AP® Physics B
2007 Free-Response Questions
Form B

TABLE OF INFORMATION FOR 2006 and 2007

CONSTANTS AND CONVERSION FACTORS	
1 unified atomic mass unit,	$1\text{ u} = 1.66 \times 10^{-27}\text{ kg}$
	$= 931\text{ MeV}/c^2$
Proton mass,	$m_p = 1.67 \times 10^{-27}\text{ kg}$
Neutron mass,	$m_n = 1.67 \times 10^{-27}\text{ kg}$
Electron mass,	$m_e = 9.11 \times 10^{-31}\text{ kg}$
Electron charge magnitude,	$e = 1.60 \times 10^{-19}\text{ C}$
Avogadro's number,	$N_0 = 6.02 \times 10^{23}\text{ mol}^{-1}$
Universal gas constant,	$R = 8.31\text{ J/(mol•K)}$
Boltzmann's constant,	$k_B = 1.38 \times 10^{-23}\text{ J/K}$
Speed of light,	$c = 3.00 \times 10^8\text{ m/s}$
Planck's constant,	$h = 6.63 \times 10^{-34}\text{ J•s}$
	$= 4.14 \times 10^{-15}\text{ eV•s}$
	$hc = 1.99 \times 10^{-25}\text{ J•m}$
	$= 1.24 \times 10^3\text{ eV•nm}$
Vacuum permittivity,	$\epsilon_0 = 8.85 \times 10^{-12}\text{ C}^2/\text{N•m}^2$
Coulomb's law constant,	$k = 1/4\pi\epsilon_0 = 9.0 \times 10^9\text{ N•m}^2/\text{C}^2$
Vacuum permeability,	$\mu_0 = 4\pi \times 10^{-7}\text{ (T•m)/A}$
Magnetic constant,	$k' = \mu_0/4\pi = 10^{-7}\text{ (T·m)/A}$
Universal gravitational constant,	$G = 6.67 \times 10^{-11}\text{ m}^3/\text{kg•s}^2$
Acceleration due to gravity at Earth's surface,	$g = 9.8\text{ m/s}^2$
1 atmosphere pressure,	$1\text{ atm} = 1.0 \times 10^5\text{ N/m}^2$
	$= 1.0 \times 10^5\text{ Pa}$
1 electron volt,	$1\text{ eV} = 1.60 \times 10^{-19}\text{ J}$

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

PREFIXES		
Factor	Prefix	Symbol
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	sin θ	cos θ	tan θ
0°	0	1	0
30°	1/2	$\sqrt{3}/2$	$\sqrt{3}/3$
37°	3/5	4/5	3/4
45°	$\sqrt{2}/2$	$\sqrt{2}/2$	1
53°	4/5	3/5	4/3
60°	$\sqrt{3}/2$	1/2	$\sqrt{3}$
90°	1	0	∞

The following conventions are used in this examination.

I. Unless otherwise stated, the frame of reference of any problem is assumed to be inertial.
II. The direction of any electric current is the direction of flow of positive charge (conventional current).
III. For any isolated electric charge, the electric potential is defined as zero at an infinite distance from the charge.
IV. For mechanics and thermodynamics equations, W represents the work done <u>on</u> a system.

