

ADVANCED PLACEMENT PHYSICS 2 TABLE OF INFORMATION

CONSTANTS AND CONVERSION FACTORS		UNIT SYMBOLS
Avogadro's number,	$N_0 = 6.02 \times 10^{23} \text{ mol}^{-1}$	ampere, A
Universal gas constant,	$R = 8.31 \text{ J}/(\text{mol} \cdot \text{K})$	coulomb, C
Boltzmann's constant,	$k_B = 1.38 \times 10^{-23} \text{ J/K}$	degree Celsius, °C
1 atmosphere of pressure,	$1 \text{ atm} = 1.0 \times 10^5 \text{ N/m}^2 = 1.0 \times 10^5 \text{ Pa}$	electron volt, eV
Coulomb constant,	$k = \frac{1}{4\pi\epsilon_0} = 9.0 \times 10^9 \frac{\text{N} \cdot \text{m}^2}{\text{C}^2}$	farad, F
Proton mass,	$m_p = 1.67 \times 10^{-27} \text{ kg}$	hertz, Hz
Neutron mass,	$m_n = 1.67 \times 10^{-27} \text{ kg}$	joule, J
Electron mass,	$m_e = 9.11 \times 10^{-31} \text{ kg}$	kelvin, K
Elementary charge,	$e = 1.60 \times 10^{-19} \text{ C}$	kilogram, kg
Vacuum permittivity,	$\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/(\text{N} \cdot \text{m}^2)$	meter, m
Vacuum permeability,	$\mu_0 = 4\pi \times 10^{-7} (\text{T} \cdot \text{m})/\text{A}$	mole, mol
1 electron volt,	$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$	newton, N
Planck's constant,	$h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s} = 4.14 \times 10^{-15} \text{ eV} \cdot \text{s}$ $hc = 1.99 \times 10^{-25} \text{ J} \cdot \text{m} = 1240 \text{ eV} \cdot \text{nm}$	ohm, Ω
Speed of light,	$c = 3.00 \times 10^8 \text{ m/s}$	pascal, Pa
Wien's constant,	$b = 2.90 \times 10^{-3} \text{ m} \cdot \text{K}$	second, s
Stefan-Boltzmann constant,	$\sigma = 5.67 \times 10^{-8} \text{ W}/(\text{m}^2 \cdot \text{K}^4)$	tesla, T
1 unified atomic mass unit,	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg} = 931 \text{ MeV}/c^2$	volt, V
Universal gravitational constant, $G = 6.67 \times 10^{-11} \text{ m}^3/(\text{kg} \cdot \text{s}^2) = 6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2$		watt, W
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, $g = 9.8 \text{ N/kg}$		

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

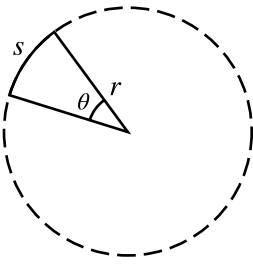
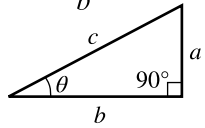
VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES							
θ	0°	30°	37°	45°	53°	60°	90°
$\sin \theta$	0	$1/2$	$3/5$	$\sqrt{2}/2$	$4/5$	$\sqrt{3}/2$	1
$\cos \theta$	1	$\sqrt{3}/2$	$4/5$	$\sqrt{2}/2$	$3/5$	$1/2$	0
$\tan \theta$	0	$\sqrt{3}/3$	$3/4$	1	$4/3$	$\sqrt{3}$	∞

The following conventions are used in this exam unless otherwise stated:

- The frame of reference is inertial.
- Frictional forces are negligible.
- Strings, springs, batteries, wires, and meters are ideal.
- Resistors and lightbulbs are ohmic.
- Ideal gases are monatomic.
- The electric potential is zero at an infinite distance from an isolated point charge.
- Current is conventional current.
- Capacitors are air-filled ($\kappa = 1.0$).
- The small angle approximation is valid for single- and double-slit diffraction.

