Last Name:________________First Name__________________Network-ID__________

Discussion Section:________Discussion TA Name:______________________________

Turn off your cell phone and put it out of sight.
Keep your calculator on your own desk. Calculators cannot be shared.
This is a closed book exam. You have ninety (90) minutes to complete it.

1. Use a #2 pencil. Do not use a mechanical pencil or pen. Darken each circle completely, but stay within the boundary. If you decide to change an answer, erase vigorously; the scanner sometimes registers incompletely erased marks as intended answers; this can adversely affect your grade. Light marks or marks extending outside the circle may be read improperly by the scanner. Be especially careful that your mark covers the **center** of its circle.

2. You may find the version of **this Exam Booklet at the top of page 2**. Mark the version circle in the TEST FORM box near the middle of your answer sheet. **DO THIS NOW!**

3. Print your **NETWORK ID** in the designated spaces at the *right* side of the answer sheet, starting in the left most column, then **mark the corresponding circle** below each character. If there is a letter "o" in your NetID, be sure to mark the "o" circle and not the circle for the digit zero. If and only if there is a hyphen "-" in your NetID, mark the hyphen circle at the bottom of the column. When you have finished marking the circles corresponding to your NetID, check particularly that you have not marked two circles in any one of the columns.

4. Print **YOUR LAST NAME** in the designated spaces at the *left* side of the answer sheet, then mark the corresponding circle below each letter. Do the same for your **FIRST NAME INITIAL**.

5. Print your UIN# in the STUDENT NUMBER designated spaces and mark the corresponding circles. You need not write in or mark the circles in the SECTION box.

6. Sign your name **(DO NOT PRINT)** on the **STUDENT SIGNATURE** *line*.

7. On the **SECTION** *line*, print your **DISCUSSION SECTION**. You need not fill in the COURSE or INSTRUCTOR lines.

Before starting work, check to make sure that your test booklet is complete. You should have 10 ***numbered pages*** *plus three (3) Formula Sheets following these instructions.*

Academic Integrity—**Giving assistance to or receiving assistance from another student or using unauthorized materials during a University Examination can be grounds for disciplinary action, up to and including dismissal from the University.**

This Exam Booklet is Version A. Mark the **A** circle in the **TEST FORM** box near the middle of your answer sheet. **DO THIS NOW!**

Exam Grading Policy—

The exam is worth a total of **116** points, composed of three types of questions.

MC5: *multiple-choice-five-answer questions, each worth 6 points.*
Partial credit will be granted as follows.

(a) If you mark only one answer and it is the correct answer,
you earn **6** points.
(b) If you mark *two* answers, one of which is the correct answer,
you earn **3** points.
(c) If you mark *three* answers, one of which is the correct answer,
you earn **2** points.
(d) If you mark no answers, or more than *three*, you earn 0 points.

MC3: *multiple-choice-three-answer questions, each worth 3 points.*
No partial credit.

(a) If you mark only one answer and it is the correct answer,
you earn **3** points.
(b) If you mark a wrong answer or no answers, you earn **0** points.

MC2: *multiple-choice-two-answer questions, each worth 2 points.*
No partial credit.

(a) If you mark only one answer and it is the correct answer,
you earn **2** points.
(b) If you mark the wrong answer or neither answer, you earn **0** points.

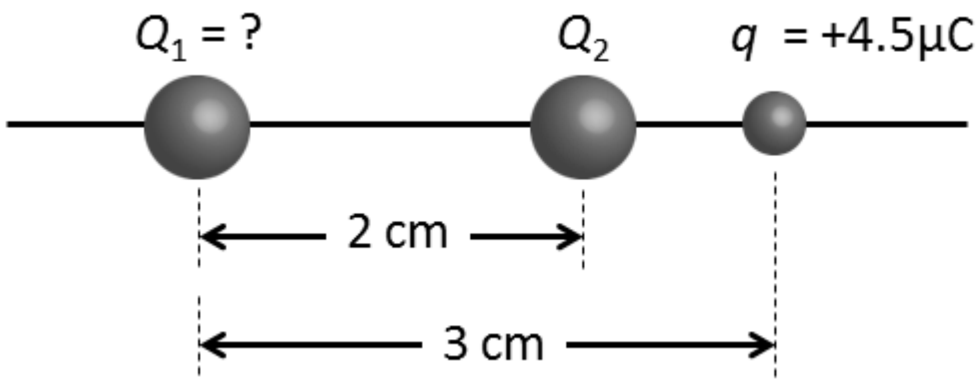
Some helpful information:

- A reminder about prefixes: p (pico) = 10^{-12}; n (nano) = 10^{-9}; μ (micro) = 10^{-6}; m (milli) = 10^{-3}; k (kilo) = 10^{+3}; M or Meg (mega) = 10^{+6}; G or Gig (giga) = 10^{+9}.

2 of 2 pages
(25 problems)

The next two questions pertain to the situation described below.

Two charges Q_1 and Q_2 are placed on the x-axis, at $x = 0$ and $x = 2\ cm$, respectively, as shown in the figure. The charge $Q_2 = 5.5\ \mu C$, whereas Q_1 is not known. A third charge $q = +4.5\ \mu C$ is placed a distance $x = 3\ cm$ from the origin, on the x-axis.



1) What must the value of Q_1 be such that the force on q due to charges 1 and 2 is <u>zero</u>?

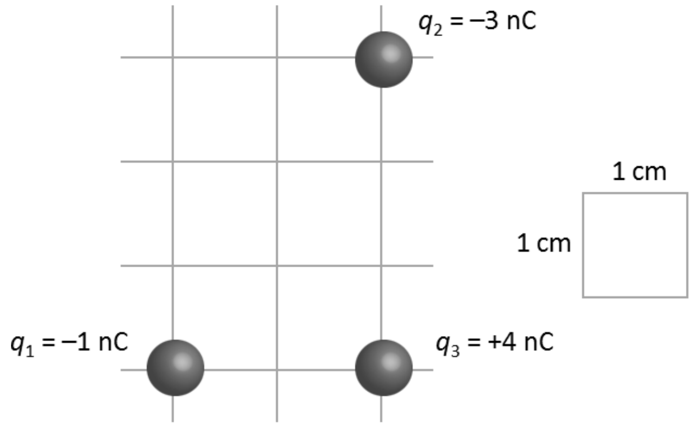
a. $Q_1 = -50\ \mu C$
b. $Q_1 = 17\ \mu C$
c. $Q_1 = 50\ \mu C$
d. $Q_1 = -17\ \mu C$
e. $Q_1 = -5.6\ \mu C$

2) Does your answer change if charge q is now negative?

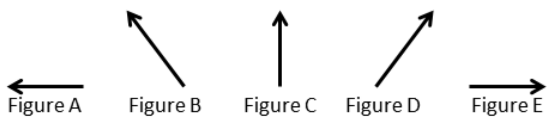
a. *No*
b. *Yes*

The next two questions pertain to the situation described below.

Consider the configuration of charges shown:
$q_1 = -1\ nC$, $q_2 = -3\ nC$, and $q_3 = +4\ nC$.
The grid is *1 cm* on a side.



3) Which of the following vectors best represents the direction of the total force $F_{3,tot}$ on charge q_3 due to q_1 and q_2?



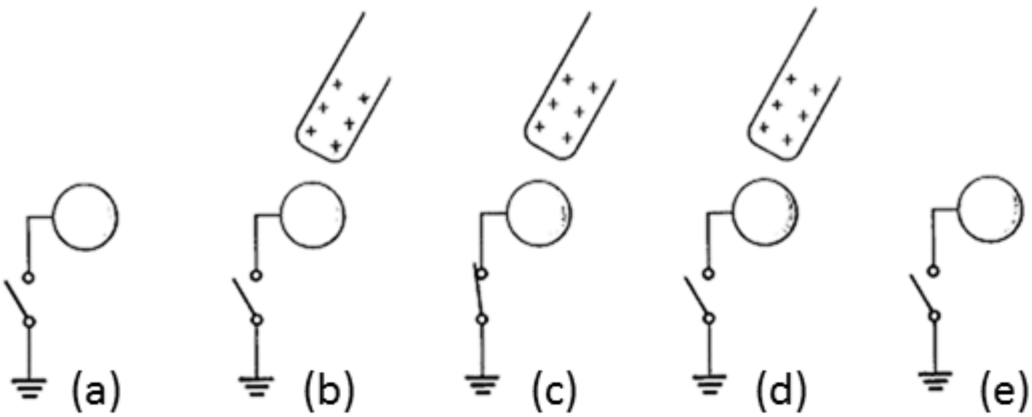
a. *Figure C*
b. *Figure D*
c. *Figure E*
d. *Figure B*
e. *Figure A*

4) Calculate the magnitude of the total force $|F_{3,tot}|$ on charge q_3 due to q_1 and q_1.

a. $|F_{3,tot}| = 26\ \mu N$
b. $|F_{3,tot}| = 150\ \mu N$
c. $|F_{3,tot}| = 2200\ \mu N$
d. $|F_{3,tot}| = 630\ \mu N$
e. $|F_{3,tot}| = 93\ \mu N$

The next two questions pertain to the situation described below.

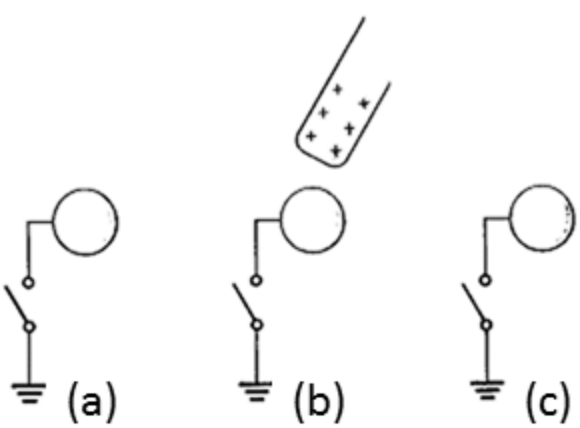
A positively charged rod is brought close but does not touch an uncharged conducting sphere (as shown in steps a-b below). As a rod approaches, the sphere is connected to ground by a conducting wire (c). The grounding wire and rod are then removed (d-e).



5) What is the charge on the conducting sphere after the sequence of steps?

a. *Zero*
b. *Positive*
c. *Negative*

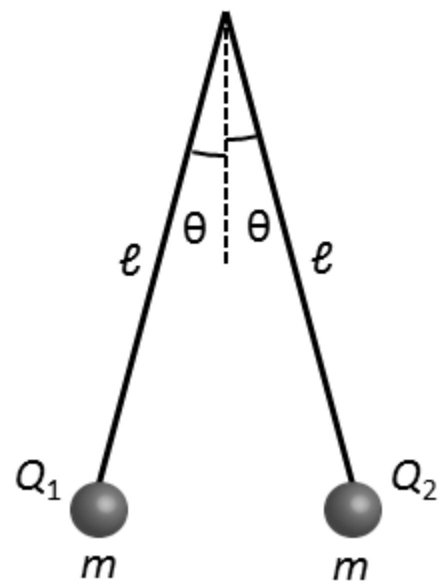
6) Now the sequence of steps is repeated, starting with the same conducting sphere (uncharged), but without grounding the sphere. What is the charge on the sphere after the sequence of steps (a-c)?



a. *Zero*
b. *Negative*
c. *Positive*

The next three questions pertain to the situation described below.

An electroscope is built by suspending two identically sized conducting spheres of mass $m = 0.02\ kg$ from thin wires of length $\ell = 15\ cm$ as shown in the figure. After charging, both spheres make an angle of $\theta = 15°$ relative to vertical and $Q_1 = Q_2$. (Note: in this problem, you may ignore any mass or charge from the thin wires.)



7) Because the system is in equilibrium:

a. *Gravity does not act on the system.*
b. *The spheres will experience a net acceleration.*
c. *The spheres will not experience a net acceleration.*

8) If the charge of *both* Q_1 and Q_2 is increased, the angle θ will:

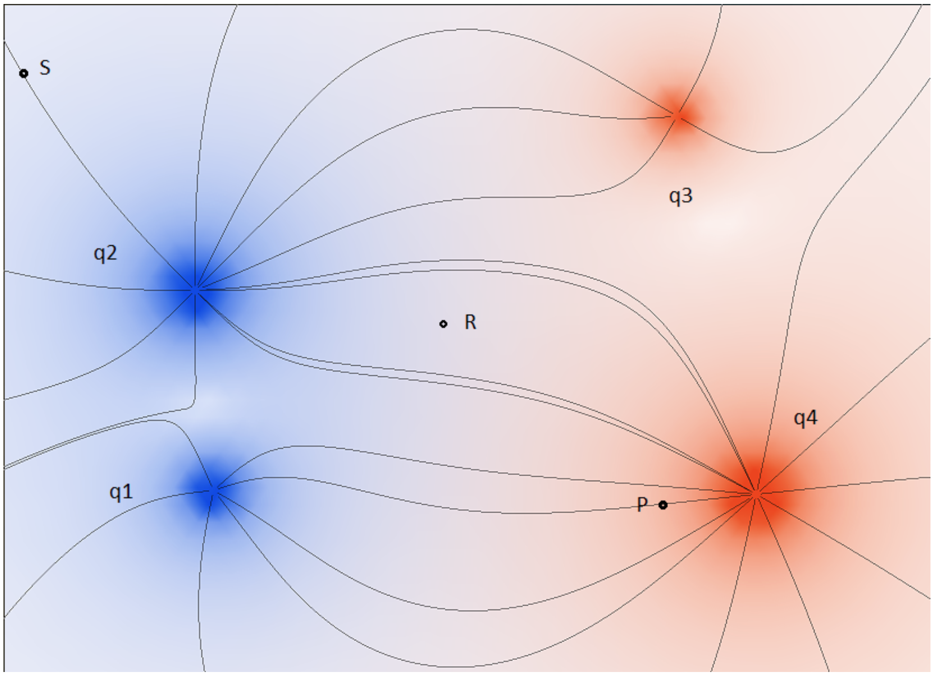
a. *decrease.*
b. *increase.*
c. *stay the same.*

9) What is the magnitude of the charge $|Q_1|$?

a. $|Q_1| = 8.4 \times 10^{-8}\ C$
b. $|Q_1| = 1.6 \times 10^{-7}\ C$
c. $|Q_1| = 5 \times 10^{-8}\ C$
d. $|Q_1| = 3.9 \times 10^{-8}\ C$
e. $|Q_1| = 1.9 \times 10^{-7}\ C$

The next three questions pertain to the situation described below.

