Practice Test 2

AP® Physics 2 Exam

SECTION I: Multiple-Choice Questions

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

At a Glance

Total Time
90 minutes
Number of Questions
50
Percent of Total Grade
50%
Writing Instrument
Pen required

Instructions

Section I of this examination contains 50 multiple-choice questions. Fill in only the ovals for numbers 1 through 50 on your answer sheet.

CALCULATORS MAY BE USED IN BOTH SECTIONS OF THE EXAMINATION.

Indicate all of your answers to the multiple-choice questions on the answer sheet. No credit will be given for anything written in this exam booklet, but you may use the booklet for notes or scratch work. After you have decided which of the suggested answers is best, completely fill in the corresponding oval on the answer sheet. Give only one answer to each question. If you change an answer, be sure that the previous mark is erased completely. Here is a sample question and answer.

Sample Question	Sample Answer
Chicago is a (A) state (B) city (C) country (D) continent	Ⓐ ● Ⓒ Ⓓ

Use your time effectively, working as quickly as you can without losing accuracy. Do not spend too much time on any one question. Go on to other questions and come back to the ones you have not answered if you have time. It is not expected that everyone will know the answers to all the multiple-choice questions.

About Guessing

Many candidates wonder whether or not to guess the answers to questions about which they are not certain. Multiple choice scores are based on the number of questions answered correctly. Points are not deducted for incorrect answers, and no points are awarded for unanswered questions. Because points are not deducted for incorrect answers, you are encouraged to answer all multiple-choice questions. On any questions you do not know the answer to, you should eliminate as many choices as you can, and then select the best answer among the remaining choices.

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ADVANCED PLACEMENT PHYSICS 2 TABLE OF INFORMATION

CONSTANTS AND CONVERSION FACTORS

Proton mass, $m_p = 1.67 \times 10^{-27}$ kg	Electron charge magnitude, $e = 1.60 \times 10^{-19}$ C
Neutron mass, $m_n = 1.67 \times 10^{-27}$ kg	1 electron volt, $1 \text{ eV} = 1.60 \times 10^{-19}$ J
Electron mass, $m_e = 9.11 \times 10^{-31}$ kg	Speed of light, $c = 3.00 \times 10^{8}$ m/s
Avogadro's number, $N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$	Universal gravitational constant, $G = 6.67 \times 10^{-11} \text{ m}^3/\text{kg}\cdot\text{s}^2$
Universal gas constant, $R = 8.31$ J/(mol•K)	Acceleration due to gravity at Earth's surface, $g = 9.8 \text{ m/s}^2$
Boltzmann's constant, $k_B = 1.38 \times 10\ ^{23}$ J/K	

1 unified atomic mass unit,	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg} = 931 \text{ MeV}/c^2$
Planck's constant,	$h = 6.63 \times 10^{-34} \text{ J}\cdot\text{s} = 4.14 \times 10^{-15} \text{ eV}\cdot\text{s}$
	$hc = 1.99 \times 10^{-25} \text{ J}\cdot\text{m} = 1.24 \times 10^{3} \text{ eV}\cdot\text{nm}$
Vacuum permittivity,	$\varepsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{N}\cdot\text{m}^2$
Coulomb's law constant,	$k = 1/4\pi\varepsilon_0 = 9.0 \times 10^{9} \text{ N}\cdot\text{m}^2/\text{C}^2$
Vacuum permeability,	$\mu_0 = 4\pi \times 10^{-7} \text{ (T}\cdot\text{m)/A}$
Magnetic constant,	$k' = \mu_0/4\pi = 1 \times 10^{-7} \text{ (T}\cdot\text{m)/A}$
1 atmosphere pressure,	$1 \text{ atm} = 1.0 \times 10^{5} \text{ N/m}^2 = 1.0 \times 10^{5} \text{ Pa}$

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

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.

I. The frame of reference of any problem is assumed to be inertial unless otherwise stated.
II. In all situations, positive work is defined as work done on a system.
III. The direction of current is conventional current: the direction in which positive charge would drift.
IV. Assume all batteries and meters are ideal unless otherwise stated.
V. Assume edge effects for the electric field of a parallel plate capacitor unless otherwise stated.
VI. For any isolated electrically charged object, the electric potential is defined as zero at infinite distance from the charged object.

ADVANCED PLACEMENT PHYSICS 2 EQUATIONS

MECHANICS

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

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

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

$$\vec{a} = \frac{\sum \vec{F}}{m} = \frac{\vec{F}_{net}}{m}$$

$$|\vec{F}_f| \le \mu |\vec{F}_n|$$

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

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

$$\Delta\vec{p} = \vec{F}\,\Delta t$$

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

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

$$P = \frac{\Delta E}{\Delta t}$$

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

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

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

$$x_{cm} = \frac{\sum m_i x_i}{\sum m_i}$$

$$\vec{\alpha} = \frac{\sum \vec{\tau}}{I} = \frac{\vec{\tau}_{net}}{I}$$

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

$$L = I\omega$$

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

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

$$|\vec{F}_s| = k|\vec{x}|$$

a = acceleration
A = amplitude
d = distance
E = energy
F = force
f = frequency
I = rotational inertia
K = kinetic energy
k = spring constant
L = angular momentum
ℓ = length
m = mass
P = power
p = momentum
r = radius or separation
T = period
t = time
U = potential energy
v = speed
W = work done on a system
x = position
y = height
α = angular acceleration
μ = coefficient of friction
θ = angle
τ = torque
ω = angular speed

