ADVANCED PLACEMENT PHYSICS ELECTRICITY AND MAGNETISM
TABLE OF INFORMATION

CONSTANTS AND CONVERSION FACTORS	
Coulomb constant,	$k = \dfrac{1}{4\pi\varepsilon_0} = 9.0\times10^{9}\ \dfrac{\text{N}\cdot\text{m}^2}{\text{C}^2}$
Vacuum permittivity,	$\varepsilon_0 = 8.85\times10^{-12}\ \text{C}^2/(\text{N}\cdot\text{m}^2)$
Vacuum permeability,	$\mu_0 = 4\pi\times10^{-7}\ (\text{T}\cdot\text{m})/\text{A}$
Proton mass,	$m_p = 1.67\times10^{-27}\ \text{kg}$
Neutron mass,	$m_n = 1.67\times10^{-27}\ \text{kg}$
Electron mass,	$m_e = 9.11\times10^{-31}\ \text{kg}$
Elementary charge,	$e = 1.60\times10^{-19}\ \text{C}$
1 electron volt,	$1\ \text{eV} = 1.60\times10^{-19}\ \text{J}$
Speed of light,	$c = 3.00\times10^{8}\ \text{m/s}$
1 unified atomic mass unit,	$1\ \text{u} = 1.66\times10^{-27}\ \text{kg} = 931\ \text{MeV}/c^2$

Universal gravitational constant, $G = 6.67\times10^{-11}\ \text{m}^3/(\text{kg}\cdot\text{s}^2) = 6.67\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2$

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
electron volt,	eV
farad,	F
henry,	H
hertz,	Hz
joule,	J
kilogram,	kg
meter,	m
newton,	N
ohm,	Ω
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 AND MAGNETISM

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

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

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\int \frac{dq}{r^2}\hat{r}$$

$$\Phi_E = \int \vec{E}\cdot d\vec{A}$$

$$\oint \vec{E}\cdot d\vec{A} = \frac{q_{\text{enc}}}{\varepsilon_0}$$

$$Q_{\text{total}} = \int \rho(r)\,dV$$

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

$$V = \frac{1}{4\pi\varepsilon_0}\int \frac{dq}{r}$$

$$\Delta V = -\int_a^b \vec{E}\cdot d\vec{r}$$

$$E_x = -\frac{dV}{dx}$$

$$\Delta U_E = q\Delta V$$

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

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

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

$$\kappa = \frac{\varepsilon}{\varepsilon_0}$$

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

$$I = \int \vec{J}\cdot d\vec{A}$$

$$\vec{E} = \rho\vec{J}$$

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

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

$$P = I\Delta V$$

A = area
C = capacitance
d = distance
E = electric field
F = force
I = current
J = current density
ℓ = length
P = power
q = charge
Q = charge
r = radius, distance, or position
R = resistance
t = time
U = potential energy
V = electric potential or volume
ε = electric permittivity
ρ = resistivity or charge density
κ = dielectric constant
Φ = flux

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

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

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

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

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

$$\oint \vec{B}\cdot d\vec{A} = 0$$

$$\vec{F}_B = q\left(\vec{v}\times\vec{B}\right)$$

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\left(d\vec{\ell}\times\hat{r}\right)}{r^2}$$

$$\vec{F}_B = \int I\left(d\vec{\ell}\times\vec{B}\right)$$

$$\oint \vec{B}\cdot d\vec{\ell} = \mu_0 I_{\text{enc}}$$

$$B_{\text{sol}} = \mu_0 n I$$

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

$$\mathcal{E} = \oint \vec{E}\cdot d\vec{\ell} = -\frac{d\Phi_B}{dt}$$

$$\left|\mathcal{E}_{\text{sol}}\right| = N\left|\frac{d\Phi_B}{dt}\right|$$

$$L_{\text{sol}} = \frac{\mu_{\text{core}}N^2 A}{\ell}$$

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

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

$$\tau = \frac{L}{R_{\text{eq}}}$$

$$\omega_{LC} = \frac{1}{\sqrt{LC}}$$

A = area
B = magnetic field
C = capacitance
F = force
I = current
ℓ = length
L = inductance
n = number of loops per unit length
N = number of loops
q = charge
r = radius, distance, or position
R = resistance
t = time
U = potential energy
v = velocity or speed
$\mathcal{E}$ = emf
μ = magnetic permeability
τ = time constant
Φ = flux
ω = angular frequency