Consider the collection of 4 charges below:



10) Using the field lines determine the correct ordering for the magnitudes of the charges

a. $|q3| < |q1| < |q2| < |q4|$
b. $|q2| < |q1| < |q4| < |q3|$
c. $|q3| < |q2| < |q1| < |q4|$
d. $|q1| < |q2| < |q3| < |q4|$
e. $|q1| < |q3| < |q2| < |q4|$

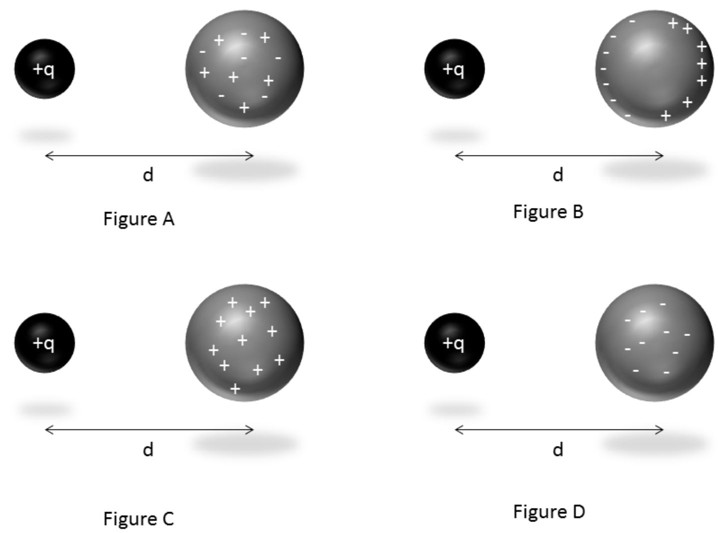
11) Based on the nature of the field lines which of the following is true:

a. *The signs of q1 and q2 are opposite of q3 and q4.*
b. *All of the charges have the same sign.*
c. *The charges q1 and q4 have the same sign.*

12) When placed at which point will a test charge experience the largest force?

a. *P*
b. *R*
c. *S*

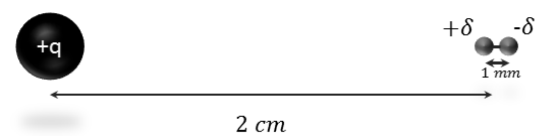
13) A sphere with charge $+q$ is placed a distance d from an uncharged metal sphere. Of the four figures shown, which figure best represents the resulting charge distribution on the metal sphere?



a. *Figure C*
b. *Figure A*
c. *Figure D*
d. *None of these*
e. *Figure B*

The next two questions pertain to the situation described below.

An electric dipole has a separation distance $d = 1\ mm$.
It is placed $2\ cm$ from a fixed, positive charge $q = 9.7\ \mu C$.



14) If $|\delta| = 0.21\ \mu C$ what is the magnitude of the net force on the dipole due to the sphere?

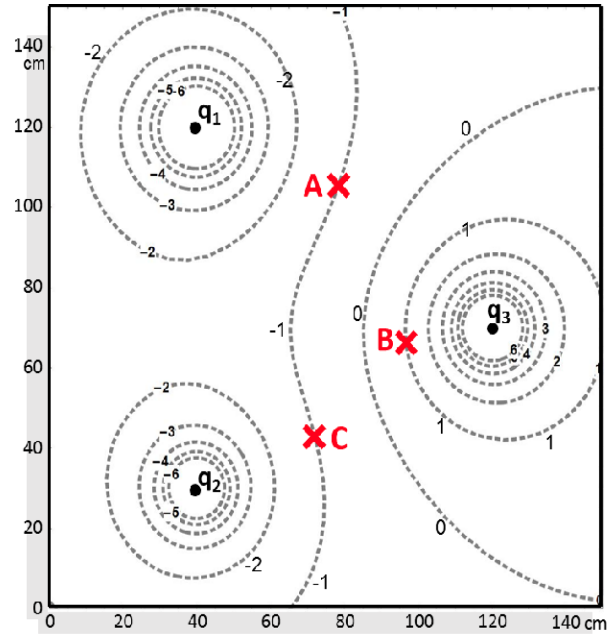
a. $F = 0\ N$
b. $F = 87\ N$
c. $F = 1.8\ N$
d. $F = 0.044\ N$
e. $F = 4.3\ N$

15) The dipole is released. In what direction will it travel?

a. *It will not move.*
b. *It will move away from the charged sphere.*
c. *It will move toward the charged sphere.*

The next two questions pertain to the situation described below.

Given is a map of equal-potential lines (see figure). The potential is created by three charges in a plane (q_1, q_2, q_3). **Potential values are given in Volts** . Note the signs (+/-). Based on the map:



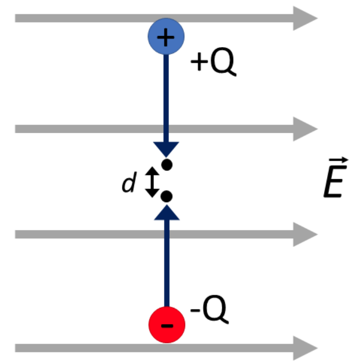
16) What is the sign (+/-) of the charge q_2?

a. +
b. -
c. *0*

17) How much total work *W* by you is required to move a charge of *1 C* from point *A* to point *B*, and then from point *B* to point *C*?

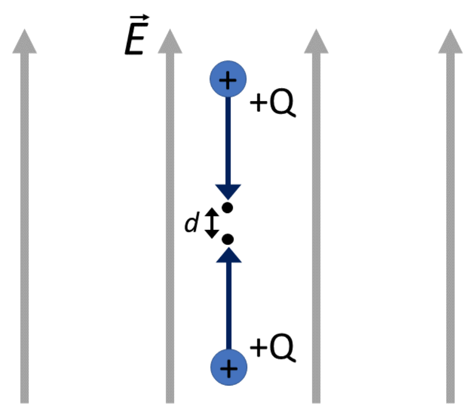
a. $W = 0\ J$
b. $W = 4\ J$
c. $W = -2\ J$
d. $W = 2\ J$
e. $W = -4\ J$

18) You move two charges closer towards each other by equal distances, until they are separated by a small distance d. They have equal masses and charges of equal magnitude and opposite sign, Q and $-Q$. The charges are exposed to a uniform electric field E, as shown in the diagram. Keeping in mind interactions between the two objects, which statement best describes the work done by you on the system of charges?



a. *I am doing negative work on the system of charges.*
b. *I am doing positive work on the system of charges.*
c. *I am doing no work on the system of charges.*

19) Choose the statement that best describes the work done by you on the system shown. The objects have equal charge Q, and the direction of electric field is vertical.

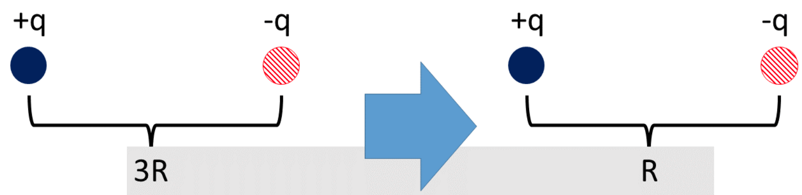


a. *I am doing positive work on the system of charges.*
b. *I am doing negative work on the system of charges.*
c. *I am doing no work on the system of charges.*

20) Consider the case of two identical charges, with equal mass $M = 0.7\ kg$ and equal charge $Q = +6\ C$, in the absence of an external electric field. The charges start at an infinitely far distance apart, and move in opposite directions directly towards one another, with velocities of $+5\ km/s$ and $-5\ km/s$, respectively. What is the closest distance d that the charges will get to one another?

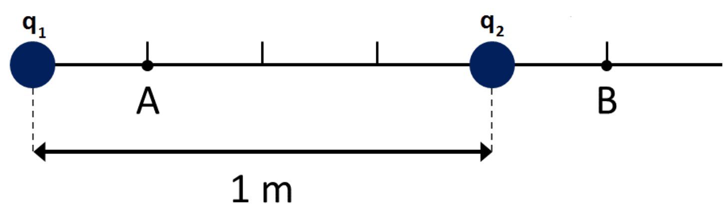
a. $d = 8700\ m$
b. $d = 58\ m$
c. $d = 2 \times 10^3\ m$
d. $d = 150\ km$
e. $d = 19\ km$

21) What is the change in potential energy of a particle of charge $+q$ that is brought from a distance of $3R$ to a distance of R from a particle of charge $-q$?



a. $U = -2kq^2/3R$
b. $U = -kq^2/4R^2$
c. $U = -2kq^2/R$
d. $U = kq^2/3R$
e. $U = kq^2/3R^2$

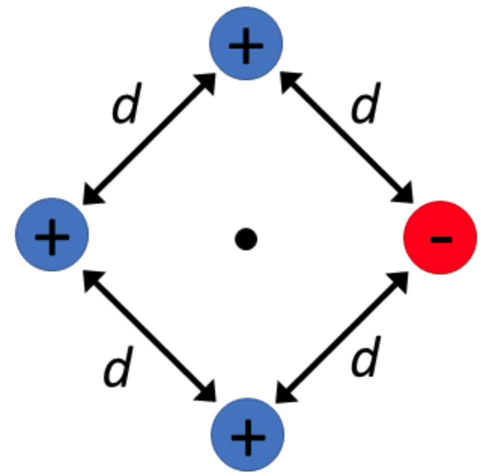
22) Two $2.9\ \mu C$ charges are held fixed at the positions shown in the figure. Note that both charges are positive.
Calculate the change in potential energy $U(B)-U(A)$ of a $1.0\ \mu C$ charge that is moved from A to B. Note that the ruler lines shown in the figure are equally spaced.



a. $U = -0.014\ J$
b. $U = -0.042\ J$
c. $U = 0\ J$
d. $U = 0.042\ J$
e. $U = 0.014\ J$

The next three questions pertain to the situation described below.

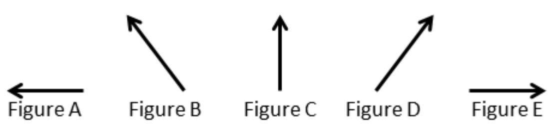
Four point charges are equally spaced by a distance $d = 4.69\ mm$ at the corners of a square, as shown in the figure. Three of the charges are positive, with $q = 2.9\ \mu C$, while one is negative with charge $q = -2.9\ \mu C$.



23) What is the electric potential at the center point between the fixed charges?

a. $V = -1.6 \times 10^7\ V$
b. $V = 1.6 \times 10^7\ V$
c. $V = 2.2 \times 10^7\ V$
d. $V = -1.1 \times 10^7\ V$
e. $V = 1.1 \times 10^7\ V$

24) Considering only the three positive charges, which vector arrow shown below best represents the direction of the electric field at the position of the negative charge?



a. *Figure A*
b. *Figure B*
c. *Figure C*
d. *Figure E*
e. *Figure D*

25) Considering only the three positive charges, what is the magnitude of the electric field at the position of the negative charge?

a. $E = 1.19 \times 10^9\ N/C$
b. $E = 2.27 \times 10^9\ N/C$
c. $E = 0\ N/C$
d. $E = 1.78 \times 10^9\ N/C$
e. $E = 1.08 \times 10^9\ N/C$

Kinematics and mechanics:

$x = x_0 + v_0 t + \frac{1}{2}at^2$ $\quad v = v_0 + at$ $\quad v^2 = v_0^2 + 2a\Delta x$

$F = ma$ $\quad a_c = \frac{v^2}{r}$

$E_{tot} = K.E. + P.E.$ $\quad K.E. = \frac{1}{2}mv^2 = \frac{p^2}{2m}$ $\quad p = mv$ $\quad W_F = Fd\cos\theta$

Electrostatics:

$F_{12} = \frac{kq_1q_2}{r^2}$ $\quad E \equiv \frac{F}{q_0}$ $\quad U_{12} = \frac{kq_1q_2}{r}$ $\quad V \equiv \frac{U}{q_0}$ $\quad W_E = -\Delta U = -W_{you}$

Point charge: $E = \frac{kq}{r^2}$ $\quad V = \frac{kq}{r}$

Electric dipole: $p \equiv qd$ $\quad \tau_{dip} = pE\sin\theta$ $\quad U_{dip} = -pE\cos\theta$

Resistance:

$R \equiv \frac{V}{I}$ $\quad I = \frac{\Delta q}{\Delta t}$ $\quad$ Physical resistance: $R = \rho\frac{L}{A}$

$P = IV = I^2R = \frac{V^2}{R}$ $\quad R_S = R_1 + R_2 + \cdots$ $\quad \frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$

Capacitance:

$C \equiv \frac{Q}{V}$ $\quad$ Parallel plate capacitor: $C = \frac{\kappa\varepsilon_0 A}{d}$, $V = Ed$

$U_C = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$ $\quad C_P = C_1 + C_2 + \cdots$ $\quad \frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots$

Circuits:

$\sum \Delta V = 0$ $\quad \sum I_{in} = \sum I_{out}$

$q(t) = q_\infty(1 - e^{-t/\tau})$ $\quad q(t) = q_0 e^{-t/\tau}$ $\quad I(t) = I_0 e^{-t/\tau}$ $\quad \tau = RC$

Magnetism:

$F = qvB\sin\theta$ $\quad r = \frac{mv}{qB}$ $\quad F_{wire} = qvB\sin\theta$ $\quad \tau_{loop} = NIAB\sin\varphi$

Magnetic dipole: $m \equiv NIA$ $\quad \tau_{dip} = mB\sin\varphi$ $\quad U_{dip} = -mB\cos\varphi$

$B_{wire} = \frac{\mu_0 I}{2\pi r}$ $\quad B_{sol} = \mu_0 nI$

Electromagnetic induction:

$\varepsilon = -N\dfrac{\Delta\Phi}{\Delta t}$ $\qquad\Phi = BA\cos\varphi$

$|\varepsilon_{bar}| = BLv$ $\qquad\varepsilon_{gen} = \varepsilon_{max}\sin\omega t = \omega NAB\sin\omega t$ $\qquad\omega = 2\pi f$

$V_{rms} = \dfrac{V_{max}}{\sqrt{2}}$ $\qquad I_{rms} = \dfrac{I_{max}}{\sqrt{2}}$ $\qquad\dfrac{V_p}{V_s} = \dfrac{I_s}{I_p} = \dfrac{N_p}{N_s}$

Electromagnetic waves:

$\lambda = \dfrac{c}{f}$ $\qquad E = cB$

$u_E = \dfrac{1}{2}\varepsilon_0 E^2$ $\qquad u_B = \dfrac{1}{2\mu_0}B^2$ $\qquad\bar{u} = \dfrac{1}{2}\varepsilon_0 E_{rms}^2 + \dfrac{1}{2\mu_0}B_{rms}^2 = \varepsilon_0 E_{rms}^2 = \dfrac{B_{rms}^2}{\mu_0}$ $\qquad S = I = \bar{u}c$