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

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

$$T = \frac{2\pi}{\omega} = \frac{1}{f}$$

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

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

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

$$\vec{g} = \frac{\vec{F}_g}{m}$$

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

ELECTRICITY AND MAGNETISM

$$|\vec{F}_E| = \frac{1}{4\pi\varepsilon_0}\frac{|q_1 q_2|}{r^2}$$

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

$$|\vec{E}| = \frac{1}{4\pi\varepsilon_0}\frac{|q|}{r^2}$$

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

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

$$|\vec{E}| = \left|\frac{\Delta V}{\Delta r}\right|$$

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

$$C = \kappa\varepsilon_0 \frac{A}{d}$$

$$E = \frac{Q}{\varepsilon_0 A}$$

$$U_C = \frac{1}{2} Q\Delta V = \frac{1}{2} C(\Delta V)^2$$

$$I = \frac{\Delta Q}{\Delta t}$$

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

$$P = I\,\Delta V$$

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

$$R_s = \sum_i R_i$$

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

$$C_p = \sum_i C_i$$

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

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

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 = separation
t = time
U = potential (stored) energy
V = electric potential
v = speed
κ = dielectric constant
ρ = resistivity
θ = angle
Φ = flux

$$\vec{F}_M = q\vec{v} \times \vec{B}$$

$$|\vec{F}_M| = |q\vec{v}||\sin\theta||\vec{B}|$$

$$\vec{F}_M = I\vec{\ell} \times \vec{B}$$

$$|\vec{F}_M| = |I\vec{\ell}||\sin\theta||\vec{B}|$$

$$\Phi_B = \vec{B} \bullet \vec{A}$$

$$\Phi_B = |\vec{B}|\cos\theta|\vec{A}|$$

$$\mathcal{E} = -\frac{\Delta\Phi_B}{\Delta t}$$

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

ADVANCED PLACEMENT PHYSICS 2 EQUATIONS

FLUID MECHANICS AND THERMAL PHYSICS

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

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

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

$$F_b = \rho V g$$

$$A_1 v_1 = A_2 v_2$$

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

$$\frac{Q}{\Delta t} = \frac{kA\,\Delta T}{L}$$

$$PV = nRT = Nk_B T$$

$$K = \frac{3}{2}k_B T$$

$$W = -P\,\Delta V$$

$$\Delta U = Q + W$$

A = area
F = force
h = depth
k = thermal conductivity
K = kinetic energy
L = thickness
m = mass
n = number of moles
N = number of molecules
P = pressure
Q = energy transferred to a system by heating
T = temperature
t = time
U = internal energy
V = volume
v = speed
W = work done on a system
y = height
ρ = density

MODERN PHYSICS

$$E = hf$$

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

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

$$E = mc^2$$

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

WAVES AND OPTICS

$$\lambda = \frac{v}{f}$$

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

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

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

$$|M| = \left|\frac{h_i}{h_o}\right| = \left|\frac{s_i}{s_o}\right|$$

$$\Delta L = m\lambda$$

$$d\sin\theta = m\lambda$$

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

GEOMETRY AND TRIGONOMETRY

Rectangle
$A = bh$

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

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

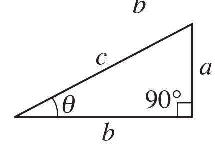
Rectangular solid
$V = \ell w h$

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

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

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

Right triangle
$c^2 = a^2 + b^2$
$\sin\theta = \frac{a}{c}$
$\cos\theta = \frac{b}{c}$
$\tan\theta = \frac{a}{b}$



AP PHYSICS 2

SECTION I

Time—90 minutes

50 Questions

Note: To simplify calculations, you may use $g = 10\text{ m/s}^2$ in all problems.

Directions: Each of the questions or incomplete statements below is followed by four suggested answers or completions. Select the one that is best in each case and mark it on your sheet.

1. A positively charged particle enters a region between the plates of a parallel plate capacitor. The particle is moving initially parallel to the plates. What is the correct description of the trajectory of the particle in the region between the plates?

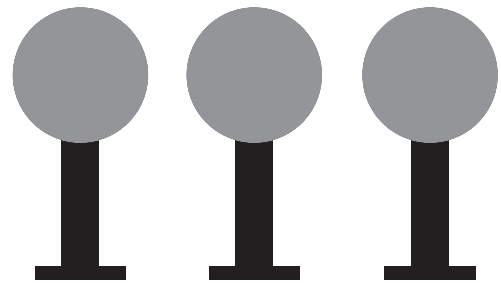
(A) The particle will continue straight.
(B) The particle will move towards the negative plate along a straight-line path.
(C) The particle will move towards the negative plate along a curved path.
(D) The particle will move towards the positive plate along a curved path.

2. Which of the following arguments does **not** support the assertion that a parallel plate capacitor held with one plate parallel to the floor is an electric analog of the gravitational field near the surface of the Earth?

(A) The voltage is constant along horizontal lines.
(B) The field changes linearly with distance from the lower plate.
(C) Both the gravitational field lines and electric field lines are vertical.
(D) Both the electrical and gravitational force are governed by inverse square laws.

3. An electromagnetic wave moves along the positive z-axis. The wave is polarized so that the magnetic field is confined in the y-axis. Where is there a non-zero electric field from this wave?

(A) The electric field exists everywhere.
(B) The electric field is only along the x-axis.
(C) The electric field is only along the y-axis.
(D) The electric field is only along the z-axis.



4. Three neutral conducting spheres sit on insulating bases. The spheres are separated by a very large distance. The sphere in the center is given a positive charge. The spheres are brought close together, as shown above, but not allowed to come into contact with one another. Which is the correct description of the net charge on each sphere?

(A) All three spheres are positively charged.
(B) The center sphere is positively charged and the two outer spheres are negatively charged.
(C) The center sphere is positively charged and the other two are neutral.
(D) All three spheres are neutral.

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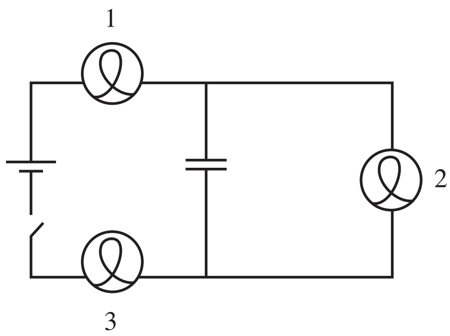
Questions 5–7 refer to the following diagram.



5. The circuit above contains a battery, a switch, three identical light bulbs, and a capacitor. The capacitor is initially uncharged. The instant the switch is closed, which of the bulbs are lit?

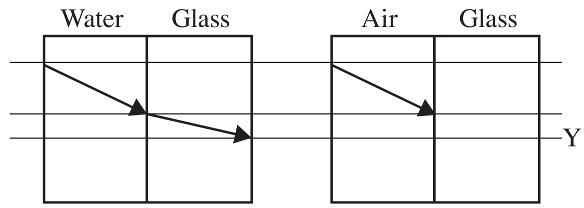
   (A) All three bulbs are unlit.
   (B) Only bulb 1 is lit.
   (C) Only bulb 2 is lit.
   (D) Bulb 1 and bulb 3 are lit.

