AP® Physics B
2006 Free-Response Questions

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TABLE OF INFORMATION FOR 2006 and 2007

CONSTANTS AND CONVERSION FACTORS

1 unified atomic mass unit,	$1\ \text{u} = 1.66\times10^{-27}$ kg
	$= 931\ \text{MeV}/c^2$
Proton mass,	$m_p = 1.67\times10^{-27}$ kg
Neutron mass,	$m_n = 1.67\times10^{-27}$ kg
Electron mass,	$m_e = 9.11\times10^{-31}$ kg
Electron charge magnitude,	$e = 1.60\times10^{-19}$ C
Avogadro's number,	$N_0 = 6.02\times10^{23}\ \text{mol}^{-1}$
Universal gas constant,	$R = 8.31$ J/(mol•K)
Boltzmann's constant,	$k_B = 1.38\times10^{-23}$ J/K
Speed of light,	$c = 3.00\times10^{8}$ m/s
Planck's constant,	$h = 6.63\times10^{-34}$ J•s
	$= 4.14\times10^{-15}$ eV•s
	$hc = 1.99\times10^{-25}$ J•m
	$= 1.24\times10^{3}$ eV•nm
Vacuum permittivity,	$\epsilon_0 = 8.85\times10^{-12}\ \text{C}^2/\text{N}\cdot\text{m}^2$
Coulomb's law constant,	$k = 1/4\pi\epsilon_0 = 9.0\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2$
Vacuum permeability,	$\mu_0 = 4\pi\times10^{-7}$ (T•m)/A
Magnetic constant,	$k' = \mu_0/4\pi = 10^{-7}$ (T·m)/A
Universal gravitational constant,	$G = 6.67\times10^{-11}\ \text{m}^3/\text{kg}\cdot\text{s}^2$
Acceleration due to gravity at Earth's surface,	$g = 9.8\ \text{m/s}^2$
1 atmosphere pressure,	$1\ \text{atm} = 1.0\times10^{5}\ \text{N/m}^2$
	$= 1.0\times10^{5}$ Pa
1 electron volt,	$1\ \text{eV} = 1.60\times10^{-19}$ 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

$$\upsilon = \upsilon_0 + at$$

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

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

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

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

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

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

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

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

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

$$\Delta U_g = mgh$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$V = IR$$

$$P = IV$$

$$C_p = \sum_i C_i$$

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

$$R_s = \sum_i R_i$$

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

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

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

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

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

$$\mathcal{E}_{avg} = -\frac{\Delta\phi_m}{\Delta t}$$

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

A = area
B = magnetic field
C = capacitance
d = distance
E = electric field
$\mathcal{E}$ = 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

$P = P_0 + \rho g h$

$F_{buoy} = \rho V g$

$A_1 \upsilon_1 = A_2 \upsilon_2$

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

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

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

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

$PV = nRT = Nk_B T$

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

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

$W = -P\Delta V$

$\Delta U = Q + W$

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

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

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
υ = velocity or speed
υ_{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

$\upsilon = f\lambda$

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

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

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

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

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

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

$d\sin\theta = m\lambda$

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

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

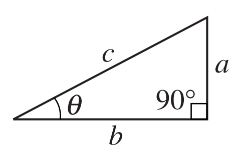
Sphere
$V = \frac{4}{3}\pi r^3$
$S = 4\pi r^2$

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

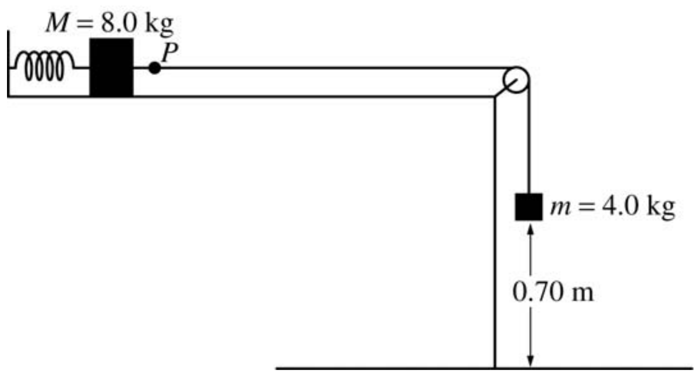
PHYSICS B

SECTION II

Time—90 minutes

6 Questions

Directions: Answer all six questions, which are weighted according to the points indicated. The suggested times are about 17 minutes for answering each of Questions 1-4 and about 11 minutes for answering each of Questions 5-6. The parts within a question may not have equal weight. Show all your work in the pink booklet in the spaces provided after each part, NOT in this green insert.