ADVANCED PLACEMENT PHYSICS B EQUATIONS FOR 2006 and 2007

NEWTONIAN MECHANICS

$$\upsilon = \upsilon_0 + at$$

$$x = x_0 + \upsilon_0 t + \frac{1}{2}at^2$$

$$\upsilon^2 = \upsilon_0^2 + 2a(x - x_0)$$

$$\sum \mathbf{F} = \mathbf{F}_{net} = m\mathbf{a}$$

$$F_{fric} \le \mu N$$

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

$$\tau = rF \sin\theta$$

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

$$\mathbf{J} = \mathbf{F}\Delta t = \Delta\mathbf{p}$$

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

$$\Delta U_g = mgh$$

$$W = F\Delta r \cos\theta$$

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

$$P = F\upsilon\cos\theta$$

$$\mathbf{F}_s = -k\mathbf{x}$$

$$U_s = \frac{1}{2}kx^2$$

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

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

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

$$F_G = -\frac{Gm_1m_2}{r^2}$$

$$U_G = -\frac{Gm_1m_2}{r}$$

a = acceleration
F = force
f = frequency
h = height
J = impulse
K = kinetic energy
k = spring constant
ℓ = length
m = mass
N = normal force
P = power
p = momentum
r = radius or distance
$\mathbf{r}$ = position vector
T = period
t = time
U = potential energy
υ = velocity or speed
W = work done on a system
x = position
μ = coefficient of friction
θ = angle
τ = torque

ELECTRICITY AND MAGNETISM

$$F = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r^2}$$

$$\mathbf{E} = \frac{\mathbf{F}}{q}$$

$$U_E = qV = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r}$$

$$E_{avg} = -\frac{V}{d}$$

$$V = \frac{1}{4\pi\epsilon_0}\sum_i \frac{q_i}{r_i}$$

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

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

$$U_c = \frac{1}{2}QV = \frac{1}{2}CV^2$$

$$I_{avg} = \frac{\Delta Q}{\Delta t}$$

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

$$V = IR$$

$$P = IV$$

$$C_p = \sum_i C_i$$

$$\frac{1}{C_s} = \sum_i \frac{1}{C_i}$$

$$R_s = \sum_i R_i$$

$$\frac{1}{R_p} = \sum_i \frac{1}{R_i}$$

$$F_B = q\upsilon B \sin\theta$$

$$F_B = BI\ell \sin\theta$$

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

$$\phi_m = BA\cos\theta$$

$$\varepsilon_{avg} = -\frac{\Delta\phi_m}{\Delta t}$$

$$\varepsilon = B\ell\upsilon$$

A = area
B = magnetic field
C = capacitance
d = distance
E = electric field
ε = emf
F = force
I = current
ℓ = length
P = power
Q = charge
q = point charge
R = resistance
r = distance
t = time
U = potential (stored) energy
V = electric potential or potential difference
υ = velocity or speed
ρ = resistivity
ϕ_m = magnetic flux

ADVANCED PLACEMENT PHYSICS B EQUATIONS FOR 2006 and 2007

FLUID MECHANICS AND THERMAL PHYSICS

$P = P_0 + \rho g h$

$F_{buoy} = \rho V g$

$A_1 v_1 = A_2 v_2$

$P + \rho g y + \frac{1}{2}\rho v^2 = \text{const.}$

$\Delta \ell = \alpha \ell_0 \Delta T$

$H = \frac{kA\Delta T}{L}$

$P = \frac{F}{A}$

$PV = nRT = Nk_B T$

$K_{avg} = \frac{3}{2}k_B T$

$v_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3k_B T}{\mu}}$

$W = -P\Delta V$

$\Delta U = Q + W$

$e = \left|\frac{W}{Q_H}\right|$

$e_c = \frac{T_H - T_C}{T_H}$

A = area
e = efficiency
F = force
h = depth
H = rate of heat transfer
k = thermal conductivity
K_{avg} = average molecular kinetic energy
ℓ = length
L = thickness
M = molar mass
n = number of moles
N = number of molecules
P = pressure
Q = heat transferred to a system
T = temperature
U = internal energy
V = volume
v = velocity or speed
v_{rms} = root-mean-square velocity
W = work done on a system
y = height
α = coefficient of linear expansion
μ = mass of molecule
ρ = density

ATOMIC AND NUCLEAR PHYSICS

$E = hf = pc$

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

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

$\Delta E = (\Delta m)c^2$

E = energy
f = frequency
K = kinetic energy
m = mass
p = momentum
λ = wavelength
ϕ = work function