6. After the capacitor is fully charged, which bulbs are lit?

   (A) All three bulbs are unlit.
   (B) Bulb 1 and bulb 3 are lit.
   (C) Only bulb 2 is lit.
   (D) All three bulbs are lit.

7. When the capacitor is fully charged, which components have equal voltage drops across them?

   (A) The capacitor and the battery
   (B) The capacitor and bulb 2
   (C) Bulb 1 and bulb 3
   (D) All three of the above selections have equal voltage drops across them.



8. A ray of light enters the pair of tanks as shown above. The light rays in the water and glass tank are shown at the left, with the light exiting the pair of tanks at a point Y. The light ray in the air tank is identical to the ray in the water tank, entering at the same height and same angle. Both sets of tanks use the same glass. How will the ray exiting the second glass tank compare to height Y?

   (A) The ray will not exit the second tank due to total internal reflection.
   (B) The exiting ray will be closer to the top of the tank than Y.
   (C) The exiting ray will be at the same height as Y.
   (D) The exiting ray will be farther from the top of the tank than Y.

9. A mirror may be used to create a real image under which of the following conditions?

   (A) Use a concave mirror and place the object between the mirror and the focal point.
   (B) Use a concave mirror and place the object beyond focal point.
   (C) Use a convex mirror and place the object between the mirror and the focal point.
   (D) Use a convex mirror and place the object beyond the focal point.

10. The pressure at location A in a pipe is known. The speed of the fluid in the pipe and the pipe diameter are also known at position A. Position B is another location in the pipe. Which pieces of data are required to calculate the speed of the fluid at position B?

    (A) The diameter at B only
    (B) The diameter at B and the height of B relative to A
    (C) The diameter at B, the height of B relative to A and the pressure at B
    (D) The diameter at B, the pressure at B, the height of B relative to A and the fluid density

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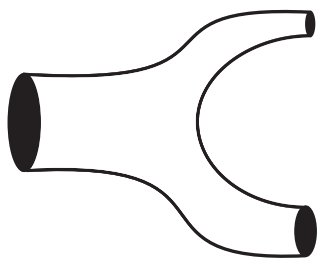

11. The tube shown above carries water. At some point, the tube splits, as shown above. Three points within the tube are labeled A, B, and C. The greatest diameter is at A and the smallest diameter is at B. How do the pressures in the pipes compare at the three points?

(A) $P_A > P_C > P_B$
(B) $P_A = P_B = P_C$
(C) $P_B = P_C > P_A$
(D) $P_B > P_C > P_A$

12. A paper-filled three ring binder sits in a room for a long time. A student touches the metal rings of the binder and the paper. She expects the two objects to feel the same temperature, but she observes that the paper feels warmer than the metal. Which of the following correctly explains her observation?

(A) The objects were in thermal equilibrium, but she must have felt the paper first, as when you feel multiple objects at the same temperature, the ones felt first will feel warmest.
(B) The objects were in thermal equilibrium, but the energy flow occurs more slowly between her fingers and the paper than her fingers and the metal, resulting in the paper feeling warmer.
(C) The objects were in thermal equilibrium and the paper warms up quickly when touched. Her perception is not instantaneous, but is the average temperature over a period of time and higher for the paper.
(D) The paper was warmer than the metal because temperature is related to the kinetic energy of the molecules, and the more massive metal molecules will have less kinetic energy than the paper molecules.

13. A hot cup of water is placed within an insulating container. Later, the water has cooled. Which of the following explains the phenomenon?

(A) The molecules in the water are fast-moving initially and transfer energy in the air in the container, resulting in the air heating up as the water cools.
(B) The molecules in the air are fast-moving initially and transfer energy to the water in the container, resulting in the water cooling down as the air heats up.
(C) As time goes on, the entropy of the system increases, which results in a decrease in energy and the loss of temperature in the cup.
(D) The total heat in the container must remain constant unless there is leakage to the outside surroundings, so the water can only cool down if the surroundings heat up.

14. A very large sheet of metal has a net negative charge. An electron is placed above the center of the sheet. Which of the following correctly describes the force on the sheet of charge from the electron?

(A) The force pulls the sheet upwards.
(B) The force pushes the sheet downwards.
(C) The electron causes a torque on the sheet, but no net upward or downward force exists.
(D) There is no force on the sheet because the electron is a test charge.

15. An experiment is conducted on a circuit consisting of a battery and several wires. The wires are all made of the same metal. It is found that as the cross-sectional area of the wire increases, the current measured coming out of the battery increases linearly. What can be concluded about the wire from this data?

(A) The battery has an internal resistance, which can be found from the slope of the area vs. current graph.
(B) The battery has an internal resistance, which can be found from the y-intercept of the area vs. current graph.
(C) The wires have the same length, which can be found from the slope of the area vs. current graph.
(D) The wires have the same length, which can be found from the y-intercept of the area vs. current graph.

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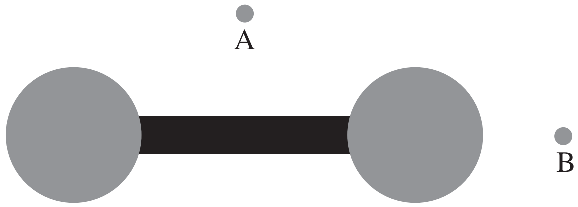


16. An insulating rod separates two conducting sphere as shown above. Point A is midway between the spheres. Point B lies on the axis of the rod. Which of the following arrangements of charges would result in a net torque on the rod?

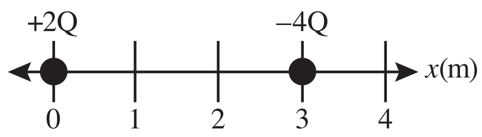
(A) Charge both spheres negatively and place a positive charge at point A.
(B) Charge one sphere negatively and the other positively and place a positive charge at point A.
(C) Charge both spheres negatively and place a positive charge at point B.
(D) Charge one sphere negatively and the other positively and place a positive charge at point B.

