



AP[®] Physics B 2007 Free-Response Questions

The College Board: Connecting Students to College Success

The College Board is a not-for-profit membership association whose mission is to connect students to college success and opportunity. Founded in 1900, the association is composed of more than 5,000 schools, colleges, universities, and other educational organizations. Each year, the College Board serves seven million students and their parents, 23,000 high schools, and 3,500 colleges through major programs and services in college admissions, guidance, assessment, financial aid, enrollment, and teaching and learning. Among its best-known programs are the SAT[®], the PSAT/NMSQT[®], and the Advanced Placement Program[®] (AP[®]). The College Board is committed to the principles of excellence and equity, and that commitment is embodied in all of its programs, services, activities, and concerns.

© 2007 The College Board. All rights reserved. College Board, Advanced Placement Program, AP, AP Central, SAT, and the acorn logo are registered trademarks of the College Board. PSAT/NMSQT is a registered trademark of the College Board and National Merit Scholarship Corporation.

Permission to use copyrighted College Board materials may be requested online at:
www.collegeboard.com/inquiry/cbpermit.html.

Visit the College Board on the Web: www.collegeboard.com.

AP Central is the official online home for the AP Program: apcentral.collegeboard.com.

TABLE OF INFORMATION FOR 2006 and 2007

CONSTANTS AND CONVERSION FACTORS		UNITS		PREFIXES		
		Name	Symbol	Factor	Prefix	Symbol
1 unified atomic mass unit,	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$ $= 931 \text{ MeV}/c^2$	meter	m	10^9	giga	G
Proton mass,	$m_p = 1.67 \times 10^{-27} \text{ kg}$	kilogram	kg	10^6	mega	M
Neutron mass,	$m_n = 1.67 \times 10^{-27} \text{ kg}$	second	s	10^3	kilo	k
Electron mass,	$m_e = 9.11 \times 10^{-31} \text{ kg}$	ampere	A	10^{-2}	centi	c
Electron charge magnitude,	$e = 1.60 \times 10^{-19} \text{ C}$	kelvin	K	10^{-3}	milli	m
Avogadro's number,	$N_0 = 6.02 \times 10^{23} \text{ mol}^{-1}$	mole	mol	10^{-6}	micro	μ
Universal gas constant,	$R = 8.31 \text{ J/(mol}\cdot\text{K)}$	hertz	Hz	10^{-9}	nano	n
Boltzmann's constant,	$k_B = 1.38 \times 10^{-23} \text{ J/K}$	newton	N	10^{-12}	pico	p
Speed of light,	$c = 3.00 \times 10^8 \text{ m/s}$	pascal	Pa	VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES		
Planck's constant,	$h = 6.63 \times 10^{-34} \text{ J}\cdot\text{s}$ $= 4.14 \times 10^{-15} \text{ eV}\cdot\text{s}$ $hc = 1.99 \times 10^{-25} \text{ J}\cdot\text{m}$ $= 1.24 \times 10^3 \text{ eV}\cdot\text{nm}$	joule	J			
Vacuum permittivity,	$\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{N}\cdot\text{m}^2$	watt	W	θ	$\sin \theta$	$\cos \theta$
Coulomb's law constant,	$k = 1/4\pi\epsilon_0 = 9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$	coulomb	C	0°	0	1
Vacuum permeability,	$\mu_0 = 4\pi \times 10^{-7} \text{ (T}\cdot\text{m)}/\text{A}$	volt	V	30°	1/2	$\sqrt{3}/2$
Magnetic constant,	$k' = \mu_0/4\pi = 10^{-7} \text{ (T}\cdot\text{m)}/\text{A}$	ohm	Ω	37°	3/5	4/5
Universal gravitational constant,	$G = 6.67 \times 10^{-11} \text{ m}^3/\text{kg}\cdot\text{s}^2$	henry	H	45°	$\sqrt{2}/2$	$\sqrt{2}/2$
Acceleration due to gravity at Earth's surface,	$g = 9.8 \text{ m/s}^2$	farad	F	53°	4/5	3/5
1 atmosphere pressure,	$1 \text{ atm} = 1.0 \times 10^5 \text{ N/m}^2$ $= 1.0 \times 10^5 \text{ Pa}$	tesla	T	60°	$\sqrt{3}/2$	1/2
1 electron volt,	$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$	degree Celsius	$^\circ\text{C}$	90°	1	0
		electron-volt	eV			∞

The following conventions are used in this examination.