ELECTRICITY	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} \frac{ q }{r^2} = k \frac{ q }{r^2}$ $U_E = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r} = k \frac{q_1 q_2}{r}$ $\Delta U_E = q\Delta V$ $V = \frac{1}{4\pi\epsilon_0} \sum_i \frac{q_i}{r_i}$ $ \vec{E} = \left \frac{\Delta V}{\Delta r} \right $ $C = \frac{Q}{\Delta V}$ $C = \kappa\epsilon_0 \frac{A}{d}$ $E_C = \frac{Q}{\kappa\epsilon_0 A}$ $U_C = \frac{1}{2} Q\Delta V$ $I = \frac{\Delta q}{\Delta t}$ $R = \frac{\rho \ell}{A}$ $P = I\Delta V$ $I = \frac{\Delta V}{R}$ $R_{\text{eq},s} = \sum_i R_i$ $\frac{1}{R_{\text{eq},p}} = \sum_i \frac{1}{R_i}$ $\frac{1}{C_{\text{eq},s}} = \sum_i \frac{1}{C_i}$ $C_{\text{eq},p} = \sum_i C_i$ $\tau = R_{\text{eq}} C_{\text{eq}}$	$F_B = qvB \sin \theta$ $B = \frac{\mu_0 I}{2\pi r}$ $F_B = I\ell B \sin \theta$ $\Phi_B = \vec{B} \cdot \vec{A}$ $\Phi_B = \vec{B} \cos \theta \vec{A} $ $ \mathcal{E} = \left \frac{\Delta \Phi_B}{\Delta t} \right $ $\mathcal{E} = B\ell v$ <i>A</i> = area <i>B</i> = magnetic field <i>F</i> = force <i>I</i> = current ℓ = length <i>q</i> = charge <i>r</i> = distance, radius, or position <i>t</i> = time <i>v</i> = velocity or speed $\mathcal{E}$ = emf θ = angle Φ = flux
	THERMAL PHYSICS
	$P = \frac{F_{\perp}}{A}$ $K_{\text{avg}} = \frac{3}{2} k_B T = \frac{1}{2} m v_{\text{rms}}^2$ $\frac{Q}{\Delta t} = \frac{kA\Delta T}{L}$ $PV = nRT = Nk_B T$ $U = \frac{3}{2} nRT = \frac{3}{2} Nk_B T$ $W = -P\Delta V$ $\Delta U = Q + W$ $Q = mc\Delta T$ <i>A</i> = area <i>c</i> = specific heat <i>F</i> = force <i>k</i> = thermal conductivity <i>K</i> = kinetic energy <i>L</i> = length <i>m</i> = mass <i>n</i> = number of moles <i>N</i> = number of atoms <i>P</i> = pressure <i>Q</i> = energy transferred to a system by heating <i>t</i> = time <i>T</i> = temperature <i>U</i> = internal energy <i>v</i> = velocity or speed <i>V</i> = volume <i>W</i> = work done on a system