17. The process of charging by induction requires which physical property of a system?

(A) Charge polarization
(B) Uneven charge distribution
(C) Zero net charge
(D) Contact between a conductor and insulator

18. To determine the direction of the force on a charge that is moving near a current carrying wire, which data do you need?

(A) Only the direction the charge is moving.
(B) The sign of the charge and its direction of motion.
(C) The sign of the charge, the direction of motion and the direction of the current.
(D) The sign of the charge, the direction of motion, the direction of the current and the position of the charge relative to the wire.

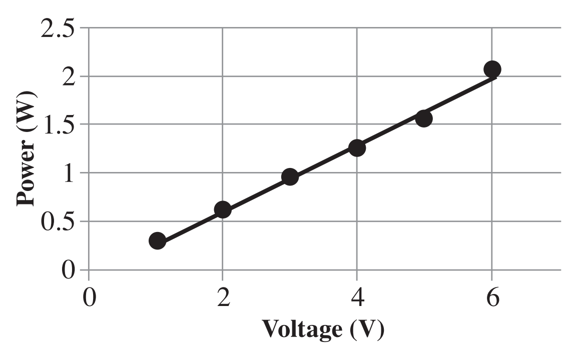


19. A positive charge of 2Q and a negative charge of 4Q are arranged at positions as shown above. What is the correct ranking of the electric potential at points along the x-axis?

(A) $V(x = 4\text{ m}) = V(x = 2\text{ m}) > V(x = 1\text{ m})$
(B) $V(x = 4\text{ m}) > V(x = 1\text{ m}) > V(x = 2\text{ m})$
(C) $V(x = 1\text{ m}) > V(x = 2\text{ m}) > V(x = 4\text{ m})$
(D) $V(x = 4\text{ m}) > V(x = 2\text{ m}) > V(x = 1\text{ m})$

20. A large piece of wood has the same weight as a small rock. Both the wood and rock are placed into a pool of liquid. The rock sinks while the wood floats. How do the buoyant forces on the wood and rock compare?

(A) The buoyant forces are the same on each.
(B) The buoyant force on the wood is greater than on the rock.
(C) The buoyant force on the wood is less than on the rock.
(D) The buoyant forces cannot be compared without the density of the liquid.



21. An experiment is conducted to determine the power output from a circuit as various voltages are supplied to the circuit. The circuit is set up so that it draws a constant current. What is the value of the current in the circuit that produced the graph above?

(A) 0.00 A
(B) 0.25 A
(C) 1.0 A
(D) 6.0 A

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22. The products of several radioactive decays are being studied. Each particle starts with the same speed and enters into a region with a uniform magnetic field directed perpendicular to the initial velocity of the particles. Which observation could be made?

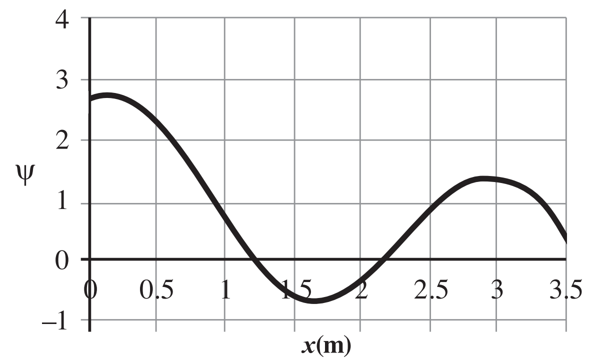
(A) A positron and an electron both turn in the same direction, but the electron turns with a larger radius.
(B) An alpha particle and an electron both turn in the same direction, but the alpha particle turns with a larger radius.
(C) An alpha particle and an electron both turn in opposite directions, but the alpha particle turns with a larger radius.
(D) A positron and an electron both turn in the opposite directions, but the electron turns with a larger radius.

23. A hypothetical atom contains an undetermined number of energy levels above the ground state. A gas of this atom is entirely in the ground state. Light with a broad spectrum is shined upon the gas and the spectrum of the light is recorded after shining through the gas. Three wavelength of light are observed to have diminished intensity. What can be concluded from this?

(A) There must be exactly two energy levels above the ground state.
(B) There must be exactly three energy levels above the ground state.
(C) There must be either exactly two or exactly three energy levels above the ground state.
(D) There are an undetermined number of energy levels above the ground state, but there are at least three levels.

24. An unknown nucleus goes through a decay process. Three ${}^{4}_{2}He$ alpha particles are emitted, along with two β^- particles. The resulting daughter nucleus is ${}^{206}_{82}Pb$. What was the atomic number of the unknown nucleus that started the process?

(A) 84
(B) 86
(C) 88
(D) 90



25. The wave function of a quantum object vs. position is graphed above. Which of the following correctly ranks the probabilities of observing the particle at the listed positions?

(A) $P(x = 0.5\text{ m}) > P(x = 2.25\text{ m}) > P(x = 1.75\text{ m})$
(B) $P(x = 0.5\text{ m}) > P(x = 1.75\text{ m}) > P(x = 1.25\text{ m})$
(C) $P(x = 3.0\text{ m}) > P(x = 1.75\text{ m}) > P(x = 2.0\text{ m})$
(D) $P(x = 3.5\text{ m}) > P(x = 3.0\text{ m}) > P(x = 1.75\text{ m})$

26. Radiothorium-228 decays into Radon-220 through two alpha decays, as shown below.

$$ {}^{228}_{90}\text{Th} \rightarrow {}^{220}_{86}\text{Rn} + {}^{4}_{2}\text{He} + {}^{4}_{2}\text{He} $$

Which equation correctly describes the energy released during this process?

(A) $(m_{\text{Th}} - m_{\text{Rn}})c^2$
(B) $(m_{\text{Th}} + 2m_{\text{He}} - m_{\text{Rn}})c^2$
(C) $(m_{\text{Th}} - 2m_{\text{He}} - m_{\text{Rn}})c^2$
(D) $(m_{\text{Rn}} + 2m_{\text{He}} - m_{\text{Th}})c^2$

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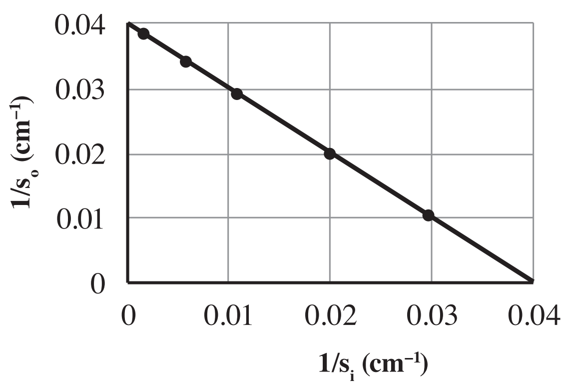
Questions 27 and 28 refer to the following graph.