$f' = f\left(1 \pm \dfrac{u}{c}\right)$ $\qquad I = I_0\cos^2\theta$

Reflection and refraction:

$\theta_r = \theta_i$ $\qquad\dfrac{1}{d_o} + \dfrac{1}{d_i} = \dfrac{1}{f}$ $\qquad f = \pm\dfrac{R}{2}$ $\qquad m = \dfrac{h_i}{h_o} = -\dfrac{d_i}{d_o}$

$n_1\sin\theta_1 = n_2\sin\theta_2$ $\qquad v = \dfrac{c}{n}$ $\qquad\sin\theta_c = \dfrac{n_2}{n_1}$ $\qquad M = \dfrac{\theta'}{\theta} \approx \dfrac{d_{near}}{f}$

Interference and diffraction:

Double slit interference: $d\sin\theta = m\lambda$ $\qquad d\sin\theta = (m + \tfrac{1}{2})\lambda$ $\qquad m = 0, \pm 1, \pm 2\ldots$

Single-slit diffraction: $w\sin\theta = m\lambda$ $\qquad m = \pm 1, \pm 2\ldots$

Circular aperture: $D\sin\theta \approx 1.22\lambda$

Thin film: $\delta_1 = (0 \text{ or } \tfrac{1}{2})$ $\qquad\delta_2 = (0 \text{ or } \tfrac{1}{2}) + 2t\dfrac{n_{film}}{\lambda_0}$ $\qquad|\delta_2 - \delta_1| = (m \text{ or } m + \tfrac{1}{2})$ $\qquad m = 0, 1, 2\ldots$

Quantum mechanics:

$E = hf = \dfrac{hc}{\lambda}$ $\qquad\lambda = \dfrac{h}{p}$

Blackbody radiation: $\lambda_{max}T = 2.898\times 10^{-3}\, m\cdot K$ $\qquad$ Photoelectric effect: $K.E. = hf - W_0$

$\Delta p_x \Delta x \geq \dfrac{\hbar}{2}$ $\qquad\hbar \equiv \dfrac{h}{2\pi}$

Bohr atom: $2\pi r_n = n\lambda$ $\qquad n = 1, 2, 3\ldots$ $\qquad L_n = mv_n r_n = n\hbar$

$r_n = \left(\dfrac{\hbar^2}{mke^2}\right)\dfrac{n^2}{Z} \approx (5.29\times 10^{-11} m)\dfrac{n^2}{Z}$ $\qquad E_n = -\left(\dfrac{mk^2e^4}{2\hbar^2}\right)\dfrac{Z^2}{n^2} \approx -(13.6\, eV)\dfrac{Z^2}{n^2}$

$$\frac{1}{\lambda} \approx (1.097\times10^{7} m^{-1}) Z^2 \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

Quantum atom: $L = \sqrt{\ell(\ell+1)}\hbar$ $L_z = m_\ell \hbar$

Nuclear physics and radioactive decay:

$A = Z + N$ $r \approx (1.2\times10^{-15} m) A^{1/3}$ $E_0 = mc^2$

$\frac{\Delta N}{\Delta t} = -\lambda N$ $N(t) = N_0 e^{-\lambda t} = N_0 2^{-t/T_{1/2}}$ $T_{1/2} \equiv \frac{\ln 2}{\lambda} \approx \frac{0.693}{\lambda}$

Constants and unit conversions:

$g = 9.8 m/s^2$ $e = 1.60\times10^{-19} C$

$\varepsilon_0 = 8.85\times10^{-12} C^2/Nm^2$ $k \equiv \frac{1}{4\pi\varepsilon_0} = 8.99\times10^{9} Nm^2/C^2$ $\mu_0 = 4\pi\times10^{-7} T\cdot m/A$

$c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} = 3\times10^{8} m/s$ $h = 6.626\times10^{-34} J\cdot s$ $hc = 1240 nm\cdot eV$

$1eV = 1.60\times10^{-19} J$ $m_{proton} = 1.67\times10^{-27} kg = 938 MeV$ $m_{electron} = 9.11\times10^{-31} kg = 511 keV$

SI Prefixes

Power	**Prefix**	**Symbol**
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{0}	—	—
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

Last Name:_________________First Name__________________Network-ID___________

Discussion Section:_________Discussion TA Name:________________________________

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1. Use a #2 pencil. Do not use a mechanical pencil or pen. Darken each circle completely, but stay within the boundary. If you decide to change an answer, erase vigorously; the scanner sometimes registers incompletely erased marks as intended answers; this can adversely affect your grade. Light marks or marks extending outside the circle may be read improperly by the scanner. Be especially careful that your mark covers the **center** of its circle.

2. You may find the version of **this Exam Booklet at the top of page 2**. Mark the version circle in the TEST FORM box near the middle of your answer sheet. **DO THIS NOW!**

3. Print your **NETWORK ID** in the designated spaces at the *right* side of the answer sheet, starting in the left most column, then **mark the corresponding circle** below each character. If there is a letter "o" in your NetID, be sure to mark the "o" circle and not the circle for the digit zero. If and only if there is a hyphen "-" in your NetID, mark the hyphen circle at the bottom of the column. When you have finished marking the circles corresponding to your NetID, check particularly that you have not marked two circles in any one of the columns.

4. Print **YOUR LAST NAME** in the designated spaces at the *left* side of the answer sheet, then mark the corresponding circle below each letter. Do the same for your **FIRST NAME INITIAL**.

5. Print your UIN# in the STUDENT NUMBER designated spaces and mark the corresponding circles. You need not write in or mark the circles in the SECTION box.

6. Sign your name **(DO NOT PRINT)** on the **STUDENT SIGNATURE** *line*.

7. On the **SECTION** *line*, print your **DISCUSSION SECTION**. You need not fill in the COURSE or INSTRUCTOR lines.

Before starting work, check to make sure that your test booklet is complete. You should have 10 ***numbered pages*** *plus three (3) Formula Sheets following these instructions.*

Academic Integrity—**Giving assistance to or receiving assistance from another student or using unauthorized materials during a University Examination can be grounds for disciplinary action, up to and including dismissal from the University.**

This Exam Booklet is Version A. Mark the **A** circle in the **TEST FORM** box near the middle of your answer sheet. **DO THIS NOW!**

Exam Grading Policy—

The exam is worth a total of **128** points, composed of three types of questions.

MC5: *multiple-choice-five-answer questions, each worth 6 points.*
Partial credit will be granted as follows.

(a) If you mark only one answer and it is the correct answer,
you earn **6** points.
(b) If you mark *two* answers, one of which is the correct answer,
you earn **3** points.
(c) If you mark *three* answers, one of which is the correct answer,
you earn **2** points.
(d) If you mark no answers, or more than *three*, you earn 0 points.

MC3: *multiple-choice-three-answer questions, each worth 3 points.*
No partial credit.

(a) If you mark only one answer and it is the correct answer,
you earn **3** points.
(b) If you mark a wrong answer or no answers, you earn **0** points.

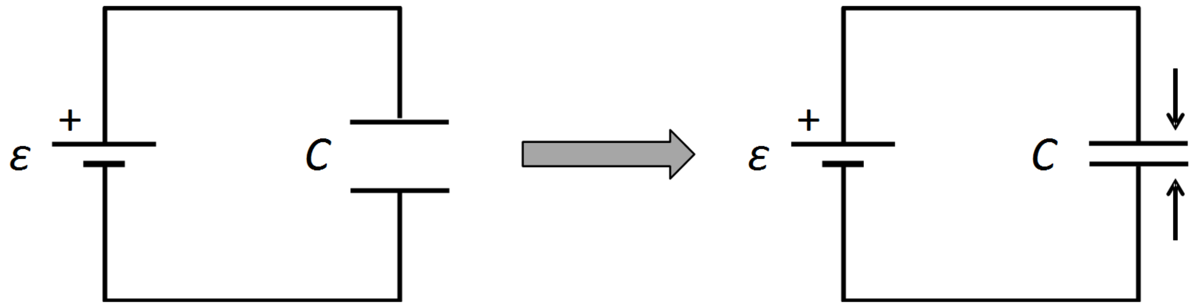
MC2: *multiple-choice-two-answer questions, each worth 2 points.*
No partial credit.

(a) If you mark only one answer and it is the correct answer,
you earn **2** points.
(b) If you mark the wrong answer or neither answer, you earn **0** points.

Some helpful information:

- A reminder about prefixes: p (pico) = 10^{-12}; n (nano) = 10^{-9}; μ (micro) = 10^{-6}; m (milli) = 10^{-3}; k (kilo) = 10^{+3}; M or Meg (mega) = 10^{+6}; G or Gig (giga) = 10^{+9}.

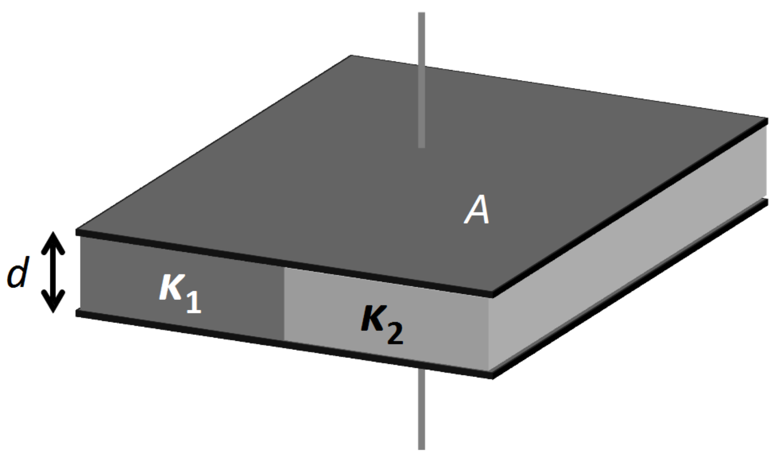
1) A parallel plate capacitor is connected to a 9 V battery, as shown below. At some time, the parallel plates are moved a small distance *closer* together.



What happens to the charge $Q \geq 0$ stored on the top capacitor plate? Note that the capacitor remains connected to the battery throughout.

a. Q increases
b. Q remains the same
c. Q decreases

2) The capacitor below is made of two parallel plates of area $A = 20\ cm^2$ separated by a distance $d = 3\ mm$. As shown below, two slabs of dielectric with dielectric constants $\kappa_1 = 2$ and $\kappa_2 = 4.5$ are placed between the two plates and take up *exactly half* the volume between the plates.

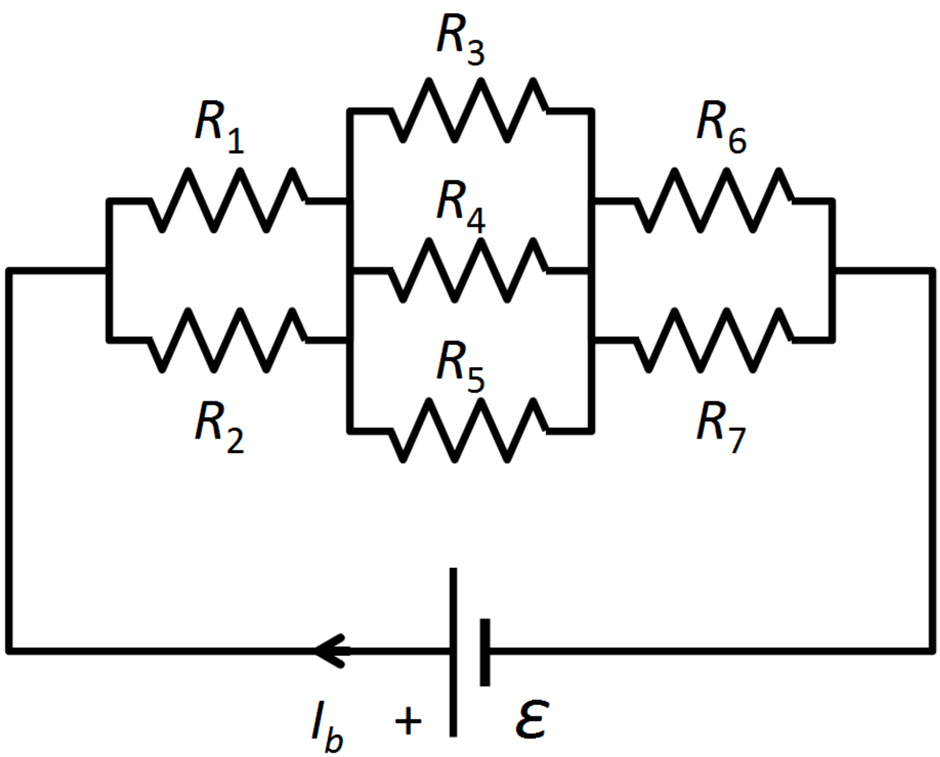


Calculate the capacitance C of this capacitor.

a. $C = 50\ pF$
b. $C = 19\ pF$
c. $C = 67\ pF$
d. $C = 81\ pF$
e. $C = 11\ pF$

The next two questions pertain to the situation described below.

Consider the following network of resistors. All of the resistors have the same resistance R. The network is connected to a battery with emf ε, through which a current I_b passes.



3) Calculate the equivalent resistance R_{eq} of the network.

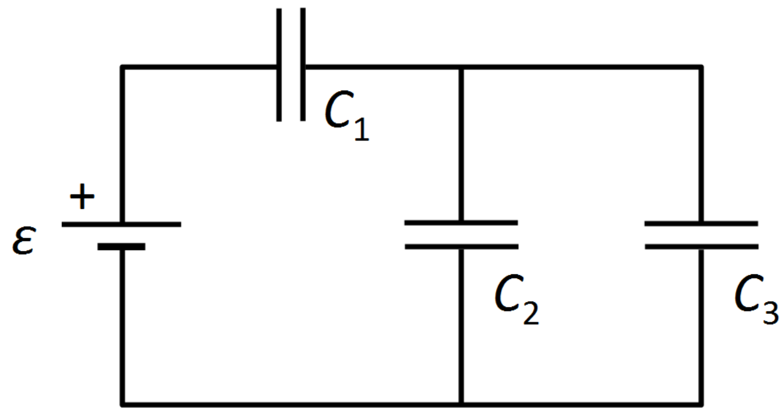
a. $R_{eq} = R/3$
b. $R_{eq} = R/2$
c. $R_{eq} = 4R/3$
d. $R_{eq} = R$
e. $R_{eq} = 3R/8$

4) Calculate the current I_4 through resistor R_4 in terms of the battery current I_b.

a. $I_4 = I_b / 3$
b. $I_4 = 3I_b / 8$
c. $I_4 = 4I_b / 3$
d. $I_4 = I_b / 2$
e. $I_4 = I_b$

The next three questions pertain to the situation described below.