WAVES AND OPTICS

$v = f\lambda$

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

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

$\sin\theta_c = \frac{n_2}{n_1}$

$\frac{1}{s_i} + \frac{1}{s_0} = \frac{1}{f}$

$M = \frac{h_i}{h_0} = -\frac{s_i}{s_0}$

$f = \frac{R}{2}$

$d\sin\theta = m\lambda$

$x_m \sim \frac{m\lambda L}{d}$

d = separation
f = frequency or focal length
h = height
L = distance
M = magnification
m = an integer
n = index of refraction
R = radius of curvature
s = distance
v = speed
x = position
λ = wavelength
θ = angle

GEOMETRY AND TRIGONOMETRY

Rectangle
$A = bh$

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

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

Parallelepiped
$V = \ell w h$

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

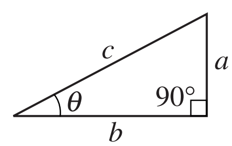
Sphere
$V = \frac{4}{3}\pi r^3$
$S = 4\pi r^2$

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

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

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

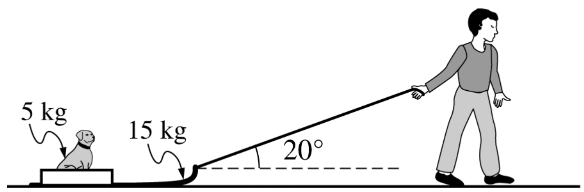
$\tan\theta = \frac{a}{b}$



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

PHYSICS B
SECTION II
Time—90 minutes
7 Questions

Directions: Answer all seven questions, which are weighted according to the points indicated. The suggested times are about 17 minutes for answering each of Questions 1 and 3 and about 11 minutes for answering each of Questions 2 and 4-7. The parts within a question may not have equal weight. Show all your work in the goldenrod booklet in the spaces provided after each part, NOT in this lavender insert.



1. (15 points)

A child pulls a 15 kg sled containing a 5.0 kg dog along a straight path on a horizontal surface. He exerts a force of 55 N on the sled at an angle of 20º above the horizontal, as shown in the figure above. The coefficient of friction between the sled and the surface is 0.22.

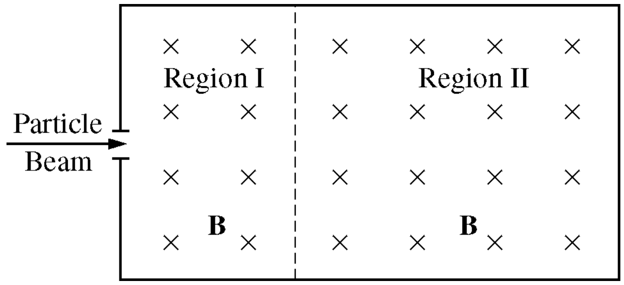
(a) On the dot below that represents the sled-dog system, draw and label a free-body diagram for the system as it is pulled along the surface.

(b) Calculate the normal force of the surface on the system.

(c) Calculate the acceleration of the system.

(d) Calculate the work done by the child's pulling force as the system moves a distance of 7.0 m.

(e) At some later time, the dog rolls off the side of the sled. The child continues to pull with the same force. On the axes below, sketch a graph of speed v versus time t for the sled. Include both the sled's travel with and without the dog on the sled. Clearly indicate with the symbol t_r the time at which the dog rolls off.



2. (10 points)

A beam of particles of charge $q = +3.2 \times 10^{-19}$ C and mass $m = 6.68 \times 10^{-26}$ kg enters region I with a range of velocities all in the direction shown in the diagram above. There is a magnetic field in region I directed into the page with magnitude $B = 0.12$ T. Charged metal plates are placed in appropriate locations to create a uniform electric field of magnitude $E = 4800$ N/C in region I. As a result, some of the charged particles pass straight through region I undeflected. Gravitational effects are negligible.