A thin lens is used to make an image for several different object distances. The image and object distances are used to make the above graph.

27. What is the approximate focal length of the lens?

(A) 1 cm
(B) 10 cm
(C) 25 cm
(D) 100 cm

28. In order to achieve a magnification of 1, how far from the lens should an object be placed?

(A) 2 cm
(B) 20 cm
(C) 50 cm
(D) 200 cm

29. A container has a round lid, with mass *M*, and makes an airtight seal with the body of the container. Some of the air in the container is pumped out. The container is turned over, but the lid stays shut. Which of the following explanations for this phenomenon is correct?

(A) Pumping the air out of the container decreases the gravitational force on the lid.
(B) Pumping the air out creates an upward force that will always balance with the gravitational force.
(C) The force on the lid downward from the molecules inside is less than the force on the lid from the particles in the air surrounding the container.
(D) The force on the lid downward from the molecules inside is less than the difference between the force on the lid from the particles in the air surrounding the container and the gravitational force on the lid.

30. A mercury thermometer is placed in a glass of ice-cold water. After some time goes by, the mercury thermometer can be read to determine that the temperature of the water is 0ºC. Several minutes later, the reading on the thermometer has not changed. What has happened to the molecules of mercury in the thermometer?

(A) Over time, all the molecules slow down, but the rate of slowing decreases as temperature decreases so it is not noticeable between the two readings.
(B) The mercury molecules stopped moving upon reaching a temperature of 0ºC and remained stopped for the second reading.
(C) The mercury molecules reached thermal equilibrium before the first reading, so all their molecules had the same non-zero speed when both readings were taken.
(D) The mercury molecules reached thermal equilibrium before the first reading, but between the readings some of the molecules sped up and others slowed down, resulting in the same reading.

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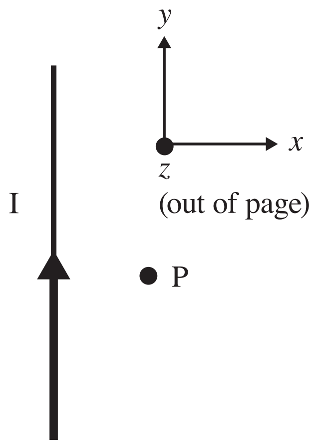
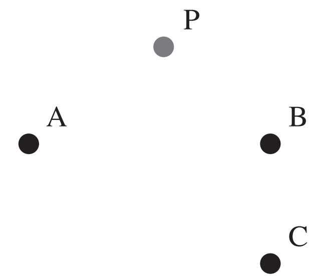


31. A current carrying wire and coordinate system is shown above. Initially, the wire carries a current *I* towards the top of the page. The amount of current is steadily decreased until it is 0 A, then steadily increased until it reaches a value of *I* in the downward direction. This change in current takes time *t*. The magnetic field versus time at the observation point P from $t = 0$ until t is graphed. Which statement is true concerning the graph if $+z$ is above the horizontal axis and $-z$ is below the horizontal axis?

(A) The graph has a constant slope.
(B) The graph is piecewise linear with a negative slope for the first half and a positive slope for the second half.
(C) The graph is piecewise linear with a positive slope for the first half and a negative slope for the second half.
(D) The graph is a curve showing an inverse relationship.



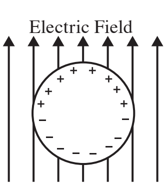
32. Charges are distributed as shown above. At point A is a charge of +3Q. At B is a charge of +1Q. At C is a charge of –1Q. What is the direction of the force on a proton located at point P?

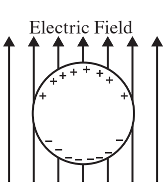
(A) Up and to the left.
(B) Down and to the left.
(C) Up and to the right.
(D) Down and to the right.

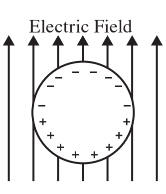
33. All of the following observations of electric field diagrams are correct EXCEPT:

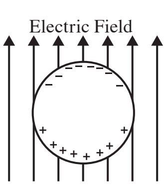
(A) Longer arrows correspond to a greater field magnitude.
(B) Field lines will be larger at positions close to sources or sinks.
(C) Arrow lengths will decrease linearly with distance from sources or sinks.
(D) Arrows point in the direction in which a positive charge would experience a force.

34. A neutral sphere of metal is placed in a region of uniform electric field. The electric field points towards the top of the page. Which of the following diagrams shows the arrangement of the charges on the surface of the sphere once electrostatic equilibrium is reached?

(A)


(B)


(C)


(D)


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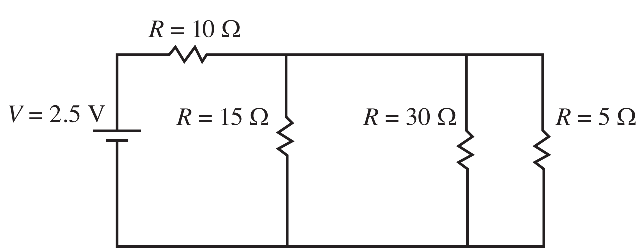
35. An electron enters a region of magnetic field created by a long current carrying wire. Along which path could the electron travel without being deflected?

(A) The electron is traveling parallel to the wire and in the same direction that the current is flowing.
(B) The electron is traveling parallel to the wire and in the opposite direction from the direction that the current is flowing.
(C) The electron is traveling straight away from the wire.
(D) The electron is traveling in a circle centered at the wire.

36. Which process will result in charging an uncharged sphere using a charged rod?

(A) Bringing the rod near the sphere and touching the two objects together, then removing the rod
(B) Grounding the sphere first, then bringing a charged object near the sphere and touching the two objects together, then removing the rod
(C) Bringing the rod near the sphere, but not touching them together, then removing the rod
(D) Grounding the sphere, moving the rod near the sphere, bringing the rod near the sphere but not touching them together, then removing the rod

Questions 37 and 38 refer to the following diagram.