The following circuit contains three capacitors $C_1 = 19\ \mu F$, $C_2 = 1\ \mu F$, and $C_3 = 7\ \mu F$ connected to a battery with an unknown emf ε. The charge on capacitor C_1 is $Q_1 = 8\ \mu C$.



5) How much energy is stored on capacitor C_1?

a. $E = 1.7 \times 10^{-6}\ J$
b. $E = 5.9 \times 10^{-6}\ J$
c. $E = 2.9 \times 10^{-6}\ J$
d. $E = 4.7 \times 10^{-7}\ J$
e. $E = 9.4 \times 10^{-7}\ J$

6) What is the charge Q_2 on capacitor C_2?

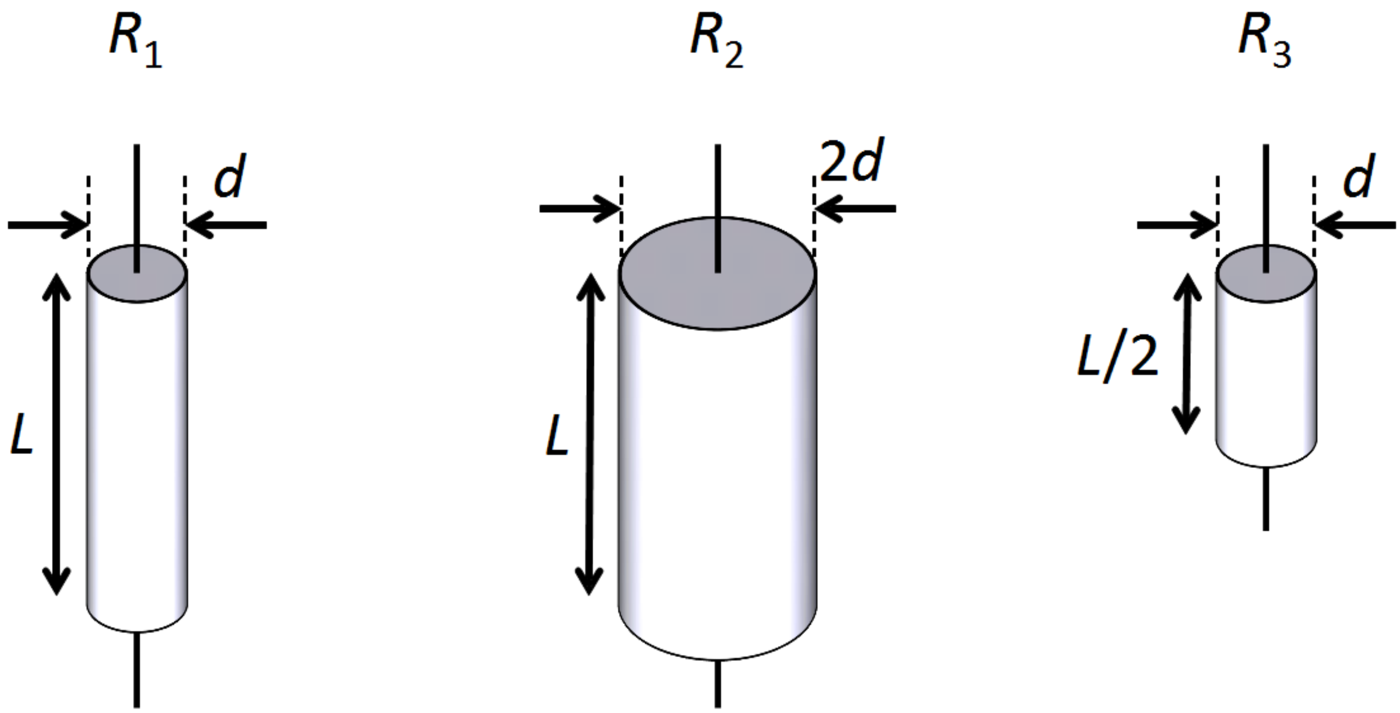
a. $Q_2 = 2.6\ \mu C$
b. $Q_2 = 0.56\ \mu C$
c. $Q_2 = 1\ \mu C$
d. $Q_2 = 3.5\ \mu C$
e. $Q_2 = 1.7\ \mu C$

7) What is the equivalent capacitance C_{eq} of the circuit?

a. $C_{eq} = 5.6\ \mu F$
b. $C_{eq} = 9.6\ \mu F$
c. $C_{eq} = 3\ \mu F$
d. $C_{eq} = 15\ \mu F$
e. $C_{eq} = 20\ \mu F$

The next two questions pertain to the situation described below.

Consider the three resistors below made of identical material but of different dimensions.



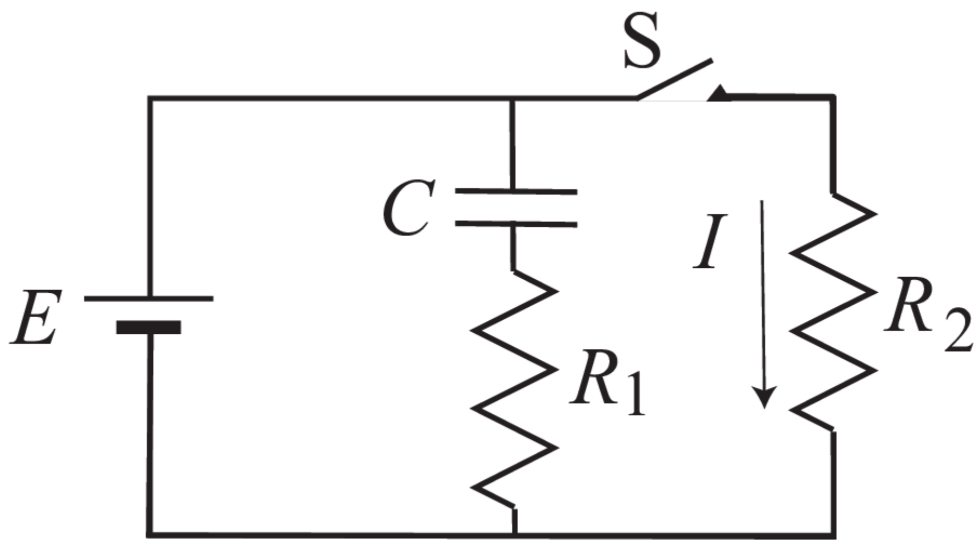
8) If the same current *I* passes through each resistor, which resistor dissipates the *most* power?

a. R_1
b. R_2
c. R_3

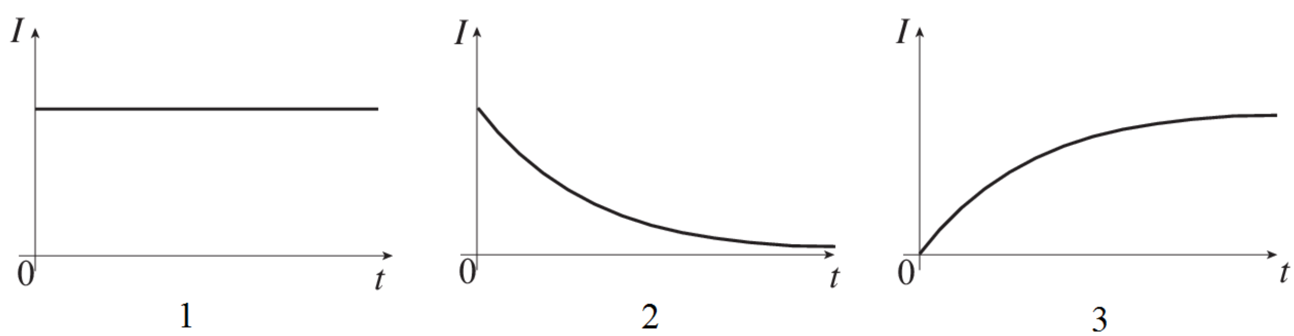
9) If the same voltage *V* is applied across each resistor, which resistor dissipates the *most* power?

a. R_1
b. R_2
c. R_3

10) In the following RC circuit with a switch S, two resistors R_1 and R_2 have the same resistance $R = 20\ \Omega$, C denotes a capacitor of capacitance $15\ \mu F$, and E denotes a 12 V battery.



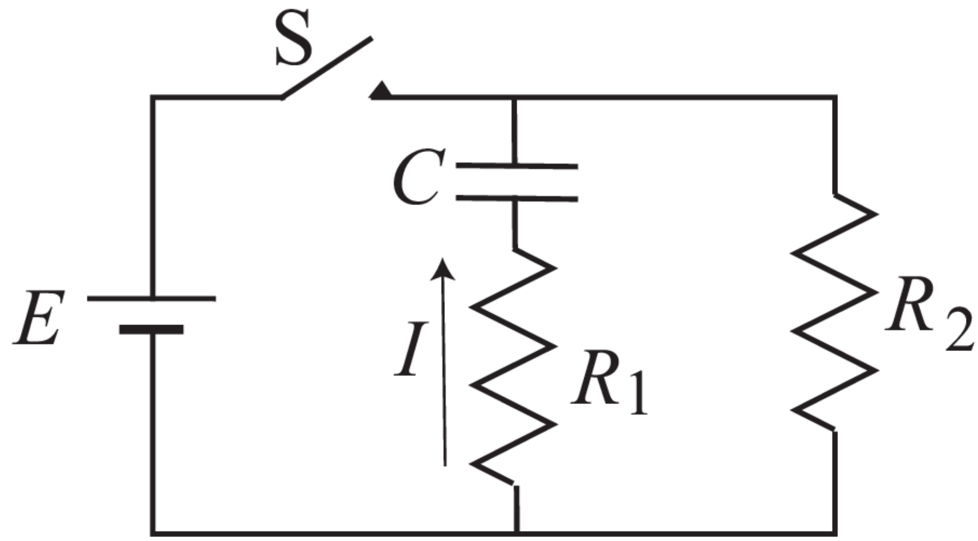
Initially, switch S is open for a long time. After $t = 0$ switch S is closed. Choose the best figure from below describing the time-dependence of the current I through R_2. Do not forget that the battery E is still connected.



a. 3
b. 2
c. 1

The next two questions pertain to the situation described below.

In the following RC circuit with a switch S, two resistors R_1 and R_2 have the same resistance $R = 29\ \Omega$, C denotes a capacitor of capacitance $7\ \mu F$, and E denotes a 12 V battery.



11) Switch S has been closed for a long time. What is the current I through R_1 immediately after S is opened? Pay attention to the direction of the current arrow in the figure.

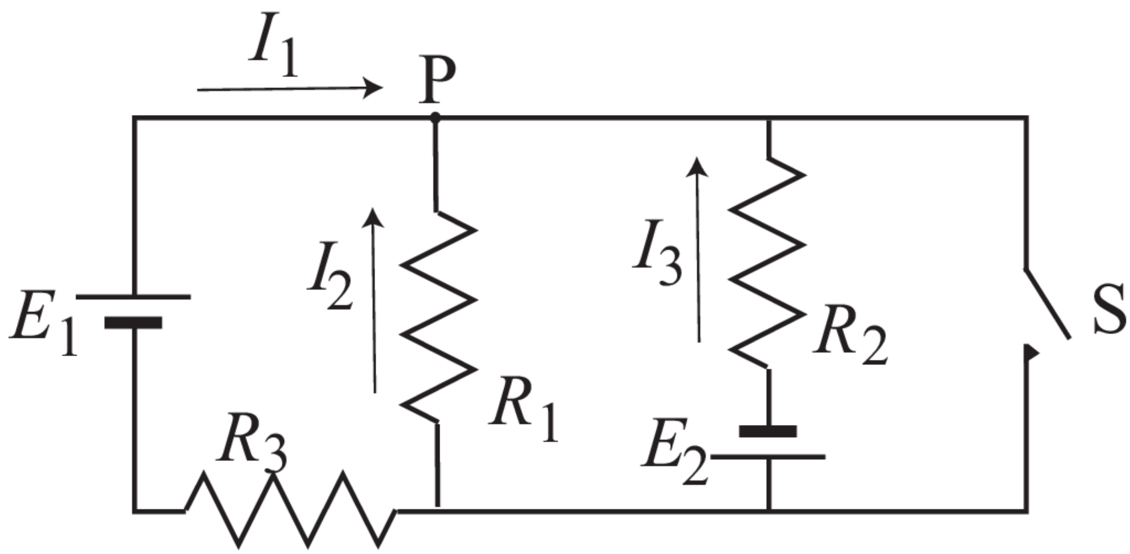
a. $I = +0.41\ A$
b. $I = -0.21\ A$
c. $I = +0.21\ A$
d. $I = 0\ A$
e. $I = -0.41\ A$

12) What is the voltage V_2 across resistor R_2 at a time of 0.5 ms after switch S is opened?

a. $V_2 = 3.2\ V$
b. $V_2 = 0.51\ V$
c. $V_2 = 1.8\ V$

The next two questions pertain to the situation described below.

In the following figure, $E_1 = 12\ V$, $E_2 = 4\ V$, $R_1 = 7\ \Omega$, $R_2 = 12\ \Omega$, and $R_3 = 4\ \Omega$. Initially, the switch S is open.



13) At junction P three currents I_1, I_2, and I_3 meet. Choose the correct relation among them from below.

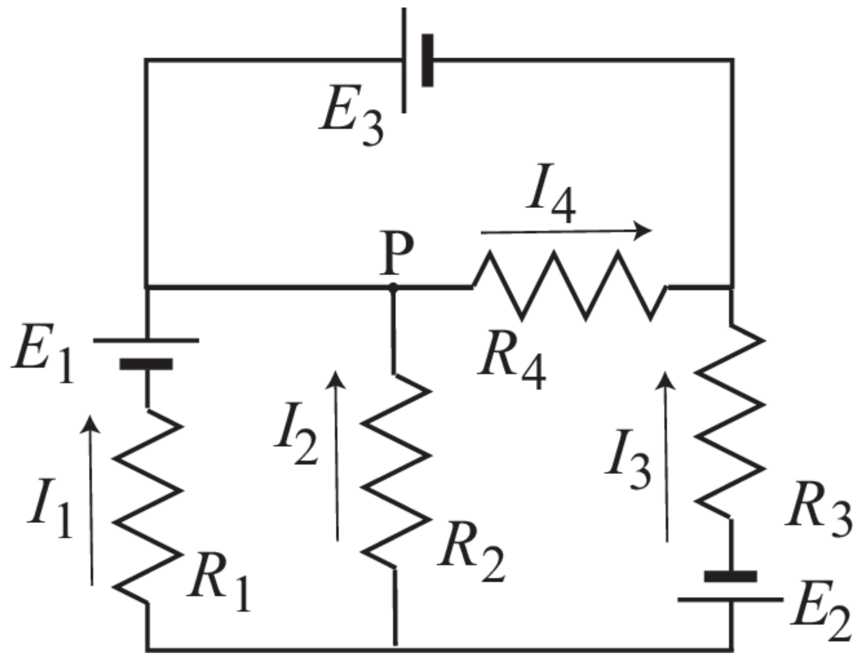
a. $I_1 + I_2 + I_3 = 0$
b. $I_1 - I_2 - I_3 = 0$
c. $-I_1 + I_2 - I_3 = 0$
d. $I_1 - I_2 + I_3 = 0$
e. $I_1 + I_2 - I_3 = 0$

14) When the switch S is closed, what is the current I_3?

a. $I_3 = 0\ A$
b. $I_3 = -0.57\ A$
c. $I_3 = -0.75\ A$
d. $I_3 = -0.33\ A$
e. $I_3 = -0.7\ A$

The next three questions pertain to the situation described below.