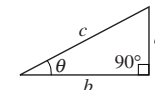
- I. Unless otherwise stated, the frame of reference of any problem is assumed to be inertial.
- II. The direction of any electric current is the direction of flow of positive charge (conventional current).
- III. For any isolated electric charge, the electric potential is defined as zero at an infinite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

ADVANCED PLACEMENT PHYSICS B EQUATIONS FOR 2006 and 2007

NEWTONIAN MECHANICS		ELECTRICITY AND MAGNETISM	
$v = v_0 + at$	a = acceleration	$F = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2}$	A = area
$x = x_0 + v_0 t + \frac{1}{2} at^2$	F = force	$\mathbf{E} = \frac{\mathbf{F}}{q}$	B = magnetic field
$v^2 = v_0^2 + 2a(x - x_0)$	f = frequency	$U_E = qV = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r}$	C = capacitance
$\Sigma \mathbf{F} = \mathbf{F}_{net} = m\mathbf{a}$	h = height	$E_{avg} = -\frac{V}{d}$	d = distance
$F_{fric} \leq \mu N$	J = impulse	$V = \frac{1}{4\pi\epsilon_0} \sum_i \frac{q_i}{r_i}$	E = electric field
$a_c = \frac{v^2}{r}$	K = kinetic energy	$C = \frac{Q}{V}$	$\mathcal{E}$ = emf
$\tau = rF \sin \theta$	k = spring constant	$C = \frac{\epsilon_0 A}{d}$	F = force
$\mathbf{p} = m\mathbf{v}$	ℓ = length	$U_c = \frac{1}{2} QV = \frac{1}{2} CV^2$	I = current
$\mathbf{J} = \mathbf{F}\Delta t = \Delta \mathbf{p}$	m = mass	$I_{avg} = \frac{\Delta Q}{\Delta t}$	ℓ = length
$K = \frac{1}{2} mv^2$	N = normal force	$R = \frac{\rho \ell}{A}$	P = power
$\Delta U_g = mgh$	P = power	$V = IR$	Q = charge
$W = F\Delta r \cos \theta$	p = momentum	$P = IV$	q = point charge
$P_{avg} = \frac{W}{\Delta t}$	r = radius or distance	$C_p = \sum_i C_i$	R = resistance
$P = Fv \cos \theta$	T = period	$\frac{1}{C_s} = \sum_i \frac{1}{C_i}$	r = distance
$\mathbf{F}_s = -k\mathbf{x}$	t = time	$R_s = \sum_i R_i$	t = time
$U_s = \frac{1}{2} kx^2$	U = potential energy	$\frac{1}{R_p} = \sum_i \frac{1}{R_i}$	U = potential (stored) energy
$T_s = 2\pi \sqrt{\frac{m}{k}}$	v = velocity or speed	$F_B = qvB \sin \theta$	V = electric potential or potential difference
$T_p = 2\pi \sqrt{\frac{\ell}{g}}$	W = work done on a system	$F_B = BI\ell \sin \theta$	v = velocity or speed
$T = \frac{1}{f}$	x = position	$B = \frac{\mu_0 I}{2\pi r}$	ρ = resistivity
$F_G = -\frac{Gm_1 m_2}{r^2}$	μ = coefficient of friction	$\phi_m = BA \cos \theta$	θ = angle
$U_G = -\frac{Gm_1 m_2}{r}$	θ = angle	$\mathcal{E}_{avg} = -\frac{\Delta \phi_m}{\Delta t}$	ϕ_m = magnetic flux
	τ = torque	$\mathcal{E} = B\ell v$	