1. (15 points)

An ideal spring of unstretched length 0.20 m is placed horizontally on a frictionless table as shown above. One end of the spring is fixed and the other end is attached to a block of mass $M = 8.0$ kg. The 8.0 kg block is also attached to a massless string that passes over a small frictionless pulley. A block of mass $m = 4.0$ kg hangs from the other end of the string. When this spring-and-blocks system is in equilibrium, the length of the spring is 0.25 m and the 4.0 kg block is 0.70 m above the floor.

(a) On the figures below, draw free-body diagrams showing and labeling the forces on each block when the system is in equilibrium.

$M = 8.0$ kg $\qquad\qquad\qquad\qquad$ $m = 4.0$ kg

(b) Calculate the tension in the string.

(c) Calculate the force constant of the spring.

The string is now cut at point P.

(d) Calculate the time taken by the 4.0 kg block to hit the floor.

(e) Calculate the frequency of oscillation of the 8.0 kg block.

(f) Calculate the maximum speed attained by the 8.0 kg block.

2. (15 points)

A world-class runner can complete a 100 m dash in about 10 s. Past studies have shown that runners in such a race accelerate uniformly for a time t_u and then run at constant speed for the remainder of the race. A world-class runner is visiting your physics class. You are to develop a procedure that will allow you to determine the uniform acceleration a_u and an approximate value of t_u for the runner in a 100 m dash. By necessity your experiment will be done on a straight track and include your whole class of eleven students.

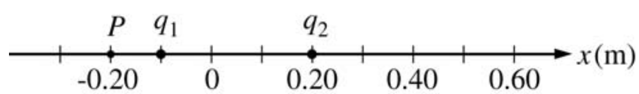
(a) By checking the line next to each appropriate item in the list below, select the equipment, other than the runner and the track, that your class will need to do the experiment.

____ Stopwatches ____ Tape measures ____ Rulers ____ Masking tape

____ Metersticks ____ Starter's pistol ____ String ____ Chalk

(b) Outline the procedure that you would use to determine a_u and t_u, including a labeled diagram of the experimental setup. Use symbols to identify carefully what measurements you would make and include in your procedure how you would use each piece of the equipment you checked in part (a).

(c) Outline the process of data analysis, including how you will identify the portion of the race that has uniform acceleration, and how you would calculate the uniform acceleration.



3. (15 points)

Two point charges, q_1 and q_2, are placed 0.30 m apart on the x-axis, as shown in the figure above. Charge q_1 has a value of -3.0×10^{-9} C. The net electric field at point P is zero.

(a) What is the sign of charge q_2?

____Positive ____ Negative

Justify your answer.

(b) Calculate the magnitude of charge q_2.

(c) Calculate the magnitude of the electric force on q_2 and indicate its direction.

(d) Determine the x-coordinate of the point on the line <u>between</u> the two charges at which the electric potential is zero.

(e) How much work must be done by an external force to bring an electron from infinity to the point at which the electric potential is zero? Explain your reasoning.

GO ON TO THE NEXT PAGE.

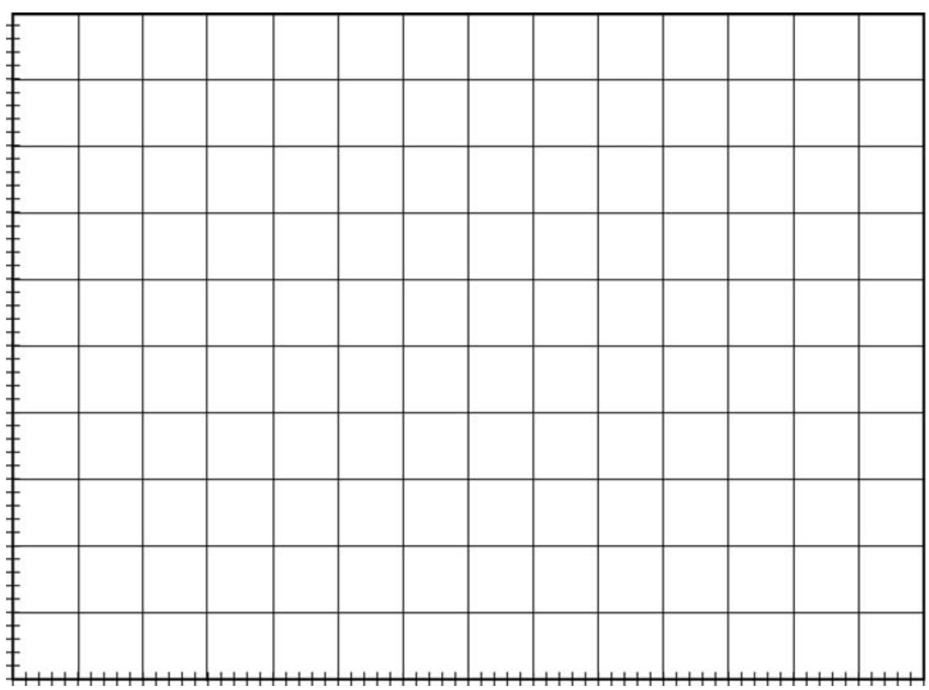
4. (15 points)