In the following figure, $E_1 = 12\ V$, $E_3 = 7\ V$, $R_1 = R_2 = R_3 = R_4 = 3\ \Omega$. E_2 is not known.



15) Choose the correct formula exhibiting Kirchhoff's loop law from the following formulas.

a. $I_2R_2 + I_4R_4 - I_3R_3 - E_2 = 0$
b. $I_2R_2 - I_4R_4 - I_3R_3 + E_2 = 0$
c. $I_2R_2 + I_4R_4 - I_3R_3 + E_2 = 0$
d. $I_2R_2 + I_4R_4 + I_3R_3 - E_2 = 0$
e. $I_2R_2 + I_4R_4 + I_3R_3 + E_2 = 0$

16) What is the current I_4? Pay attention to the direction of the current arrow in the figure.

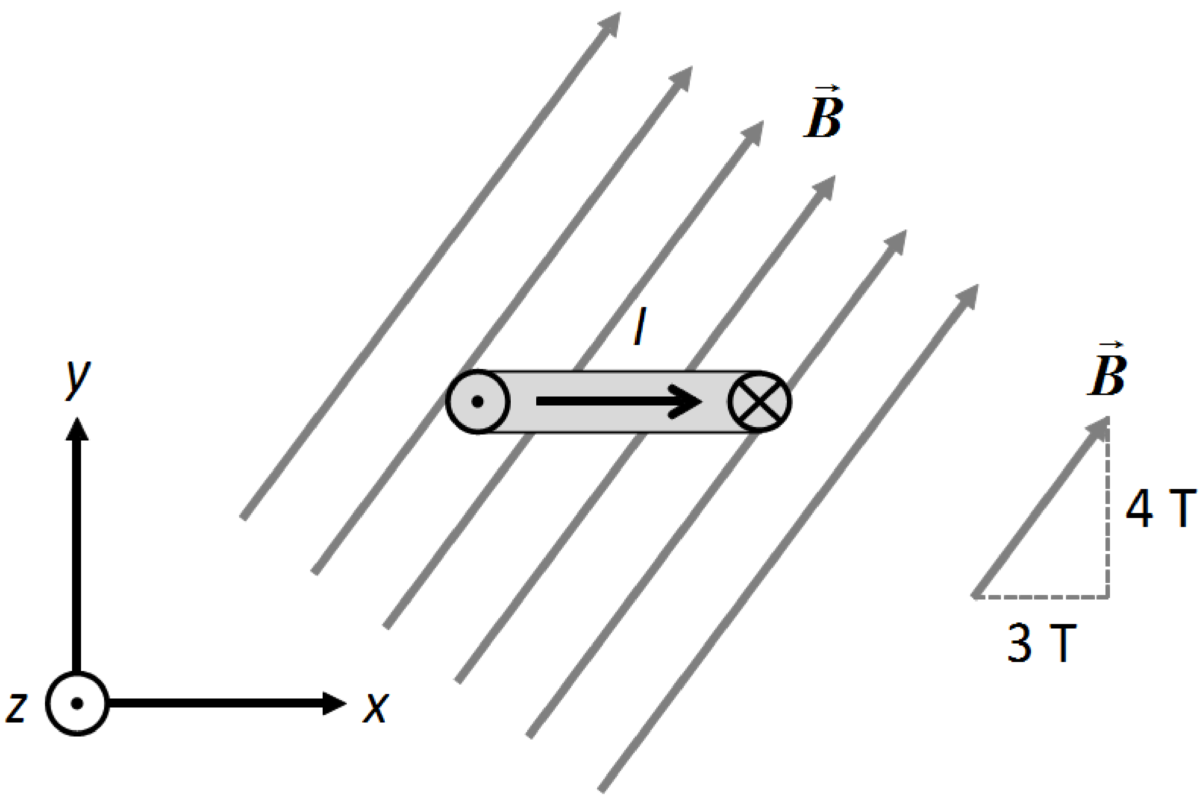
a. $I_4 = 0\ A$
b. $I_4 = +1.2\ A$
c. $I_4 = -2.3\ A$
d. $I_4 = +2.3\ A$
e. $I_4 = -1.2\ A$

17) The current I_2 is measured to be $-1.5\ A$. What is the current I_1? Again, pay attention to the direction of the current arrow in the figure.

a. $I_1 = +2.5\ A$
b. $I_1 = -2.5\ A$
c. $I_1 = -5.5\ A$
d. $I_1 = +5.5\ A$
e. $I_1 = 0\ A$

The next two questions pertain to the situation described below.

A current carrying loop of radius *r = 14 cm* is oriented horizontally, with its area parallel to the x-z-plane in the figure below, and a uniform magnetic field is applied that has no z-component. The x-component of the B field is *3 T* and its y-component is *4 T*. The current *I = 7 A* is flowing into the (–z) direction at the rightmost point of the loop, as denoted in the figure that shows a side view of the loop. (The (–z)-direction points into the page).



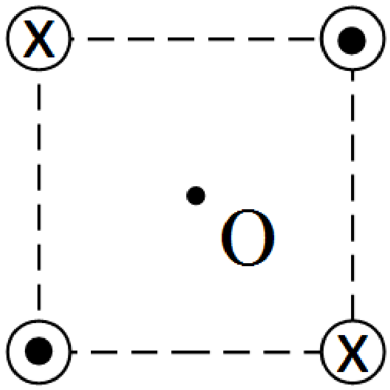
18) What is the **magnitude** of the torque on the current loop?

a. $\tau = 1.7\ N \cdot m$
b. $\tau = 2500\ N \cdot m$
c. $\tau = 2.2\ N \cdot m$
d. $\tau = 1.3\ N \cdot m$
e. $\tau = 1800\ N \cdot m$

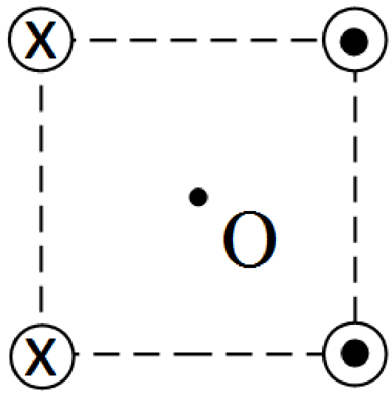
19) In which direction will the loop *start to turn* if left free?

a. Clockwise about an axis parallel to the z-axis
b. Counter-clockwise about an axis parallel to the z-axis
c. Around an axis that is *not* parallel to the z axis.

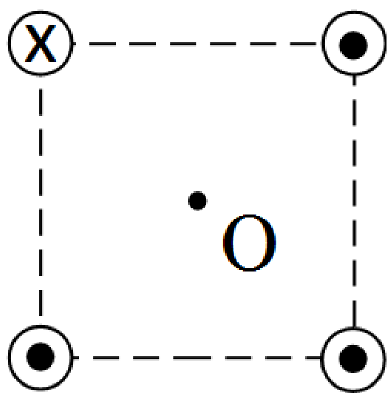
20) Four long straight wires carrying currents of equal magnitude ($I_1 = I_2 = I_3 = I_4 = I$) are parallel or antiparallel to each other such that their cross sections form the corners of a square, as shown in the figures. The figures indicate the directions of the current in each wire. In which case is the magnitude of the total magnetic field at the center of the square (O) the largest?



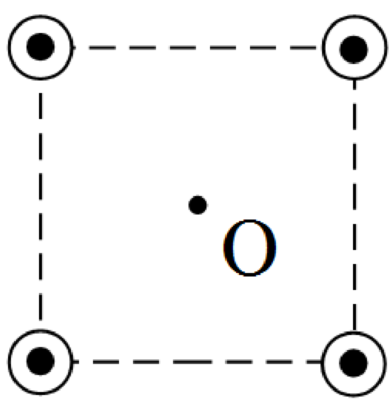
a.



b.

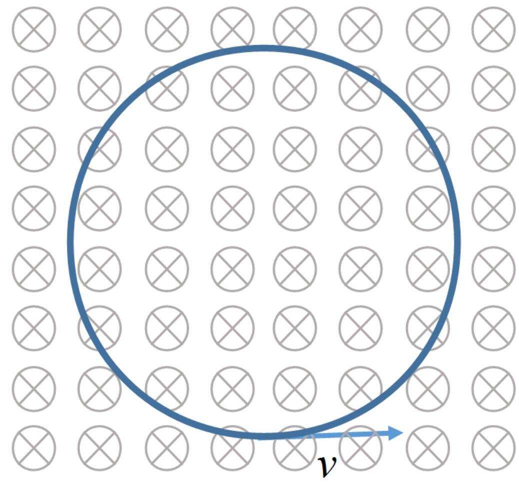


c.



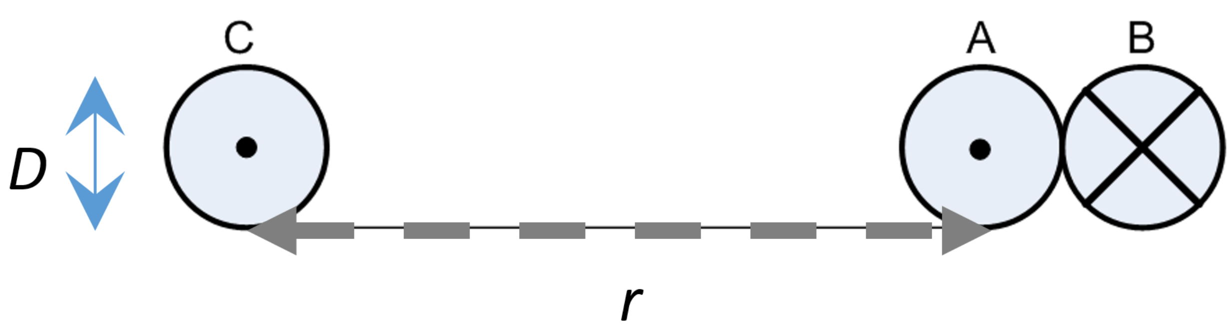
d.

21) A charged particle travels counterclockwise with speed v on a circle in the plane of the page, while a uniform magnetic field B is applied in a perpendicular direction, pointing into the page (as shown below). The period T is the amount of time the particle takes to travel around one complete circle. How would the period change if the speed of the particle was doubled?



a. T would increase by a factor of 4.
b. T would remain unchanged.
c. T would increase by a factor of 2.
d. T would decrease by a factor of 2.
e. T would decrease by a factor of 4.

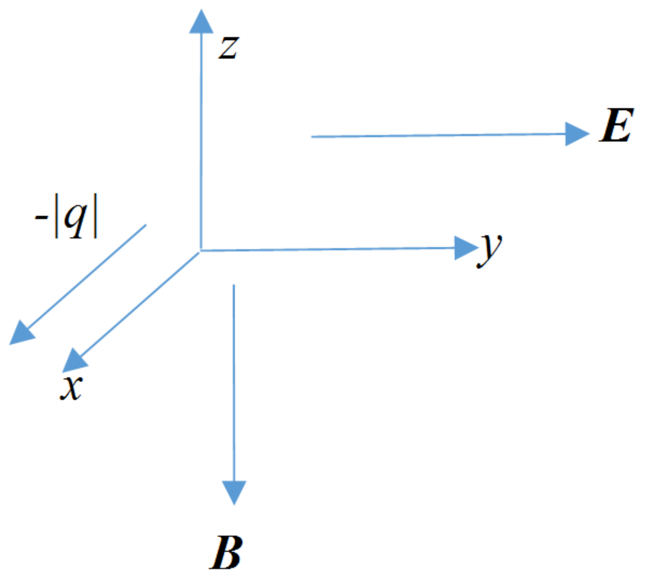
22) Three long, parallel straight wires A, B and C carry a constant current of $I = 3\ A$ each. The direction of the current of each wire is as indicated in the figure below. The length of the wires is $L = 1\ m$ and the diameter is $D = 8\ mm$. Wires A and B are stuck to each other but electrically insulated from each other. We call the combination of wires A and B a "double wire AB". The distance from the center of C to the center of A is $r = 2\ cm$.



What is the net force on the double wire AB due to wire C?

a. $F = 1.5 \times 10^{-4}\ N$
b. $F = 0\ N$
c. $F = 2.6 \times 10^{-5}\ N$

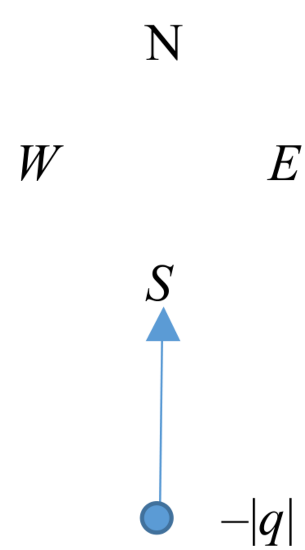
23) A particle of charge $-|q|$ moves in the positive x-direction with speed v. There is a uniform electric field $\boldsymbol{E}$ of magnitude $|E|$ pointing in the positive y-direction and a uniform magnetic field $\boldsymbol{B}$ pointing in the *negative z-direction*. What must be the magnitude of the magnetic field, $|E|$, such that the particle does not accelerate? (Hint: Pay careful attention to the given direction of $\boldsymbol{E}$ and $\boldsymbol{B}$).



a. $|B| = |E|$
b. The charge will accelerate for any magnetic field $\boldsymbol{B}$ pointing in the negative z-direction.
c. $|B| = |E|/v$

24) A negatively charged particle enters a uniform magnetic field from the south and is pushed to the east.