(a)

i. On the diagram above, sketch electric field lines in region I.

ii. Calculate the speed of the particles that pass straight through region I.

The particles that pass straight through enter region II in which there is no electric field and the magnetic field has the same magnitude and direction as in region I. The path of the particles in region II is a circular arc of radius R.

(b) Calculate the radius R.

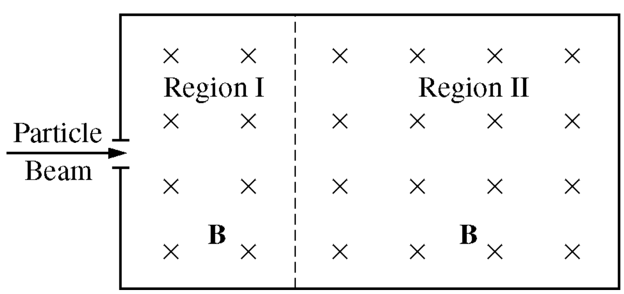
(c) Within the beam there are particles moving slower than the speed you calculated in (a)ii. In what direction is the net initial force on these particles as they enter region I?

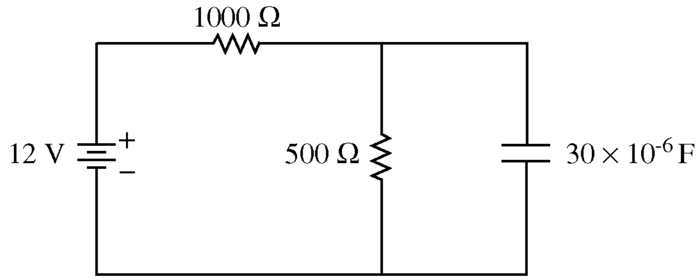
____ To the left ____ Toward the top of the page ____ Out of the plane of the page

____ To the right ____ Toward the bottom of the page ____ Into the plane of the page

Justify your answer.

(d) A particle of the same mass and the same speed as in (a)ii but with charge $q = -3.2 \times 10^{-19}$ C enters region I. On the following diagram, sketch the complete resulting path of the particle.





3. (15 points)

In the circuit above, a 12.0 V battery is connected to two resistors, one of resistance $1000\ \Omega$ and the other of resistance $500\ \Omega$. A capacitor with a capacitance of 30×10^{-6} F is connected in parallel with the $500\ \Omega$ resistor. The circuit has been connected for a long time, and all currents have reached their steady states.

(a) Calculate the current in the $500\ \Omega$ resistor.

(b)

i. Draw an ammeter in the circuit above in a location such that it could measure the current in the $500\ \Omega$ resistor. Use the symbol (A) to indicate the ammeter.

ii. Draw a voltmeter in the circuit above in a location such that it could measure the voltage across the $1000\ \Omega$ resistor. Use the symbol (V) to indicate the voltmeter.

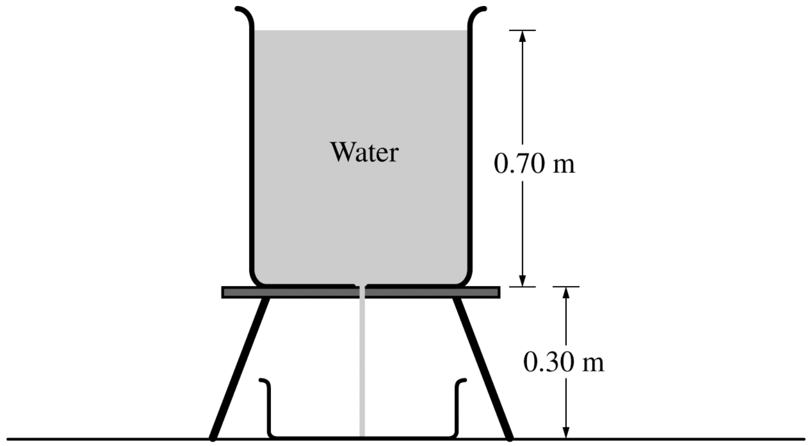
(c) Calculate the charge stored on the capacitor.