A student performs an experiment to determine the index of refraction n of a rectangular glass slab in air. She is asked to use a laser beam to measure angles of incidence θ_i in air and corresponding angles of refraction θ_r in glass. The measurements of the angles for five trials are given in the table below.

Trial	θ_i	θ_r		
1	30°	20°		
2	40°	27°		
3	50°	32°		
4	60°	37°		
5	70°	40°		

(a) Complete the last two columns in the table by calculating the quantities that need to be graphed to provide a linear relationship from which the index of refraction can be determined. Label the top of each column.

(b) On the grid below, plot the quantities calculated in (a) and draw an appropriate graph from which the index of refraction can be determined. Label the axes.



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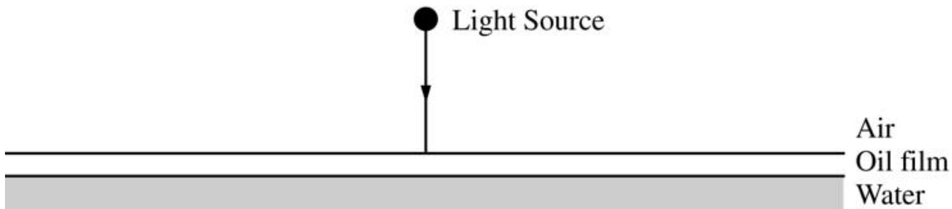
(c) Using the graph, calculate the index of refraction of the glass slab.



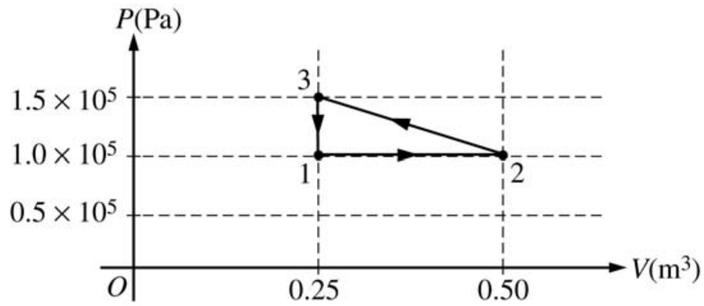
The student is also asked to determine the thickness of a film of oil ($n = 1.43$) on the surface of water ($n = 1.33$). Light from a variable wavelength source is incident vertically onto the oil film as shown above. The student measures a maximum in the intensity of the reflected light when the incident light has a wavelength of 600 nm.

(d) At which of the two interfaces does the light undergo a 180º phase change on reflection?

___The air-oil interface only ___The oil-water interface only

___Both interfaces ___Neither interface

(e) Calculate the minimum possible thickness of the oil film.



5. (10 points)

A cylinder with a movable frictionless piston contains an ideal gas that is initially in state 1 at 1×10^5 Pa, 373 K, and $0.25\ \text{m}^3$. The gas is taken through a reversible thermodynamic cycle as shown in the PV diagram above.

(a) Calculate the temperature of the gas when it is in the following states.

i. State 2

ii. State 3

(b) Calculate the net work done on the gas during the cycle.

(c) Was heat added to or removed from the gas during the cycle?

____ Added ____ Removed ____ Neither added nor removed

Justify your answer.

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6. (10 points)

A photon with a wavelength of 1.5×10^{-8} m is emitted from an ultraviolet source into a vacuum.

(a) Calculate the energy of the photon.

(b) Calculate the de Broglie wavelength of an electron with kinetic energy equal to the energy of the photon.

(c) Describe an experiment that illustrates the wave properties of this electron.

END OF EXAM