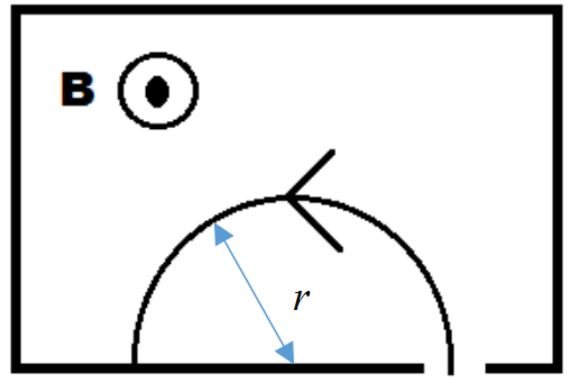
In which direction does the magnetic field point?



a. The magnetic field points into the page.
b. The magnetic field points out of the page.

The next two questions pertain to the situation described below.

A negatively charged particle with charge $q = -3e$ enters a uniform magnetic field $B = 0.3\ T$ pointing out of the page with a speed of $v = 10^6\ m/s$ and sweeps out a half circle of radius $r = 5.9\ cm$ before leaving the field.



25) What is the particle's mass?

a. More information is required to determine the mass of the particle.
b. $m = 2.8 \times 10^{-20}\ kg$
c. $m = 8.5 \times 10^{-27}\ kg$
d. $m = 8.5 \times 10^{-21}\ kg$
e. $m = 2.8 \times 10^{-26}\ kg$

26) What is the speed v of the particle upon exiting the region with the B field?

a. $v = 10^5\ m/s$
b. $v = 10^7\ m/s$
c. $v = 10^4\ m/s$
d. $v = 0\ m/s$
e. $v = 10^6\ m/s$

Physic 102 formula sheet (SP2015)

Kinematics and mechanics

$x = x_0 + v_0 t + \frac{1}{2}at^2$ $\quad v = v_0 + at$ $\quad v^2 = v_0^2 + 2a\Delta x$

$F = ma$ $\quad a_c = \frac{v^2}{r}$

$E_{\text{tot}} = K + U$ $\quad K = \frac{1}{2}mv^2 = \frac{p^2}{2m}$ $\quad p = mv$ $\quad W_F = Fd\cos\theta$

Electrostatics

$F_{12} = k\frac{q_1 q_2}{r^2}$ $\quad E = \frac{F}{q_0}$ $\quad U_{12} = k\frac{q_1 q_2}{r}$ $\quad V \equiv \frac{U}{q_0}$ $\quad W_E = -\Delta U = -W_{\text{you}}$

Point charge $\quad E = k\frac{q}{r^2}$ $\quad V = k\frac{q}{r}$

Electric dipole $\quad p = qd$ $\quad \tau_{\text{dip}} = pE\sin\theta$ $\quad U_{\text{dip}} = -pE\cos\theta$

Resistance

$R = \frac{V}{I}$ $\quad I = \frac{\Delta q}{\Delta t}$ $\quad$ Physical resistance: $R = \rho\frac{L}{A}$

$P = IV = I^2R = \frac{V^2}{R}$ $\quad R_{\text{S}} = R_1 + R_2 + \cdots$ $\quad \frac{1}{R_{\text{P}}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$

Capacitance

$C = \frac{Q}{V}$ $\quad$ Parallel plate capacitor: $C = \frac{\kappa\epsilon_0 A}{d}$ $\quad E = \frac{Q}{\epsilon_0 A}$ $\quad V = Ed$

$U_C = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$ $\quad C_{\text{P}} = C_1 + C_2 + \cdots$ $\quad \frac{1}{C_{\text{S}}} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots$

Circuits

$\sum \Delta V = 0$ $\quad \sum I_{\text{in}} = \sum I_{\text{out}}$

$q(t) = q_\infty(1 - e^{-t/\tau})$ $\quad q(t) = q_0 e^{-t/\tau}$ $\quad I(t) = I_0 e^{-t/\tau}$ $\quad \tau = RC$

Magnetism

$F = qvB\sin\theta$ $\quad r = \frac{mv}{qB}$ $\quad F_{\text{wire}} = ILB\sin\theta$ $\quad \tau_{\text{loop}} = NIAB\sin\varphi$

Magentic dipole: $\quad \mu = NIA$ $\quad \tau_{\text{dip}} = \mu B\sin\varphi$ $\quad U_{\text{dip}} = -\mu B\cos\varphi$

$B_{\text{wire}} = \frac{\mu_0 I}{2\pi r}$ $\quad B_{\text{sol}} = \mu_0 nI$

Electromagnetic induction

$\mathcal{E} = -N\frac{\Delta\Phi}{\Delta t}$ $\quad \Phi = BA\cos\varphi$

$|\mathcal{E}_{\text{bar}}| = BLv$ $\quad \mathcal{E}_{\text{gen}} = \mathcal{E}_{\text{max}}\sin\omega t = \omega NAB\sin\omega t$ $\quad \omega = 2\pi f$

$V_{\text{rms}} = \frac{V_{\text{max}}}{\sqrt{2}}$ $\quad I_{\text{rms}} = \frac{I_{\text{max}}}{\sqrt{2}}$ $\quad \frac{V_{\text{p}}}{V_{\text{s}}} = \frac{I_{\text{s}}}{I_{\text{p}}} = \frac{N_{\text{p}}}{N_{\text{s}}}$

Electromagnetic waves

$\lambda = \frac{c}{f}$ $\quad E = cB$

$u_E = \frac{1}{2}\epsilon_0 E^2$ $\quad u_B = \frac{1}{2\mu_0}B^2$ $\quad \overline{u} = \frac{1}{2}\epsilon_0 E_{\text{rms}}^2 + \frac{1}{2\mu_0}B_{\text{rms}}^2 = \epsilon_0 E_{\text{rms}}^2 = \frac{B_{\text{rms}}^2}{\mu_0}$ $\quad S = I = \overline{u}c = \frac{P}{A}$

$f_0 = f_e\sqrt{\frac{1 + v_{\text{rel}}/c}{1 - v_{\text{rel}}/c}} \approx f_e\left(1 + \frac{v_{\text{rel}}}{c}\right)$ $\quad I = I_0\cos^2\theta$

Reflection and refraction

$\theta_r = \theta_i$ $\quad$ $\frac{1}{d_o} + \frac{1}{d_1} = \frac{1}{f}$ $\quad$ $f = \pm\frac{R}{2}$ $\quad$ $m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$

$n_1 \sin\theta_1 = n_2 \sin\theta_2$ $\quad$ $v = \frac{c}{n}$ $\quad$ $\sin\theta_c = \frac{n_2}{n_1}$ $\quad$ $M = \frac{\theta'}{\theta} \approx \frac{d_{\text{near}}}{f}$

Compound microscope: $m_{\text{obj}} = \frac{L_{\text{tube}}}{f_{\text{obj}}}$ $\quad$ $M_{\text{eye}} = \frac{d_{\text{near}}}{f_{\text{eye}}}$ $\quad$ $M_{\text{tot}} = M_{\text{eye}} m_{\text{obj}}$

Interference and diffraction

Double-slit interference: $d \sin\theta = m\lambda$ $\quad$ $d \sin\theta = \left(m + \frac{1}{2}\right)\lambda$ $\quad$ $m = 0, \pm 1, \pm 2, \cdots$

Single-slit diffraction: $a \sin\theta = m\lambda$ $\quad$ $m = 0, \pm 1, \pm 2, \cdots$

Circular aperture: $a \sin\theta \approx 1.22\lambda$

Quantum mechanics

$E = hf = \frac{hc}{\lambda}$ $\quad$ $\lambda = \frac{h}{p}$ $\quad$ $\Delta p_x \Delta x \geq \frac{\hbar}{2}$ $\quad$ $\hbar = \frac{h}{2\pi}$

Bohr atom: $2\pi r_n = n\lambda$ $\quad$ $n = 1, 2, 3, \cdots$ $\quad$ $L_n = m_e v_n r_n = n\hbar$

$r_n = \left(\frac{\hbar^2}{m_e k e^2}\right)\frac{n^2}{Z} \approx (5.29 \times 10^{-11}\ \text{m})\frac{n^2}{Z}$ $\quad$ $E_n = -\left(\frac{m_e k^2 e^4}{2\hbar^2}\right)\frac{Z^2}{n^2} \approx -(13.6\ \text{eV})\frac{Z^2}{n^2}$

$\frac{1}{\lambda} \approx (1.097 \times 10^7\ \text{m}^{-1}) Z^2 \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

Quantum atom: $L = \sqrt{\ell(\ell+1)}\hbar$ $\quad$ $L_Z = m_{\epsilon,,}\hbar$ $\quad$ $S_z = m_s\hbar$

Atomic magnetism: $\mu_{e,z} = -\frac{e}{2m_e} L_z$ $\quad$ $\mu_{s,z} = -\frac{ge}{2m_e} S_z, g \approx 2$ $\quad$ $\mu_B \equiv \frac{e\hbar}{2m_e} \approx 5.8 \times 10^{-5}\ \text{eV/T}$

Nuclear physics and radioactive decay

$A = Z + N$ $\quad$ $r \approx (1.2 \times 10^{-15}\ \text{m}) A^{1/3}$ $\quad$ $E_0 = mc^2$

$m_{\text{nucleus}} = Z m_{\text{proton}} + N m_{\text{neutron}} - \frac{|E_{\text{bind}}|}{c^2}$

$\frac{\Delta N}{\Delta t} = \lambda N$ $\quad$ $N(t) = N_0 e^{-\lambda t} = N_0 2^{-t/T_{1/2}}$ $\quad$ $T_{1/2} = \frac{\ln 2}{\lambda} \approx \frac{0.693}{\lambda}$

Constants and unit conversion

$g = 9.8\ \text{m/s}^2$ $\quad$ $e = 1.60 \times 10^{-19}\ \text{C}$

$\epsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2/\text{Nm}^2$ $\quad$ $k \equiv \frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9\ \text{Nm}^2/\text{C}^2$ $\quad$ $\mu_0 = 4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A}$

$c = \frac{1}{\sqrt{\epsilon_0 \mu_0}} = 3 \times 10^8\ \text{m/s}$ $\quad$ $h = 6.626 \times 10^{-34}\ \text{J}\cdot\text{s}$ $\quad$ $hc = 1240\ \text{eV}\cdot\text{nm}$

$1\ \text{eV} = 1.60 \times 10^{-19}\ \text{J}$ $\quad$ $m_{\text{electron}} = 9.11 \times 10^{-31}\ \text{kg} = 511\ \text{keV}/c^2$

$m_{\text{proton}} = 1.673 \times 10^{-27}\ \text{kg} = 938\ \text{MeV}/c^2$ $\quad$ $m_{\text{neutron}} = 1.675 \times 10^{-27}\ \text{kg} = 939.5\ \text{MeV}/c^2$

SI Prefixes

Power	Prefix	Symbol
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^0	—	—
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

Last Name:________________ First Name________________ Network-ID__________

Discussion Section:________ Discussion TA Name:______________________________

Turn off your cell phone and put it out of sight.
Keep your calculator on your own desk. Calculators cannot be shared.
This is a closed book exam. You have ninety (90) minutes to complete it.

1. Use a #2 pencil. Do not use a mechanical pencil or pen. Darken each circle completely, but stay within the boundary. If you decide to change an answer, erase vigorously; the scanner sometimes registers incompletely erased marks as intended answers; this can adversely affect your grade. Light marks or marks extending outside the circle may be read improperly by the scanner. Be especially careful that your mark covers the **center** of its circle.

2. You may find the version of **this Exam Booklet at the top of page 2**. Mark the version circle in the TEST FORM box near the middle of your answer sheet. **DO THIS NOW!**

3. Print your **NETWORK ID** in the designated spaces at the *right* side of the answer sheet, starting in the left most column, then **mark the corresponding circle** below each character. If there is a letter "o" in your NetID, be sure to mark the "o" circle and not the circle for the digit zero. If and only if there is a hyphen "-" in your NetID, mark the hyphen circle at the bottom of the column. When you have finished marking the circles corresponding to your NetID, check particularly that you have not marked two circles in any one of the columns.

4. Print **YOUR LAST NAME** in the designated spaces at the *left* side of the answer sheet, then mark the corresponding circle below each letter. Do the same for your **FIRST NAME INITIAL**.

5. Print your UIN# in the STUDENT NUMBER designated spaces and mark the corresponding circles. You need not write in or mark the circles in the SECTION box.

6. Sign your name **(DO NOT PRINT)** on the **STUDENT SIGNATURE** *line*.

7. On the **SECTION** *line*, print your **DISCUSSION SECTION**. You need not fill in the COURSE or INSTRUCTOR lines.

Before starting work, check to make sure that your test booklet is complete. You should have 10 ***numbered pages*** *plus three (3) Formula Sheets following these instructions.*

Academic Integrity—**Giving assistance to or receiving assistance from another student or using unauthorized materials during a University Examination can be grounds for disciplinary action, up to and including dismissal from the University.**

This Exam Booklet is Version A. Mark the **A** circle in the **TEST FORM** box near the middle of your answer sheet. **DO THIS NOW!**

Exam Grading Policy—

The exam is worth a total of **110** points, composed of three types of questions.

MC5: *multiple-choice-five-answer questions, each worth 6 points.*
Partial credit will be granted as follows.

(a) If you mark only one answer and it is the correct answer,
you earn **6** points.
(b) If you mark *two* answers, one of which is the correct answer,
you earn **3** points.
(c) If you mark *three* answers, one of which is the correct answer,
you earn **2** points.
(d) If you mark no answers, or more than *three*, you earn 0 points.

MC3: *multiple-choice-three-answer questions, each worth 3 points.*
No partial credit.

(a) If you mark only one answer and it is the correct answer,
you earn **3** points.
(b) If you mark a wrong answer or no answers, you earn **0** points.

MC2: *multiple-choice-two-answer questions, each worth 2 points.*
No partial credit.

(a) If you mark only one answer and it is the correct answer,
you earn **2** points.
(b) If you mark the wrong answer or neither answer, you earn **0** points.