(d) Calculate the power dissipated in the $1000\ \Omega$ resistor.

(e) The capacitor is now discharged, and the $500\ \Omega$ resistor is removed and replaced by a resistor of greater resistance. The circuit is reconnected, and currents are again allowed to come to their steady-state values. Is the charge now stored on the capacitor larger, smaller, or the same as it was in part (c)?

____ Larger ____ Smaller ____ The same as

Justify your answer.



4. (10 points)

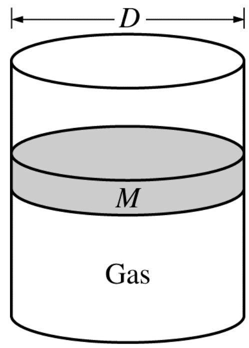
A cylindrical tank containing water of density 1000 kg/m^3 is filled to a height of 0.70 m and placed on a stand as shown in the cross section above. A hole of radius 0.0010 m in the bottom of the tank is opened. Water then flows through the hole and through an opening in the stand and is collected in a tray 0.30 m below the hole. At the same time, water is added to the tank at an appropriate rate so that the water level in the tank remains constant.

(a) Calculate the speed at which the water flows out from the hole.

(b) Calculate the volume rate at which water flows out from the hole.

(c) Calculate the volume of water collected in the tray in $t = 2.0$ minutes.

(d) Calculate the time it takes for a given droplet of water to fall 0.25 m from the hole.



5. (10 points)

The cylinder above contains an ideal gas and has a movable, frictionless piston of diameter D and mass M. The cylinder is in a laboratory with atmospheric pressure P_{atm}. Express all algebraic answers in terms of the given quantities and fundamental constants.

(a) Initially, the piston is free to move but remains in equilibrium. Determine each of the following.

i. The force that the confined gas exerts on the piston

ii. The absolute pressure of the confined gas

(b) If a net amount of heat is transferred to the confined gas when the piston is fixed, what happens to the pressure of the gas?

____ Pressure goes up. ____ Pressure goes down. ____ Pressure stays the same.

Explain your reasoning.

(c) In a certain process the absolute pressure of the confined gas remains constant as the piston moves up a distance x_0. Calculate the work done by the confined gas during the process.