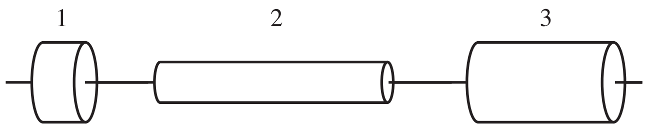


37. The current drawn from the battery is most nearly equal to what value?

(A) 0.042 A
(B) 0.19 A
(C) 0.30 A
(D) 0.68 A

38. A fifth resistor is placed in the circuit. It is parallel beside the 5 Ω resistor. The voltage drop across this resistor is found to be $V = 0.50$ V. What is the resistance of the additional resistor?

(A) 5 Ω
(B) 10 Ω
(C) 15 Ω
(D) 30 Ω



39. Three cylinders of the same metal act as resistors arranged in series, as shown above. Which of the following correctly ranks the voltage drops across the three resistors?

(A) $V_1 = V_2 = V_3$
(B) $V_3 > V_1 > V_2$
(C) $V_2 > V_3 > V_1$
(D) $V_1 > V_3 > V_2$

40. An electron experiences both electric and magnetic forces. Those forces are balanced. What must be true about the motion of the particle and the alignment of the two fields?

(A) The fields point along the same axis and the velocity of the electron is parallel to that axis.
(B) The fields point along the same axis and the velocity of the electron is perpendicular to that axis.
(C) The fields point the perpendicular axes and the velocity is parallel to the axis of the electric field.
(D) The fields point along the perpendicular axes and the velocity along the third perpendicular axis.

41. A pair of electrons are held a fixed distance apart. Which of the following correctly describes the electrical and gravitational forces between the electrons?

(A) The electrical force is much greater than the gravitational force.
(B) The gravitational force is much greater than the electrical force.
(C) The forces are equal as both the gravitational force and electrical force are governed by inverse square laws.
(D) The forces cannot be compared without knowing the value of the distance between the electrons.

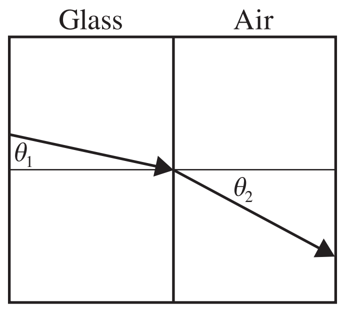
GO ON TO THE NEXT PAGE.

42. An electron travels down the center of a solenoid, carrying a current I. Which of the following explanations for the motion of the electron is correct?

(A) The electron accelerates due to the electric force from the charges in the current in the wire.
(B) The electron accelerates due to the magnetic field generated by the current in the wires of the solenoid.
(C) The electron travels at a constant speed but changes direction due to the magnetic field generated by the current in the wires.
(D) The electron travels at a constant velocity because there is no net force on the electron.

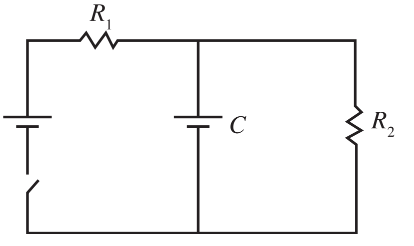
43. A voltage is sent through a tube containing hydrogen gas. The gas emits light. When the light is sent into a spectrometer, several distinct bright lines are seen. Why does this occur?

(A) The voltage causes the gas to heat up to specific temperatures, which are characterized by the lines.
(B) The voltage causes gas molecules to move at specific speeds, which are characterized by the lines.
(C) The voltage sets up standing waves due to the pressure of the gas in the tube, which can be characterized by the lines.
(D) The voltage excites electrons in the gas into specific energy levels, which can be characterized by the lines.



44. An experiment is conducted to determine the critical angle for light going from glass into air, as shown above. A linear plot is made with a vertical axis of sin (θ_1) and a horizontal axis of sin (θ_2). How is the critical angle determined from the graph?

(A) The critical angle can be found from the slope of the line.
(B) The critical angle can be found from the y-intercept of the line.
(C) The critical angle can be found from the horizontal axis value which corresponds to the maximum vertical value.
(D) The critical angle can be found from the vertical axis value which corresponds to the maximum horizontal value.



45. The circuit shown above is set up. The switch is closed and a long time passes. What conditions on the two resistors result in the greatest amount of energy stored in the capacitor?

(A) The energy stored in the capacitor will be greatest if $R_1 > R_2$.
(B) The energy stored in the capacitor will be greatest if $R_1 = R_2$.
(C) The energy stored in the capacitor will be greatest if $R_1 < R_2$.
(D) The energy will be the same regardless of the resistor values.

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Directions: For questions 46-50 below, <u>two</u> of the suggested answers will be correct. Select the two answers that are best in each case, and then fill in both of the corresponding circles on the answer sheet.

46. A wire is placed vertically and carries a current in the upward direction. A compass is located directly to the north of the wire. Which of the following observations can be made about the compass needle deflection? Select two answers.

(A) The deflection grows larger as the compass is moved farther from the wire.
(B) The deflection is to the west.
(C) The deflection grows larger as the current is increased.
(D) The deflection changes direction as the compass is moved upward.

47. An ideal gas is confined to a leak-proof box. What type of processes could occur to cause the gas to absorb heat, but have no net work done on the gas? Select two answers.

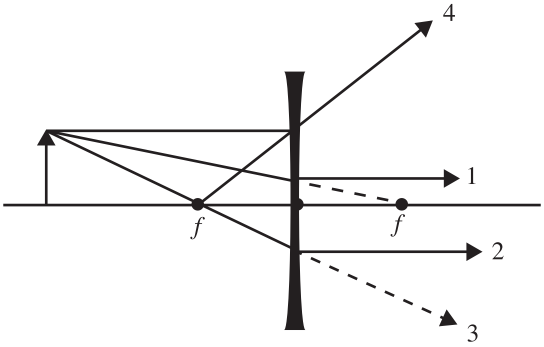
(A) Isothermal expansion to the original volume, then isobaric compression to the original volume
(B) A doubling of pressure at constant volume
(C) A doubling of pressure at constant volume, then doubling the volume at constant pressure, then halving the pressure at constant volume, and finally halving the volume at constant pressure to return to the initial state
(D) A doubling of pressure at constant volume, then finally halving the pressure at constant volume, then doubling the volume at constant pressure, then finally halving the volume at constant pressure to return to the initial state

48. Which of the following results of the photoelectric effect give support for the particle nature of light? Select two answers.