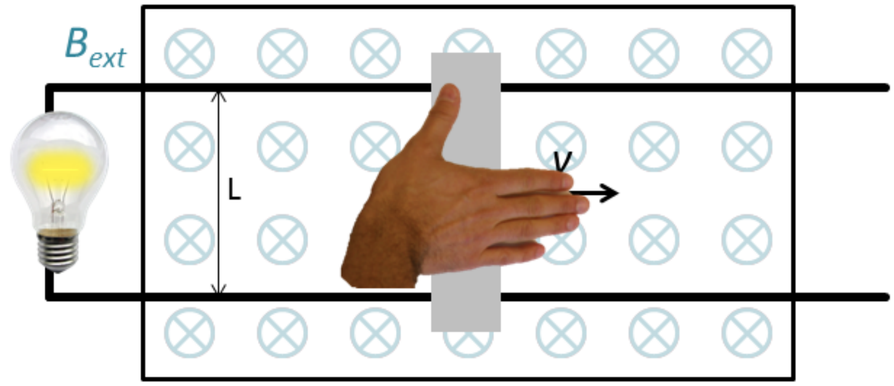
Some helpful information:

- A reminder about prefixes: p (pico) = 10^{-12}; n (nano) = 10^{-9}; μ (micro) = 10^{-6}; m (milli) = 10^{-3}; k (kilo) = 10^{+3}; M or Meg (mega) = 10^{+6}; G or Gig (giga) = 10^{+9}.

The next two questions pertain to the situation described below.

A light bulb is attached to a frictionless, conducting track as shown in the figure. The tracks run through an area containing a magnetic field, $B_{ext} = 4\ T$, pointing into the page. The tracks are $L = 0.45\ m$ apart.

The lightbulb produces *60 W* when attached to a *115 V* power source. A conducting bar is attached to the track. You push the bar with constant velocity *v* to the right as shown.



1) With what speed must the bar travel for the light bulb to dissipate *60 W* of power?

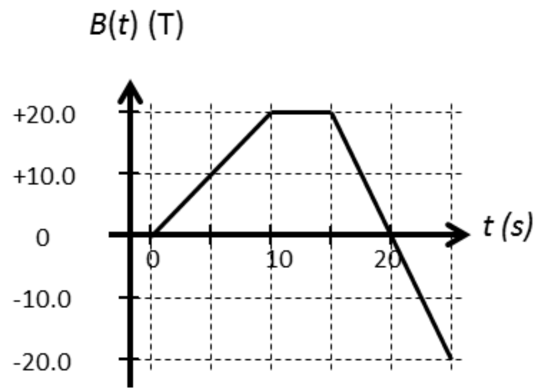
a. $v = 13\ m/s$
b. $v = 64\ m/s$
c. $v = 200\ m/s$

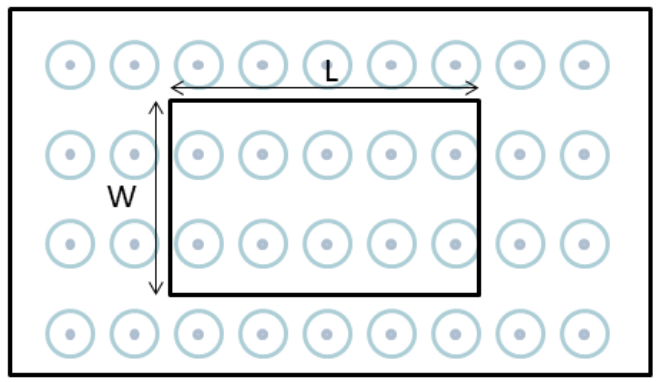
2) Once the bar is pushed outside of the magnetic field area, the light bulb will continue to produce light.

a. *True*
b. *False*

The next three questions pertain to the situation described below.

A loop of wire length $L = 90\ cm$ and width $W=40\ cm$ sits in a magnetic field which varies with time, as shown in the graph. The magnetic field points out of the page.





3) During which times does current flow through the loop?

a. $0\ s < t < 10\ s$ and $15\ s < t < 25\ s$
b. $10\ s < t < 15\ s$ and $15\ s < t < 25\ s$
c. $0\ s < t < 10\ s$ and $10\ s < t < 15\ s$
d. $0\ s < t < 10\ s$ only
e. $15\ s < t < 25\ s$ only

4) In what direction does current flow between $0\ s < t < 10\ s$?

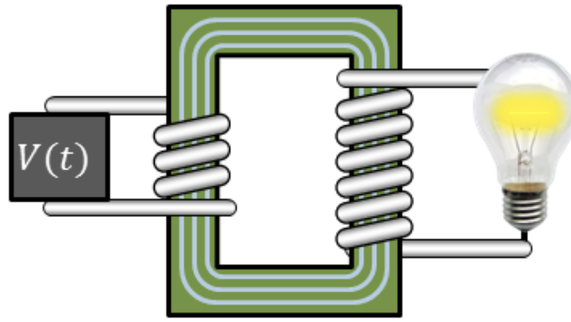
a. *current does not flow*
b. *clockwise*
c. *counter-clockwise*

5) What is the magnitude of the EMF, $|\varepsilon|$, between $0\ s < t < 10\ s$?

a. $|\varepsilon| = 0.72\ V$
b. $|\varepsilon| = 0.32\ V$
c. $|\varepsilon| = 0\ V$

A light bulb is attached to a "step-up" transformer as shown in the figure. The light bulb produces *60 W* when attached to a *115 V* power source.

The transformer is attached to a power source with a voltage that varies with time. The primary coil has $N_p = 15$ turns of wire.

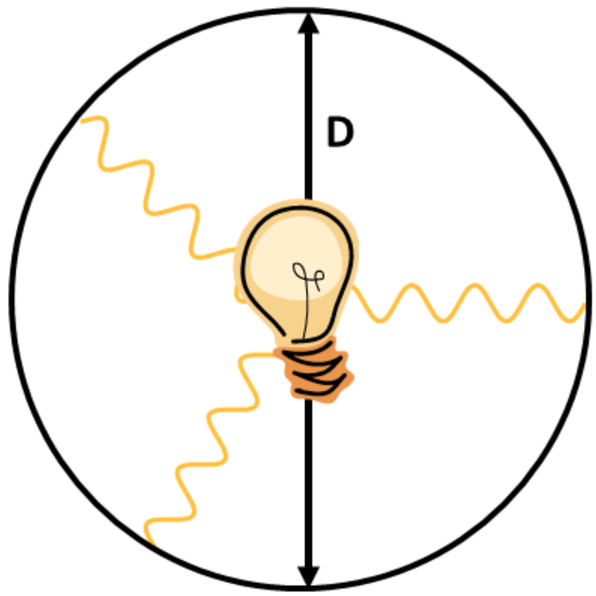


6) What is the maximum number of turns on the secondary coil for the output voltage not to exceed *115 V* when the voltage on the primary coil is $V = 20\ V$?

a. $N_s = 430$
b. $N_s = 29$
c. $N_s = 86$

7) As shown in the figure, a small light bulb that emits an average power of *40 W* is placed inside of a sphere of diameter $D = 20\ m$. What is the root mean square (rms) electric field strength at a point on the inner surface of the sphere?

Remember: The surface area of a sphere is $4\pi r^2$

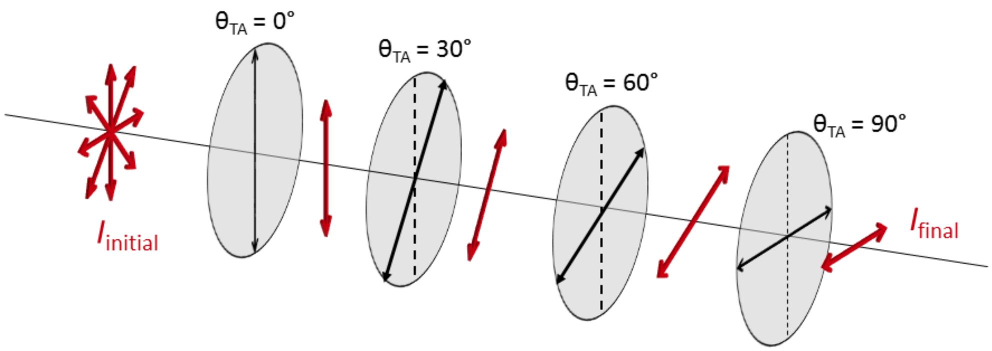


a. $E_{rms} = 0.29\ V/m$
b. $E_{rms} = 3.5\ V/m$
c. $E_{rms} = 1.7\ V/m$
d. $E_{rms} = 6.9\ V/m$
e. $E_{rms} = 4.9\ V/m$

8) This question refers to the figure.

Randomly polarized light of intensity $I_{initial}$ is incident on 4 linear polarizers. The initial polarizer's transmission axis is aligned vertically, at $\theta_{TA} = 0^\circ$. The final polarizer is aligned horizontally at $\theta_{TA} = 90^\circ$. The angles of the intermediary polarizers are evenly spaced, rotating from vertical to horizontal, as shown.

What is the intensity of light after the final polarizer?



a. $I_{final} = 0.42\ I_{initial}$
b. $I_{final} = 1.2\ I_{initial}$
c. $I_{final} = 0.75\ I_{initial}$
d. $I_{final} = 0.21\ I_{initial}$
e. $I_{final} = 0.32\ I_{initial}$

9) From the choices below, which option properly orders different types of electromagnetic radiation from highest to lowest frequency?

a. *ultraviolet, visible light, infra-red radiation, radio waves*
b. *X-rays, infra-red radiation, visible light, radio waves*
c. *radio waves, X-rays, ultraviolet, visible light*

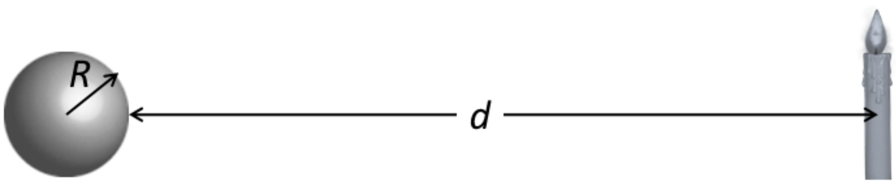
10) Laser light with a frequency $f_{air} = 400\ THz$ is sent from vacuum to a medium with index of refraction $n = 1.6$. What is the radiation's frequency in this material?

a. $f_{material} = 250\ THz$
b. $f_{material} = 400\ THz$
c. $f_{material} = 640\ THz$

11) A microwave horn antenna is driven at a frequency $f = 1.3\ GHz$. What is the wavelength in air of the electromagnetic radiation emitted from the horn?

a. $\lambda = 4.3\ cm$
b. $\lambda = 12\ cm$
c. $\lambda = 23\ cm$

The next two questions pertain to the situation described below.



A silvered sphere has a radius $R = 5\ cm$. A candle of height $h_o = 7\ cm$ is placed at a distance of $d = 23\ cm$ from the surface the sphere, as shown.

12) Which of the following statements on the image formed by the sphere is TRUE?

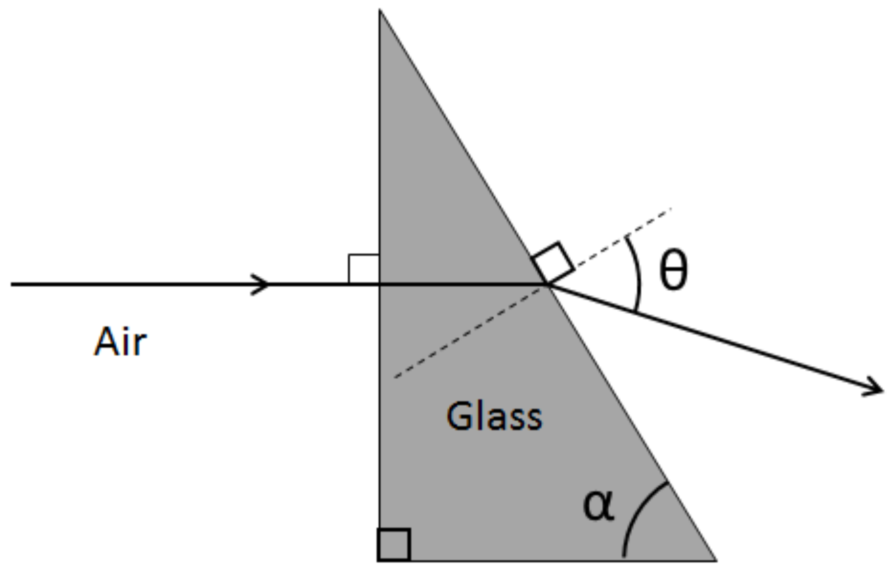
a. *The image is virtual and inverted*
b. *The image is virtual and upright*
c. *The image is real and upright*

13) What is the height $|h_i|$ of the candle's image?

a. $h_i = 0.85\ cm$
b. $h_i = 1.3\ cm$
c. $h_i = 0.69\ cm$

The next three questions pertain to the situation described below.

Consider a glass prism in the shape of a right triangle that makes an angle $\alpha = 70^{\text{o}}$, as shown. The glass has index of refraction $n_{red} = 1.5$ and $n_{blue} = 1.53$ for red and blue light, respectively.



14) A ray of red, monochromatic light travelling in air to the right hits the surface of the prism at 90°, as shown in the figure. What is the angle θ at which the light emerges?

a. $\theta = 20°$
b. $\theta = 46°$
c. $\theta = 70°$
d. $\theta = 31°$
e. $\theta = 59°$

15) Now, the prism is immersed in water. What happens to the angle θ from the previous question?

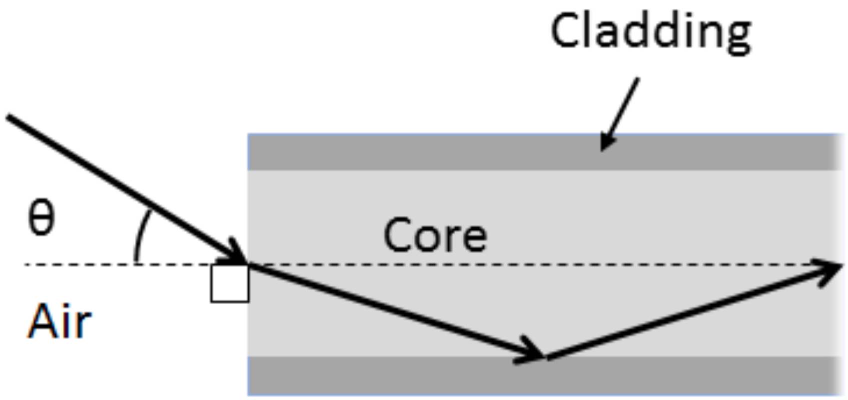
a. *θ increases*
b. *θ decreases*
c. *θ remains the same*

16) Now, a ray of white light hits the surface of the prism at 90°. In what order, from top to bottom do the different colored rays emerge?

a. *Red ray on top, blue ray on the bottom*
b. *Red and blue rays at the same angle*
c. *Blue ray on top, red ray on the bottom*

The next two questions pertain to the situation described below.

