

$I = \sum m_i r_i^2$

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

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

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

$W = \tau\Delta\theta$

$L = I\omega$

$L = rmv\sin\theta$

$\Delta L = \tau\Delta t$

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

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

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

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

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

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

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

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

$P = P_0 + \rho gh$

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

$F_b = \rho V g$

$A_1 v_1 = A_2 v_2$

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

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