MECHANICS

$v_x = v_{x0} + a_x t$

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

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

$\Delta x = \int v_x\left(t\right)dt$

$\Delta v_x = \int a_x\left(t\right)dt$

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

$\vec{r}_{\text{cm}} = \frac{\int \vec{r}\, dm}{\int dm}$

$\lambda = \frac{d}{d\ell}m\left(\ell\right)$

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

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

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

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

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

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

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

$W = \int_a^b \vec{F}\cdot d\vec{r}$

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

$\Delta U = -\int_a^b \vec{F}_{\text{cf}}(r)\cdot d\vec{r}$

$F_x = -\frac{dU(x)}{dx}$

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

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

$\Delta U_g = mg\Delta y$

a = acceleration
E = energy
f = frequency
F = force
h = height
J = impulse
k = spring constant
K = kinetic energy
ℓ = length
m = mass
M = mass
p = momentum
P = power
r = radius, distance, or position
t = time
T = period
U = potential energy
v = velocity or speed
W = work
x = position or distance
y = height
λ = linear mass density
μ = coefficient of friction

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

$P_{\text{inst}} = \frac{dW}{dt}$

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

$\vec{F}_{\text{net}} = \frac{d\vec{p}}{dt}$

$\vec{J} = \int_{t_1}^{t_2} \vec{F}_{\text{net}}\left(t\right)dt = \Delta\vec{p}$

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

$\omega = \frac{d\theta}{dt}$

$\alpha = \frac{d\omega}{dt}$

$\omega = \omega_0 + \alpha t$

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

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

$v = r\omega$

$a_T = r\alpha$

$\vec{\tau} = \vec{r}\times\vec{F}$

$I_{\text{tot}} = \sum I_i = \sum m_i r_i^2$

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

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

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

$K_{\text{rot}} = \frac{1}{2}I\omega^2$

$W = \int \tau\cdot d\theta$

$\vec{L} = \vec{r}\times\vec{p} = I\vec{\omega}$

$\Delta L = \int \tau\, dt$

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

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

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

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

$T_{\text{phys}} = 2\pi\sqrt{\frac{I}{mgd}}$

$x = x_{\text{max}}\cos\left(\omega t + \phi\right)$

a = acceleration
d = distance
f = frequency
F = force
I = rotational inertia
k = spring constant
K = kinetic energy
ℓ = length
L = angular momentum
m = mass
M = mass
p = momentum
r = radius, distance, or position
t = time
T = period
v = velocity or speed
W = work
x = position or distance
α = angular acceleration
θ = angle
τ = torque
ϕ = phase angle
ω = angular frequency or angular speed

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

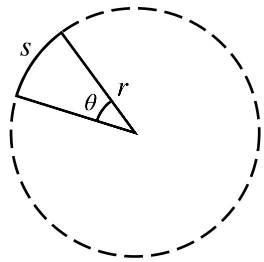
$V = \pi r^2 \ell$

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

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

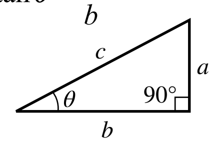
Right Triangle

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

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

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

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



VECTORS	CALCULUS	IDENTITIES
$\vec{A}\cdot\vec{B} = AB\cos\theta$	$\frac{df}{dx} = \frac{df}{du}\frac{du}{dx}$	$\log\left(a \cdot b^x\right) = \log a + x\log b$
$\left\lvert\vec{A}\times\vec{B}\right\rvert = AB\sin\theta$	$\frac{d}{dx}\left(x^n\right) = nx^{n-1}$	$\sin^2\theta + \cos^2\theta = 1$
$\vec{r} = \left(A\hat{i} + B\hat{j} + C\hat{k}\right)$	$\frac{d}{dx}\left(e^{ax}\right) = ae^{ax}$	$\sin\left(2\theta\right) = 2\sin\theta\cos\theta$
$\vec{C} = \vec{A} + \vec{B}$	$\frac{d}{dx}\left(\ln ax\right) = \frac{1}{x}$	$\frac{\sin\theta}{\cos\theta} = \tan\theta$
$\vec{C} = \left(A_x + B_x\right)\hat{i} + \left(A_y + B_y\right)\hat{j}$	$\frac{d}{dx}\left[\sin(ax)\right] = a\cos(ax)$	
	$\frac{d}{dx}\left[\cos(ax)\right] = -a\sin(ax)$	
	$\int x^n\,dx = \frac{1}{n+1}x^{n+1}, n \neq -1$	
	$\int e^{ax}\,dx = \frac{1}{a}e^{ax}$	
	$\int \frac{dx}{x+a} = \ln\lvert x+a\rvert$	
	$\int \cos(ax)\,dx = \frac{1}{a}\sin(ax)$	
	$\int \sin(ax)\,dx = -\frac{1}{a}\cos(ax)$	