ADVANCED PLACEMENT PHYSICS B EQUATIONS FOR 2006 and 2007

FLUID MECHANICS AND THERMAL PHYSICS		WAVES AND OPTICS	
$P = P_0 + \rho gh$	A = area	$v = f\lambda$	d = separation
$F_{buoy} = \rho Vg$	e = efficiency	$n = \frac{c}{v}$	f = frequency or focal length
$A_1 v_1 = A_2 v_2$	F = force	$n_1 \sin \theta_1 = n_2 \sin \theta_2$	h = height
$P + \rho gy + \frac{1}{2} \rho v^2 = \text{const.}$	h = depth	$\sin \theta_c = \frac{n_2}{n_1}$	L = distance
$\Delta \ell = \alpha \ell_0 \Delta T$	H = rate of heat transfer	$\frac{1}{s_i} + \frac{1}{s_o} = \frac{1}{f}$	M = magnification
$H = \frac{kA\Delta T}{L}$	k = thermal conductivity	$M = \frac{h_i}{h_o} = -\frac{s_i}{s_o}$	m = an integer
$P = \frac{F}{A}$	K_{avg} = average molecular kinetic energy	$d \sin \theta = m\lambda$	n = index of refraction
$PV = nRT = Nk_B T$	ℓ = length	$x_m \sim \frac{m\lambda L}{d}$	R = radius of curvature
$K_{avg} = \frac{3}{2} k_B T$	L = thickness		s = distance
$v_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3k_B T}{\mu}}$	M = molar mass		v = speed
$W = -P\Delta V$	n = number of moles		x = position
$\Delta U = Q + W$	N = number of molecules		λ = wavelength
$e = \left \frac{W}{Q_H} \right $	P = pressure		θ = angle
$e_c = \frac{T_H - T_C}{T_H}$	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		GEOMETRY AND TRIGONOMETRY	
$E = hf = pc$	E = energy	Rectangle	A = area
$K_{max} = hf - \phi$	f = frequency	$A = bh$	C = circumference
$\lambda = \frac{h}{p}$	K = kinetic energy	Triangle	V = volume
$\Delta E = (\Delta m)c^2$	m = mass	$A = \frac{1}{2} bh$	S = surface area
	p = momentum	Circle	b = base
	λ = wavelength	$A = \pi r^2$	h = height
	ϕ = work function	$C = 2\pi r$	ℓ = length
		Parallelepiped	w = width
		$V = \ell wh$	r = radius
		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	
		$a^2 + b^2 = c^2$	
		$\sin \theta = \frac{a}{c}$	
		$\cos \theta = \frac{b}{c}$	
		$\tan \theta = \frac{a}{b}$	



2007 AP[®] PHYSICS B FREE-RESPONSE QUESTIONS

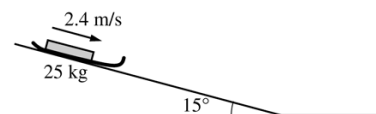
PHYSICS B

SECTION II

Time—90 minutes

7 Questions

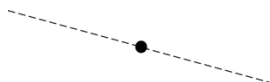
Directions: Answer all seven questions, which are weighted according to the points indicated. The suggested times are about 17 minutes for answering each of Questions 1 and 3 and about 11 minutes for answering each of Questions 2 and 4-7. The parts within a question may not have equal weight. Show all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



1. (15 points)

An empty sled of mass 25 kg slides down a muddy hill with a constant speed of 2.4 m/s. The slope of the hill is inclined at an angle of 15° with the horizontal as shown in the figure above.

- Calculate the time it takes the sled to go 21 m down the slope.
- On the dot below that represents the sled, draw and label a free-body diagram for the sled as it slides down the slope.



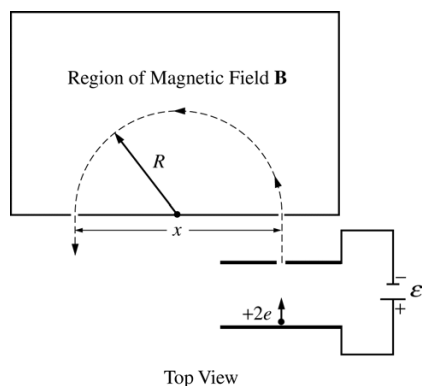
- Calculate the frictional force on the sled as it slides down the slope.
- Calculate the coefficient of friction between the sled and the muddy surface of the slope.
- The sled reaches the bottom of the slope and continues on the horizontal ground. Assume the same coefficient of friction.
 - In terms of velocity and acceleration, describe the motion of the sled as it travels on the horizontal ground.

2007 AP[®] PHYSICS B FREE-RESPONSE QUESTIONS

- On the axes below, sketch a graph of speed v versus time t for the sled. Include both the sled's travel down the slope and across the horizontal ground. Clearly indicate with the symbol t_f the time at which the sled leaves the slope.



2007 AP[®] PHYSICS B FREE-RESPONSE QUESTIONS



2. (10 points)

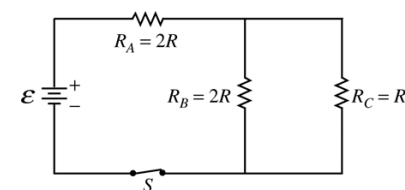
Your research director has assigned you to set up the laboratory's mass spectrometer so that it will separate strontium ions having a net charge of $+2e$ from a beam of mixed ions. The spectrometer above accelerates a beam of ions from rest through a potential difference $\mathcal{E}$, after which the beam enters a region containing a uniform magnetic field $\mathbf{B}$ of constant magnitude and perpendicular to the plane of the path of the ions. The ions leave the spectrometer at a distance x from the entrance point. You can manually change $\mathcal{E}$.