(A) There is a threshold frequency below in which no electrons are emitted.
(B) Above the threshold frequency, the number of electrons emitted increases with increasing intensity.
(C) The stopping voltage is related only to the maximum kinetic energy electron, not all of the electrons ejected from the metal.
(D) The stopping voltage increases linearly with frequency above the threshold frequency regardless of the light intensity.

49. A circuit contains four resistors R_1, R_2, R_3, and R_4 and a battery. The first two are in series and the second two are in parallel. How can a fifth resistor, R_5, be added to the circuit to increase the current draw out of the battery? Select two answers.

(A) Place R_5 in parallel with R_1.
(B) Place R_5 in series with R_2.
(C) Place R_5 in parallel with R_3.
(D) Place R_5 in series with R_4.



50. For the diverging lens shown above, which principle rays are correctly drawn? Select two answers.

(A) 1
(B) 2
(C) 3
(D) 4

END OF SECTION I

AP PHYSICS 2

SECTION II

Time—90 minutes

4 Questions

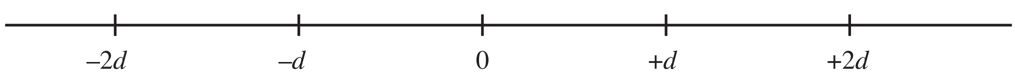
Directions: Questions 1 and 2 are long free-response questions that require about 30 minutes to answer. Questions 3 and 4 are short answer questions that require about 15 minutes to answer. Show your work for each part in the space provided after that part.

1. Three charges are fixed at positions along the x-axis at positions $-d$, 0, and $+d$. The charges at $-d$ and $+d$ are both negative, and the charge a 0 is positive.

(a) A positively charged object of mass m is placed on the x-axis between 0 and $+d$, close to the position $x = 0$. If the three charges described above do not move as a result of this new charged object, describe the motion of the object after it is released as it moves in the region $0 < x < d$.

The charge at 0 has a magnitude of $2Q$, while the other two charges have a magnitude of Q.

(b) On the axes below, sketch the electric field along the x-axis in the vicinity of the charges. An electric field to the right should be graphed as positive and a field pointing left should be graphed as negative.



(c) Write a mathematical function, $E(x)$, that gives the value of the electric field at any position along the x-axis for $0 < x < d$. Give your answer in terms of Q, d, and fundamental constants.

(d) In order to originally assemble the three charges on the x-axis, some work had to be done. Consider arranging the charges along the x-axis in the following manner: first, bring the $+2Q$ charge to position $x = 0$, then bring the $-Q$ charge to $x = +d$, and finally, bring in the last charge. Bringing the $+2Q$ charge to position 0 required no work. Bringing in the second charge required an amount of work W. Explain whether bringing in the third charge will require more work, less work, or an amount of work equal to W.

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2. A student has a convex lens of unknown focal length. He lights a candle in a darkened room and uses the lens and moves a screen until he forms a sharp image. He then records the distance from the candle to the lens and the distance from the lens to the screen. Below is a sketch of his set-up and his data.

S_o (cm)	S_i (cm)
15	61.5
30	19.3
50	15.6
80	13.9
90	13.7
110	13.4

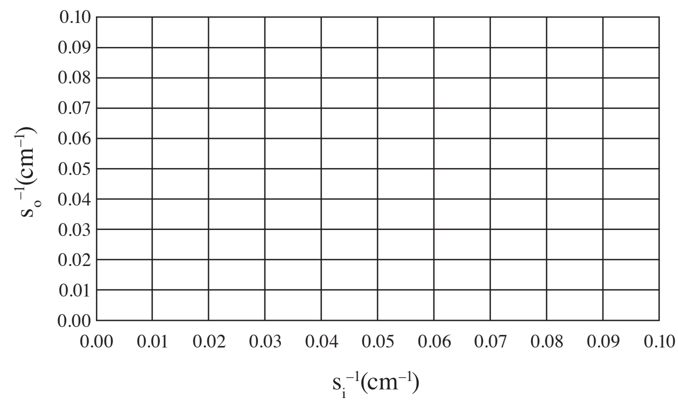
Selected values of the object and image distances.

S_o^{-1} (cm^{-1})	S_i^{-1} (cm^{-1})
0.067	0.016
0.050	0.034
0.033	0.052
0.020	0.064
0.017	0.065
0.014	0.068

Selected values of the inverse of the object and inverse of the image distances.

(a) Explain how a graph of $1/s_o$ vs. $1/s_i$ can be used to find the focal length of the lens.

(b) Create a graph of and find the focal length of the lens used in the experiment.



(c) Use ray tracing to make a sketch when the object is 6 cm from the lens.

(d) The top half of the lens is now covered by a sheet of cardboard so that light rays can only strike the bottom half of the lens. Briefly explain what effect this has on the image and how this would affect a ray tracing diagram.

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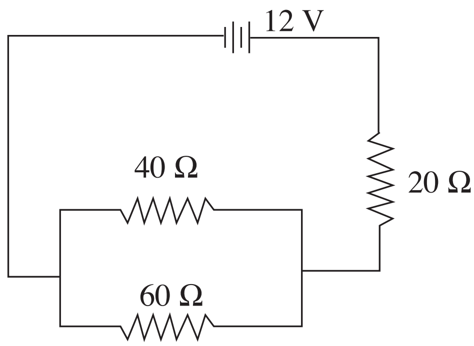

3. The circuit shown is built and the voltage source supplies voltage for 15 minutes before the battery is completely drained. Assume the voltage supplied by the battery is constant at 12 V until the battery is drained, after which the battery supplies 0 V.

(a) What is the equivalent resistance of the circuit?