WAVES, SOUND, AND OPTICS		MODERN PHYSICS	
$\lambda = \frac{v}{f}$	$a = \text{width}$	$E = hf$	$A = \text{area}$
$n = \frac{c}{v}$	$A = \text{amplitude}$	$\lambda = \frac{h}{p}$	$E = \text{energy}$
$n_1 \sin \theta_1 = n_2 \sin \theta_2$	$d = \text{separation}$	$\lambda = \frac{c}{f}$	$f = \text{frequency}$
$\frac{1}{s_i} + \frac{1}{s_o} = \frac{1}{f}$	$D = \text{path length}$	$\lambda_{\text{max}} = \frac{b}{T}$	$K = \text{kinetic energy}$
$ M = \left \frac{h_i}{h_o} \right = \left \frac{s_i}{s_o} \right $	$f = \text{frequency or focal length}$	$P = A\sigma T^4$	$m = \text{mass}$
$\Delta D = m\lambda$	$F = \text{force}$	$K_{\text{max}} = hf - \phi$	$N = \text{number of particles}$
$\Delta D = a \sin \theta$	$h = \text{height}$	$\Delta \lambda = \frac{h}{m_e c} (1 - \cos \theta)$	$p = \text{momentum}$
$a \left(\frac{y_{\text{min}}}{L} \right) \approx m\lambda$	$\ell = \text{length}$	$E = mc^2$	$P = \text{power}$
$\Delta D = d \sin \theta$	$L = \text{distance}$	$N = N_0 e^{-\lambda t}$	$t = \text{time}$
$d \left(\frac{y_{\text{max}}}{L} \right) \approx m\lambda$	$m = \text{order or mass}$	$\lambda = \frac{\ln 2}{t_{1/2}}$	$T = \text{absolute temperature}$
$v_{\text{string}} = \sqrt{\frac{F_T}{m/\ell}}$	$M = \text{magnification}$		$\theta = \text{angle}$
$T = \frac{1}{f}$	$n = \text{index of refraction}$		$\lambda = \text{wavelength or decay constant}$
$x(t) = A \cos(\omega t) = A \cos(2\pi ft)$	$s = \text{position}$		$\phi = \text{work function}$
$y(x) = A \cos \left(2\pi \frac{x}{\lambda} \right)$	$t = \text{time}$		
$ f_{\text{beat}} = f_1 - f_2 $	$T = \text{period}$		
	$v = \text{speed}$		
	$x = \text{position}$		
	$y = \text{position}$		
	$\lambda = \text{wavelength}$		
	$\theta = \text{angle}$		
	$\omega = \text{angular frequency}$		

GEOMETRY AND TRIGONOMETRY			
Rectangle $A = bh$	Rectangular Solid $V = \ell wh$		Right Triangle $a^2 + b^2 = c^2$
Triangle $A = \frac{1}{2}bh$	Cylinder $V = \pi r^2 \ell$ $S = 2\pi r \ell + 2\pi r^2$		$\sin \theta = \frac{a}{c}$
Circle $A = \pi r^2$ $C = 2\pi r$ $s = r\theta$	Sphere $V = \frac{4}{3}\pi r^3$ $S = 4\pi r^2$		$\cos \theta = \frac{b}{c}$
		$A = \text{area}$ $b = \text{base}$ $C = \text{circumference}$ $h = \text{height}$ $\ell = \text{length}$ $r = \text{radius}$ $s = \text{arc length}$ $S = \text{surface area}$ $V = \text{volume}$ $w = \text{width}$ $\theta = \text{angle}$	$\tan \theta = \frac{a}{b}$ 

MECHANICS AND FLUIDS

$$v_x = v_{x0} + a_x t$$

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

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

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

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

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

$$|\vec{F}_f| \leq |\mu \vec{F}_N|$$

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

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

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

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

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

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

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

$$\Delta U_g = m g \Delta y$$

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

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

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

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

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

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

a = acceleration

d = distance

E = energy

F = force

J = impulse

k = spring constant

K = kinetic energy

m = mass

p = momentum

P = power

r = radius or distance

t = time

U = potential energy

v = velocity or speed

W = work

x = position

y = vertical position

θ = angle

μ = coefficient of friction

$$\omega = \omega_0 + \alpha t$$

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

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

$$v = r\omega$$

$$a_r = r\alpha$$

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

$$I = \sum m_i r_i^2$$

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

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

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

$$W = \tau \Delta \theta$$

$$L = I \omega$$

$$L = r m v \sin \theta$$

$$\Delta L = \tau \Delta t$$

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

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

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

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

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

$$x = A \sin(2\pi f t)$$

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

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

$$P = P_0 + \rho g h$$

$$P_{\text{gauge}} = \rho g h$$

$$F_b = \rho V g$$

$$A_1 v_1 = A_2 v_2$$

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

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 or distance

t = time

T = period

v = velocity or speed

V = volume

W = work

x = position

y = vertical position

α = angular acceleration

θ = angle or angular position

ρ = density

τ = torque

ω = angular speed