

ADVANCED PLACEMENT PHYSICS C: ELECTRICITY AND MAGNETISM

TABLE OF INFORMATION

CONSTANTS AND CONVERSION FACTORS	
Coulomb constant,	$k = \frac{1}{4\pi\epsilon_0} = 9.0 \times 10^9 \frac{\text{N} \cdot \text{m}^2}{\text{C}^2}$
Vacuum permittivity,	$\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2 / (\text{N} \cdot \text{m}^2)$
Vacuum permeability,	$\mu_0 = 4\pi \times 10^{-7} (\text{T} \cdot \text{m}) / \text{A}$
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,	$e = 1.60 \times 10^{-19} \text{ C}$
1 electron volt,	$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$
Speed of light,	$c = 3.00 \times 10^8 \text{ m/s}$
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
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

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

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

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \int \frac{dq}{r^2} \hat{r}$$

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

$$\oint \vec{E} \cdot d\vec{A} = \frac{q_{\text{enc}}}{\epsilon_0}$$

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

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

$$V = \frac{1}{4\pi\epsilon_0} \int \frac{dq}{r}$$

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

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

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

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

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

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

$$\kappa = \frac{\epsilon}{\epsilon_0}$$

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

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

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

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

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

$$P = I\Delta V$$

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

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

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

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

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

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

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

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

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

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

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

$$B_{\text{sol}} = \mu_0 nI$$

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

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

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

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

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

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

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

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

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

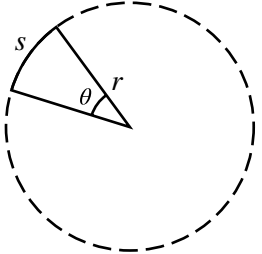
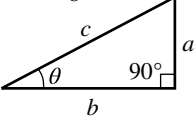
ω = angular frequency

MECHANICS

$v_x = v_{x0} + a_x t$	a = acceleration
$x = x_0 + v_{x0} t + \frac{1}{2} a_x t^2$	E = energy
$v_x^2 = v_{x0}^2 + 2a_x (x - x_0)$	f = frequency
$\Delta x = \int v_x(t) dt$	F = force
$\Delta v_x = \int a_x(t) dt$	h = height
$\vec{x}_{\text{cm}} = \frac{\sum m_i \vec{x}_i}{\sum m_i}$	J = impulse
$\vec{r}_{\text{cm}} = \frac{\int \vec{r} dm}{\int dm}$	k = spring constant
$\lambda = \frac{d}{d\ell} m(\ell)$	K = kinetic energy
$\vec{a}_{\text{sys}} = \frac{\sum \vec{F}}{m_{\text{sys}}} = \frac{\vec{F}_{\text{net}}}{m_{\text{sys}}}$	ℓ = length
$ \vec{F}_g = G \frac{m_1 m_2}{r^2}$	m = mass
$ \vec{F}_f \leq \mu \vec{F}_N $	M = mass
$\vec{F}_s = -k \Delta \vec{x}$	p = momentum
$a_c = \frac{v^2}{r} = r \omega^2$	P = power
$T = \frac{1}{f}$	r = radius, distance, or position
$K = \frac{1}{2} m v^2$	t = time
$W = \int_a^b \vec{F} \cdot d\vec{r}$	T = period
$\Delta K = \sum W_i = \sum F_{\parallel,i} d_i$	U = potential energy
$\Delta U = - \int_a^b \vec{F}_{\text{cf}}(r) \cdot d\vec{r}$	v = velocity or speed
$F_x = - \frac{dU(x)}{dx}$	W = work
$U_s = \frac{1}{2} k (\Delta x)^2$	x = position or distance
$U_G = -G \frac{m_1 m_2}{r}$	y = height
$\Delta U_g = mg \Delta y$	λ = linear mass density
	μ = coefficient of friction

$\omega = \frac{d\theta}{dt}$	a = acceleration
$\alpha = \frac{d\omega}{dt}$	d = distance
$\omega = \omega_0 + \alpha t$	f = frequency
$\theta = \theta_0 + \omega_0 t + \frac{1}{2} \alpha t^2$	F = force
$\omega^2 = \omega_0^2 + 2\alpha(\theta - \theta_0)$	I = rotational inertia
$v = r \omega$	k = spring constant
$a_T = r \alpha$	K = kinetic energy
$\vec{\tau} = \vec{r} \times \vec{F}$	ℓ = length
$I_{\text{tot}} = \sum I_i = \sum m_i r_i^2$	L = angular momentum
$I = \int r^2 dm$	m = mass
$I' = I_{\text{cm}} + M d^2$	M = mass
$\alpha_{\text{sys}} = \frac{\sum \tau}{I_{\text{sys}}} = \frac{\tau_{\text{net}}}{I_{\text{sys}}}$	p = momentum
$K_{\text{rot}} = \frac{1}{2} I \omega^2$	r = radius, distance, or position
$W = \int \tau \cdot d\theta$	t = time
$\vec{L} = \vec{r} \times \vec{p} = I \vec{\omega}$	T = period
$\Delta L = \int \tau dt$	v = velocity or speed
$\Delta x_{\text{cm}} = r \Delta \theta$	W = work
$T = \frac{2\pi}{\omega} = \frac{1}{f}$	x = position or distance
$T_s = 2\pi \sqrt{\frac{m}{k}}$	α = angular acceleration
$T_p = 2\pi \sqrt{\frac{\ell}{g}}$	θ = angle
$T_{\text{phys}} = 2\pi \sqrt{\frac{I}{mgd}}$	τ = torque
$x = x_{\text{max}} \cos(\omega t + \phi)$	ϕ = phase angle
	ω = angular frequency or angular speed

GEOMETRY AND TRIGONOMETRY

Rectangle $A = bh$	Rectangular Solid $V = \ell wh$		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 $a^2 + b^2 = c^2$ $\sin \theta = \frac{a}{c}$ $\cos \theta = \frac{b}{c}$ $\tan \theta = \frac{a}{b}$
Triangle $A = \frac{1}{2}bh$	Cylinder $V = \pi r^2 \ell$ $S = 2\pi r \ell + 2\pi r^2$			
Circle $A = \pi r^2$ $C = 2\pi r$ $s = r\theta$	Sphere $V = \frac{4}{3}\pi r^3$ $S = 4\pi r^2$			

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