Numerical values for this experiment:

Strontium atomic number:	38
Strontium ion mass:	1.45×10^{-25} kg
Magnitude of B field:	0.090 T
Desired exit distance x :	1.75 m

- In what direction must $\mathbf{B}$ point to produce the trajectory of the ions shown?
- The ions travel at constant speed around the semicircular path. Explain why the speed remains constant.
- Calculate the speed of the ions with charge $+2e$ that exit at distance x .
- Calculate the accelerating voltage $\mathcal{E}$ needed for the ions with charge $+2e$ to attain the speed you calculated in part (c).

2007 AP[®] PHYSICS B FREE-RESPONSE QUESTIONS



3. (15 points)

The circuit above contains a battery with negligible internal resistance, a closed switch S , and three resistors, each with a resistance of R or $2R$.

(a)

- Rank the currents in the three resistors from greatest to least, with number 1 being greatest. If two resistors have the same current, give them the same ranking.

_____ I_A _____ I_B _____ I_C

- Justify your answers.

(b)

- Rank the voltages across the three resistors from greatest to least, with number 1 being greatest. If two resistors have the same voltage across them, give them the same ranking.

_____ V_A _____ V_B _____ V_C

- Justify your answers.

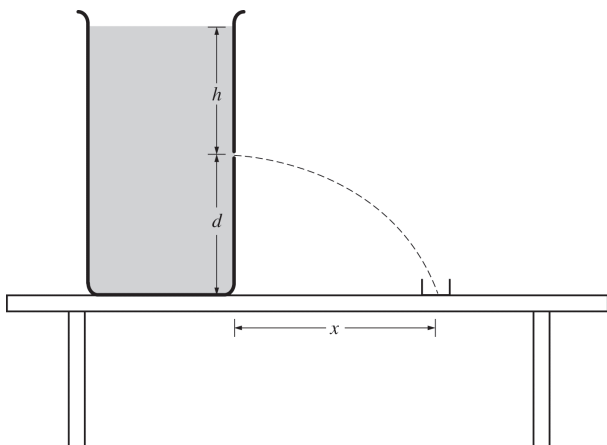
For parts (c) through (e), use $\mathcal{E} = 12$ V and $R = 200 \, \Omega$.

(c) Calculate the equivalent resistance of the circuit.

(d) Calculate the current in resistor R_C .

(e) The switch S is opened, resistor R_B is removed and replaced by a capacitor of capacitance 2.0×10^{-6} F, and the switch S is again closed. Calculate the charge on the capacitor after all the currents have reached their final steady-state values.

2007 AP[®] PHYSICS B FREE-RESPONSE QUESTIONS



4. (10 points)

The large container shown in the cross section above is filled with a liquid of density $1.1 \times 10^3 \text{ kg/m}^3$. A small hole of area $2.5 \times 10^{-6} \text{ m}^2$ is opened in the side of the container a distance h below the liquid surface, which allows a stream of liquid to flow through the hole and into a beaker placed to the right of the container. At the same time, liquid is also added to the container at an appropriate rate so that h remains constant. The amount of liquid collected in the beaker in 2.0 minutes is $7.2 \times 10^{-4} \text{ m}^3$.

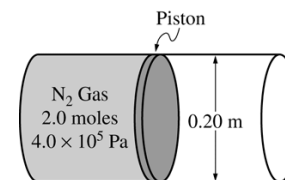
- Calculate the volume rate of flow of liquid from the hole in m^3/s .
- Calculate the speed of the liquid as it exits from the hole.
- Calculate the height h of liquid needed above the hole to cause the speed you determined in part (b).
- Suppose that there is now less liquid in the beaker so that the height h is reduced to $h/2$. In relation to the beaker, where will the liquid hit the tabletop?

___ Left of the beaker ___ In the beaker ___ Right of the beaker

Justify your answer.

should say "container"

2007 AP[®] PHYSICS B FREE-RESPONSE QUESTIONS



5. (10 points)

The figure above shows a 0.20 m diameter cylinder fitted with a frictionless piston, initially fixed in place. The cylinder contains 2.0 moles of nitrogen gas at an absolute pressure of $4.0 \times 10^5 \text{ Pa}$. Nitrogen gas has a molar mass of 28 g/mole and it behaves as an ideal gas.