A beam of monochromatic green light of wavelength $\lambda = 532\ nm$ (measured in air) is incident on the core of an optical fiber with refractive index $n_{core} = 1.48$, as shown. The core is surrounded by a cladding of refractive index $n_{cladding} = 1.39$.



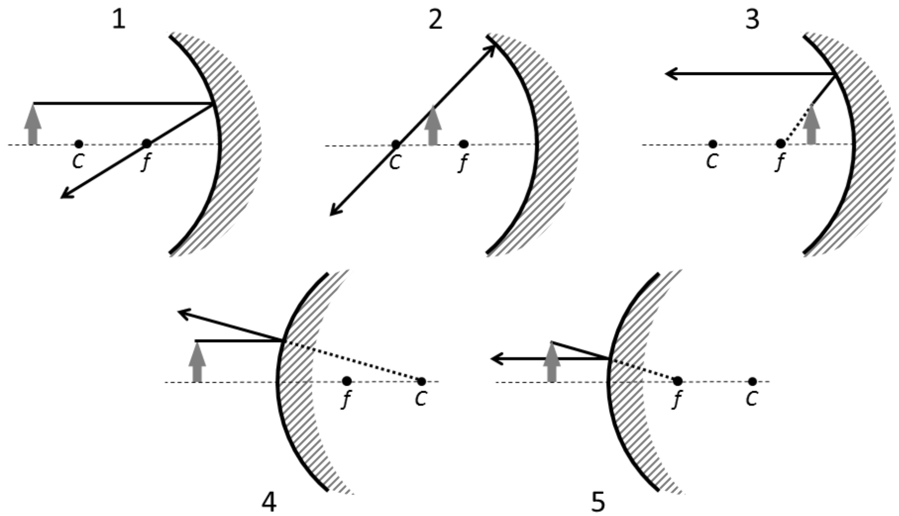
17) What must be the maximum incident angle θ of the beam at the air-core interface, as shown in the figure, such that light cannot escape through the cladding of the optical fiber?

a. $\theta_{max} = 43.4°$
b. $\theta_{max} = 39.4°$
c. *There is no such angle*
d. $\theta_{max} = 13.4°$
e. $\theta_{max} = 30.5°$

18) Now suppose $n_{cladding} = 1.53$. What must be the maximum incident angle θ of the beam at the air-core interface such that light cannot escape through the cladding of the optical fiber?

a. *There is no such angle*
b. $\theta_{max} = 30.5°$
c. $\theta_{max} = 13.4°$
d. $\theta_{max} = 39.4°$
e. $\theta_{max} = 43.4°$

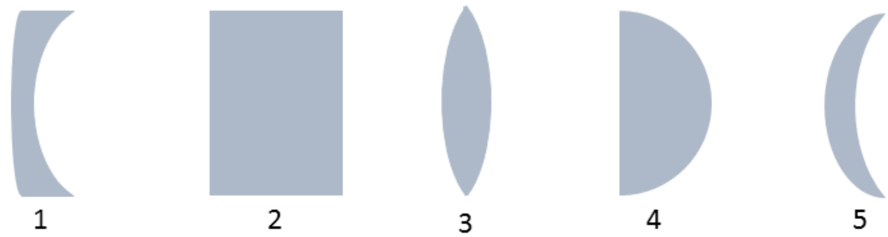
19) Which of the ray tracing diagrams is INCORRECT?



a. *Diagram 1*
b. *Diagram 5*
c. *Diagram 4*
d. *Diagram 3*
e. *Diagram 2*

The next two questions pertain to the situation described below.

The optical components shown are all made of the same material.



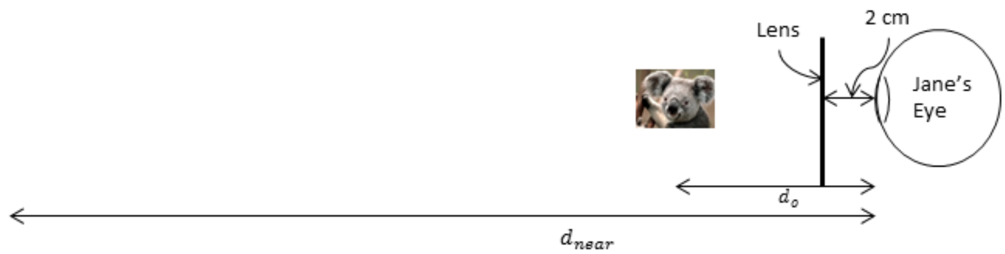
20) Which of the above is a diverging lens?

a. *Figure 2*
b. *Figure 4*
c. *Figure 3*
d. *Figure 1*
e. *Figure 5*

21) Which of the above has the largest magnitude of focal length $|f|$?

a. *Figure 1*
b. *Figure 3*
c. *Figure 2*
d. *Figure 4*
e. *Figure 5*

The next two questions pertain to the situation described below.



Jane is having trouble seeing through her glasses. Close objects are blurry. Her corrective lenses sit 2 cm from her eyes as shown in the figure.

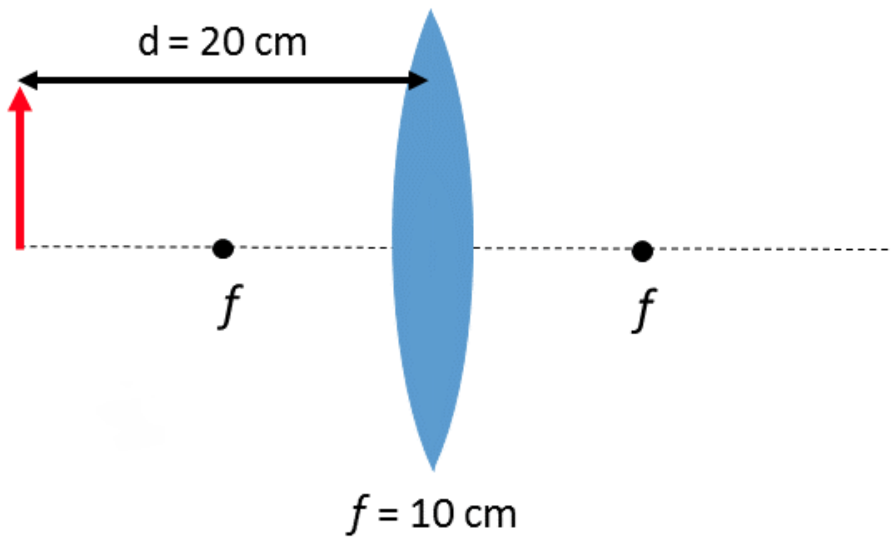
22) Jane is

a. *far-sighted.*
b. *neither.*
c. *near-sighted.*

23) Jane's near-point is $d_{near} = 4.5\ m$. Remembering that a diopter is $P = 1/f$ where f is measured in meters, what should her corrective lens prescription be to see an object $d_o = 25\ cm$ from her eye clearly?

a. *0.22 diopters*
b. *4.1 diopters*
c. *4.6 diopters*
d. *-0.22 diopters*
e. *-4.1 diopters*

The next two questions pertain to the situation described below.



An arrow is located a distance $d = 20\ cm$ to the left of a convex lens, which has a focal length of $f = 10\ cm$.

24) At what position relative to the lens (positive being to the right, negative to the left) will the image of the arrow be formed?

a. $x = 20\ cm$
b. $x = -10\ cm$
c. $x = 10\ cm$
d. $x = 30\ cm$
e. $x = +\infty$

25) What is the magnification of the image?

a. $m = 1$
b. $m = -1$
c. $m = 0.5$
d. $m = -0.5$
e. $m = 0$

Kinematics and mechanics:

$x = x_0 + v_0 t + \frac{1}{2}at^2$ $v = v_0 + at$ $v^2 = v_0^2 + 2a\Delta x$

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

$E_{tot} = K.E. + P.E.$ $K.E. = \frac{1}{2}mv^2 = \frac{p^2}{2m}$ $p = mv$ $W_F = Fd\cos\theta$

Electrostatics:

$F_{12} = \frac{kq_1q_2}{r^2}$ $E \equiv \frac{F}{q_0}$ $U_{12} = \frac{kq_1q_2}{r}$ $V \equiv \frac{U}{q_0}$ $W_E = -\Delta U = -W_{you}$

Point charge: $E = \frac{kq}{r^2}$ $V = \frac{kq}{r}$

Electric dipole: $p \equiv qd$ $\tau_{dip} = pE\sin\theta$ $U_{dip} = -pE\cos\theta$

Resistance:

$R \equiv \frac{V}{I}$ $I = \frac{\Delta q}{\Delta t}$ Physical resistance: $R = \rho\frac{L}{A}$

$P = IV = I^2R = \frac{V^2}{R}$ $R_S = R_1 + R_2 + \cdots$ $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$

Capacitance:

$C \equiv \frac{Q}{V}$ Parallel plate capacitor: $C = \frac{\kappa\varepsilon_0 A}{d}$, $E = \frac{Q}{\varepsilon_0 A}$, $V = Ed$

$U_C = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$ $C_P = C_1 + C_2 + \cdots$ $\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots$

Circuits:

$\sum \Delta V = 0$ $\sum I_{in} = \sum I_{out}$

$q(t) = q_\infty(1 - e^{-t/\tau})$ $q(t) = q_0 e^{-t/\tau}$ $I(t) = I_0 e^{-t/\tau}$ $\tau = RC$

Magnetism:

$F = qvB\sin\theta$ $r = \frac{mv}{qB}$ $F_{wire} = ILB\sin\theta$ $\tau_{loop} = NIAB\sin\varphi$

Magnetic dipole: $\mu \equiv NIA$ $\tau_{dip} = \mu B\sin\varphi$ $U_{dip} = -\mu B\cos\varphi$

$B_{wire} = \frac{\mu_0 I}{2\pi r}$ $B_{sol} = \mu_0 nI$

Electromagnetic induction:

$\varepsilon = -N\dfrac{\Delta\Phi}{\Delta t}$ $\Phi = BA\cos\varphi$

$|\varepsilon_{bar}| = BLv$ $\varepsilon_{gen} = \varepsilon_{max}\sin\omega t = \omega NAB\sin\omega t$ $\omega = 2\pi f$

$V_{rms} = \dfrac{V_{max}}{\sqrt{2}}$ $I_{rms} = \dfrac{I_{max}}{\sqrt{2}}$ $\dfrac{V_p}{V_s} = \dfrac{I_s}{I_p} = \dfrac{N_p}{N_s}$

Electromagnetic waves:

$\lambda = \dfrac{c}{f}$ $E = cB$

$u_E = \dfrac{1}{2}\varepsilon_0 E^2$ $u_B = \dfrac{1}{2\mu_0}B^2$ $\bar{u} = \dfrac{1}{2}\varepsilon_0 E_{rms}^2 + \dfrac{1}{2\mu_0}B_{rms}^2 = \varepsilon_0 E_{rms}^2 = \dfrac{B_{rms}^2}{\mu_0}$ $S = I = \bar{u}c = \dfrac{P}{A}$

$f' = f\left(1 \pm \dfrac{u}{c}\right)$ $I = I_0\cos^2\theta$

Reflection and refraction:

$\theta_r = \theta_i$ $\dfrac{1}{d_o} + \dfrac{1}{d_i} = \dfrac{1}{f}$ $f = \pm\dfrac{R}{2}$ $m = \dfrac{h_i}{h_o} = -\dfrac{d_i}{d_o}$

$n_1\sin\theta_1 = n_2\sin\theta_2$ $v = \dfrac{c}{n}$ $\sin\theta_c = \dfrac{n_2}{n_1}$ $M = \dfrac{\theta'}{\theta} \approx \dfrac{d_{near}}{f}$

Compound microscope: $m_{obj} = -\dfrac{L_{tube}}{f_{obj}}$ $M_{eye} = \dfrac{d_{near}}{f_{eye}}$ $M_{tot} = M_{eye}m_{obj}$

Interference and diffraction:

Double slit interference: $d\sin\theta = m\lambda$ $d\sin\theta = (m+\tfrac{1}{2})\lambda$ $m = 0, \pm 1, \pm 2\ldots$

Single-slit diffraction: $a\sin\theta = m\lambda$ $m = \pm 1, \pm 2\ldots$

Circular aperture: $a\sin\theta \approx 1.22\lambda$

Quantum mechanics:

$E = hf = \dfrac{hc}{\lambda}$ $\lambda = \dfrac{h}{p}$ $\Delta p_x \Delta x \geq \dfrac{\hbar}{2}$ $\hbar \equiv \dfrac{h}{2\pi}$

Bohr atom: $2\pi r_n = n\lambda$ $n = 1, 2, 3\ldots$ $L_n = mv_n r_n = n\hbar$

$r_n = \left(\dfrac{\hbar^2}{mke^2}\right)\dfrac{n^2}{Z} \approx (5.29\times 10^{-11}m)\dfrac{n^2}{Z}$ $E_n = -\left(\dfrac{mk^2e^4}{2\hbar^2}\right)\dfrac{Z^2}{n^2} \approx -(13.6\,eV)\dfrac{Z^2}{n^2}$

$\dfrac{1}{\lambda} \approx (1.097\times 10^7 m^{-1})Z^2\left(\dfrac{1}{n_f^2} - \dfrac{1}{n_i^2}\right)$

Quantum atom: $L = \sqrt{\ell(\ell+1)}\hbar$ $L_z = m_\ell \hbar$

Nuclear physics and radioactive decay:

$A = Z + N$ $r \approx (1.2\times10^{-15} m)A^{1/3}$ $E_0 = mc^2$

$\frac{\Delta N}{\Delta t} = -\lambda N$ $N(t) = N_0 e^{-\lambda t} = N_0 2^{-t/T_{1/2}}$ $T_{1/2} \equiv \frac{\ln 2}{\lambda} \approx \frac{0.693}{\lambda}$

Constants and unit conversions:

$g = 9.8\, m/s^2$ $e = 1.60\times10^{-19}\, C$

$\varepsilon_0 = 8.85\times10^{-12}\, C^2/Nm^2$ $k \equiv \frac{1}{4\pi\varepsilon_0} = 8.99\times10^9\, Nm^2/C^2$ $\mu_0 = 4\pi\times10^{-7}\, T\cdot m/A$

$c = \frac{1}{\sqrt{\varepsilon_0\mu_0}} = 3\times10^8\, m/s$ $h = 6.626\times10^{-34}\, J\cdot s$ $hc = 1240\, nm\cdot eV$

$1eV = 1.60\times10^{-19}\, J$ $m_{proton} = 1.67\times10^{-27}\, kg = 938\, MeV$ $m_{electron} = 9.11\times10^{-31}\, kg = 511\, keV$

SI Prefixes

Power	Prefix	Symbol
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^0	—	—
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p