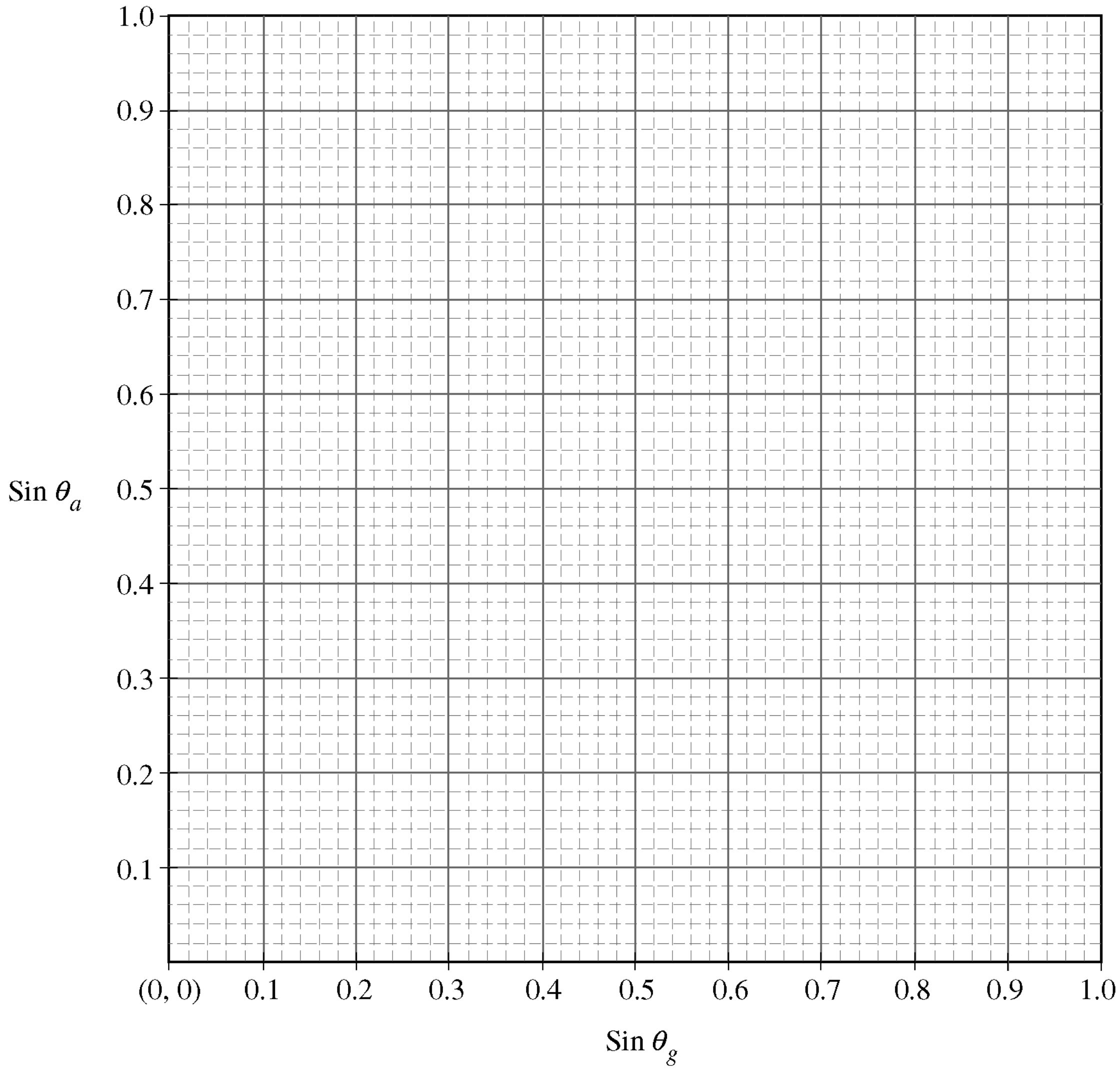
6. (10 points)

A student is asked to determine the index of refraction of a glass slab. She conducts several trials for measurement of angle of incidence θ_a in the air versus angle of refraction θ_g in the glass at the surface of the slab. She records her data in the following table. The index of refraction in air is 1.0.

Trial #	θ_g (degrees)	θ_a (degrees)	Sin θ_g	Sin θ_a
1	5.0	8.0	0.09	0.14
2	15	21	0.26	0.36
3	25	39	0.42	0.63
4	35	56	0.57	0.83

GO ON TO THE NEXT PAGE.

(a) Plot the data points on the axes below and draw a best-fit line through the points.



(b) Calculate the index of refraction of the glass slab from your best-fit line.

(c) Describe how you could use the graph to determine the critical angle for the glass-air interface. Do not use the answer to the part (b) for this purpose.

(d) On the graph in (a), sketch and label a line for a material of higher index of refraction.

GO ON TO THE NEXT PAGE.

7. (10 points)

In the vicinity of a heavy nucleus, a high-energy photon can be converted into two particles: an electron and a positron. A positron has the same mass as the electron and equal but opposite charge. This process is called pair production.

(a) Calculate the rest energy of an electron, in eV.

(b) Determine the minimum energy, in eV, that a photon must have to give rise to pair production.

(c) Calculate the wavelength corresponding to the photon energy found in part (b).

(d) Calculate the momentum of the photon.

END OF EXAM