(b) Two students are discussing the apparatus. Student 1 says, "If the 20 Ω resistor were not present, the overall resistance of the circuit would have been lower and the battery would have lasted longer." Student 2 says, "If the 20 Ω resistor were not present, I think the power output would have been higher and the battery would have drained faster."

(i) Use equations to show whether the overall resistance would have been lower without the 20 Ω resistor present.

(ii) Use equations to determine whether the overall power output would have been higher.

(iii) Which student is correct about the battery life?

(c) The 20 Ω resistor is replaced with a capacitor.

(i) As soon as the circuit is connected, explain without using equations how the current drawn out of the battery compares between the original circuit and the circuit with the capacitor.

(ii) After the capacitor has been connected for a long time, but before the battery is completely drained, how does the current drawn out of the battery compare between the original circuit and the circuit with the capacitor?

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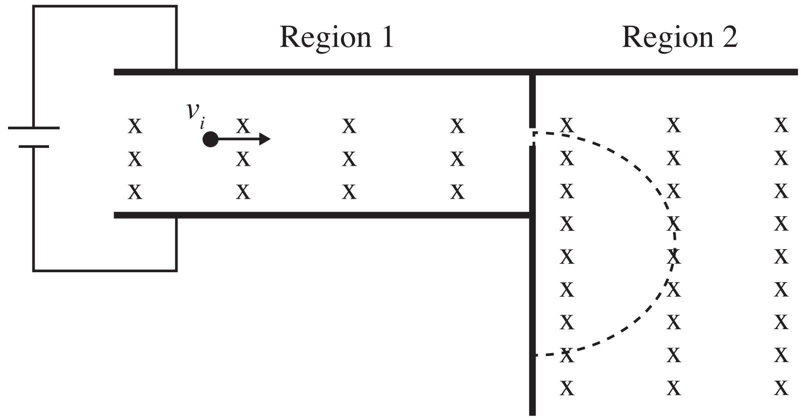

4. In both region 1 and region 2, there is a uniform magnetic field, B, directed into the page. There is a uniform electric field, E, in region 1 established by the battery.

(a) A charged particle moves through region 1 undeflected.

(i) Explain how this balance occurs between the electric and magnetic forces.

(ii) What would happen to the particle if it was moving at a speed $v_2 > v_i$?

(iii) How, if at all, would the set up in region 1 have to change if the particle was of the other sign?

(b) A particle at speed v_i travels through region 1 undeflected. It then enters region 2 and follows the dotted path that is indicated.

(i) Is this a positively or negatively charged particle?

(ii) What distance from the opening in the boundary between region 1 and region 2 does the particle hit the wall? Answer in terms of m, B, E, v_1, and q.

(c) A similar apparatus is used to determine the percentage of $^{238}_{92}U$ and $^{235}_{92}U$ in a gas sample. Explain how such an apparatus can differentiate between the two isotopes.

(d) Another similar apparatus is unable to distinguish between two objects:

The first object has amu 14 and a charge of –1e.

The second object has amu 28 and charge –2e.

Why can this detector not distinguish between these two objects?

STOP

END OF EXAM

Completely darken bubbles with a No. 2 pencil. If you make a mistake, be sure to erase mark completely. Erase all stray marks.

1.

YOUR NAME: ______________________ (Print) Last First M.I.

SIGNATURE: ______________________ DATE: ___ / ___ / ___

HOME ADDRESS: ______________________ (Print) Number and Street

______________________ City State Zip Code

PHONE NO.: ______________________ (Print)

IMPORTANT: Please fill in these boxes exactly as shown on the back cover of your test book.

2. TEST FORM

3. TEST CODE

0	A	J	0	0
1	B	K	1	1
2	C	L	2	2
3	D	M	3	3
4	E	N	4	4
5	F	O	5	5
6	G	P	6	6
7	H	Q	7	7
8	I	R	8	8
9			9	9

4. REGISTRATION NUMBER

0	0	0	0	0	0
1	1	1	1	1	1
2	2	2	2	2	2
3	3	3	3	3	3
4	4	4	4	4	4
5	5	5	5	5	5
6	6	6	6	6	6
7	7	7	7	7	7
8	8	8	8	8	8
9	9	9	9	9	9

5. YOUR NAME

First 4 letters of last name					FIRST INIT	MID INIT
A	A	A	A		A	A
B	B	B	B		B	B
C	C	C	C		C	C
D	D	D	D		D	D
E	E	E	E		E	E
F	F	F	F		F	F
G	G	G	G		G	G
H	H	H	H		H	H
I	I	I	I		I	I
J	J	J	J		J	J
K	K	K	K		K	K
L	L	L	L		L	L
M	M	M	M		M	M
N	N	N	N		N	N
O	O	O	O		O	O
P	P	P	P		P	P
Q	Q	Q	Q		Q	Q
R	R	R	R		R	R
S	S	S	S		S	S
T	T	T	T		T	T
U	U	U	U		U	U
V	V	V	V		V	V
W	W	W	W		W	W
X	X	X	X		X	X
Y	Y	Y	Y		Y	Y
Z	Z	Z	Z		Z	Z

6. DATE OF BIRTH

Month	Day		Year	
JAN				
FEB	0	0	0	0
MAR	1	1	1	1
APR	2	2	2	2
MAY	3	3	3	3
JUN		4	4	4
JUL		5	5	5
AUG		6	6	6
SEP		7	7	7
OCT		8	8	8
NOV		9	9	9
DEC				

7. SEX

MALE

FEMALE

1. A B C D	14. A B C D	27. A B C D	40. A B C D
2. A B C D	15. A B C D	28. A B C D	41. A B C D
3. A B C D	16. A B C D	29. A B C D	42. A B C D
4. A B C D	17. A B C D	30. A B C D	43. A B C D
5. A B C D	18. A B C D	31. A B C D	44. A B C D
6. A B C D	19. A B C D	32. A B C D	45. A B C D
7. A B C D	20. A B C D	33. A B C D	46. A B C D
8. A B C D	21. A B C D	34. A B C D	47. A B C D
9. A B C D	22. A B C D	35. A B C D	48. A B C D
10. A B C D	23. A B C D	36. A B C D	49. A B C D
11. A B C D	24. A B C D	37. A B C D	50. A B C D
12. A B C D	25. A B C D	38. A B C D	
13. A B C D	26. A B C D	39. A B C D	