- Calculate the force that the nitrogen gas exerts on the piston.
- Calculate the volume of the gas if the temperature of the gas is 300 K.
- In a certain process, the piston is allowed to move, and the gas expands at constant pressure and pushes the piston out 0.15 m. Calculate how much work is done by the gas.
- Which of the following is true of the heat energy transferred to or from the gas, if any, in the process in part (c)?

___ Heat is transferred to the gas.

___ Heat is transferred from the gas.

___ No heat is transferred in the process.

Justify your answer.

2007 AP[®] PHYSICS B FREE-RESPONSE QUESTIONS

6. (10 points)

You are asked to experimentally determine the focal length of a converging lens.

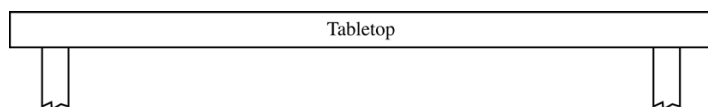
- (a) Your teacher first asks you to estimate the focal length by using a distant tree visible through the laboratory window. Explain how you will estimate the focal length.

To verify the value of the focal length, you are to measure several object distances s_o and image distances s_i using equipment that can be set up on a tabletop in the laboratory.

- (b) In addition to the lens, which of the following equipment would you use to obtain the data?

☐ Lighted candle ☐ Candleholder ☐ Desk lamp ☐ Plane mirror
☐ Vernier caliper ☐ Meterstick ☐ Ruler ☐ Lens holder
☐ Stopwatch ☐ Screen ☐ Diffraction grating

- (c) On the tabletop below, sketch the setup used to obtain the data, labeling the lens, the distances s_o and s_i , and the equipment checked in part (b).

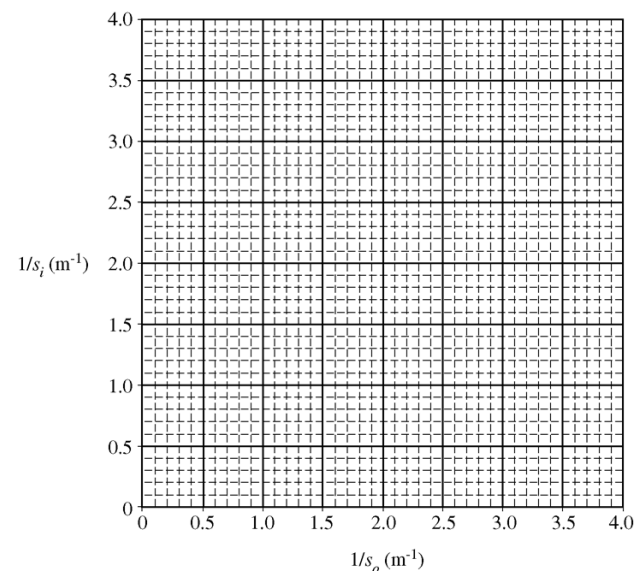


You are to determine the focal length using a linear graph of $1/s_i$ versus $1/s_o$. Assume that you obtain the following data for object distance s_o and image distance s_i .

Trial #	s_o (m)	s_i (m)	$1/s_o$ (m^{-1})	$1/s_i$ (m^{-1})
1	0.40	1.10	2.5	0.91
2	0.50	0.75	2.0	1.3
3	0.60	0.60	1.7	1.7
4	0.80	0.50	1.2	2.0
5	1.20	0.38	0.83	2.6

2007 AP[®] PHYSICS B FREE-RESPONSE QUESTIONS

- (d) On the grid below, plot the points in the last two columns of the table above and draw a best-fit line through the points.



- (e) Calculate the focal length from the best-fit line.

2007 AP[®] PHYSICS B FREE-RESPONSE QUESTIONS

7. (10 points)

It is possible for an electron and a positron to orbit around their stationary center of mass until they annihilate each other, creating two photons of equal energy moving in opposite directions. A positron is a particle that has the same mass as an electron and equal but opposite charge. The amount of kinetic energy of the electron-positron pair before annihilation is negligible compared to the energy of the photons created.

- (a) Calculate, in eV, the rest energy of a positron.
- (b) Determine, in eV, the energy each emitted photon must have.
- (c) Calculate the wavelength of each created photon.
- (d) Calculate the magnitude of the momentum of each photon.
- (e) Determine the total momentum of the two-photon system.

END OF EXAM