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.**

(25 problems)

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 **102** points, composed of three types of questions.

MC5: *multiple-choice-five-answer questions, each worth 6 points.*
No partial credit.

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

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

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 three questions pertain to the situation described below.

Illustrated below is a parallel plate capacitor. The terminals of the capacitor are open.

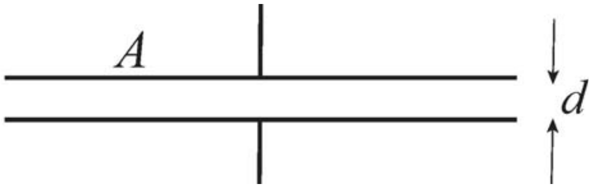


Plate Area: $A = 0.8\ \mathrm{m}^2$

Plate Spacing: $d = 0.2$ mm

Charge Stored: $Q = 3.7\ \mu$C

1) What is the voltage, V, across the spacing of this capacitor?

a. $V = 105$ V
b. $V = 252$ V
c. $V = 399$ V
d. $V = 158$ V
e. $V = 57.8$ V

If you understand electric flux, E = (Q/A)/epslon_0.
E is the (negative) slope of Vm so V = Ed = dQ/epsilon_0A
or
Q = VC with C = epsilon_0 A/d, so V = Q/C = dQ//epsilon_0A

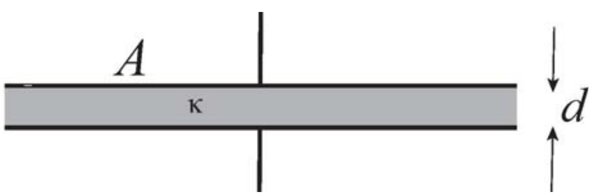
```
V = dQ/A\epsilon_0 = 0.2x10^{-3}x3.7x10^{-6}/0.8 x8.85x10^{-12}
 = 0.1045 x10^{3} = 104.5
```

2) You insert a slab of a dielectric material between the plates. The dielectric material fits the capacitor spacing exactly.

After the insertion of the slab, the voltage difference between the two plates is 1/3 of the value asked in question 1.

C -> kappa C, because C = kappa epsilon_0 A/d

What is the dielectric constant κ of the inserted material?




```
Since Q is kept constant (terminals are open!),
V =Q/C -> V/kappa.  Hence, kappa = 3.
```

a. $\kappa = 1/3$
b. $\kappa = 1$
c. $\kappa = 3$

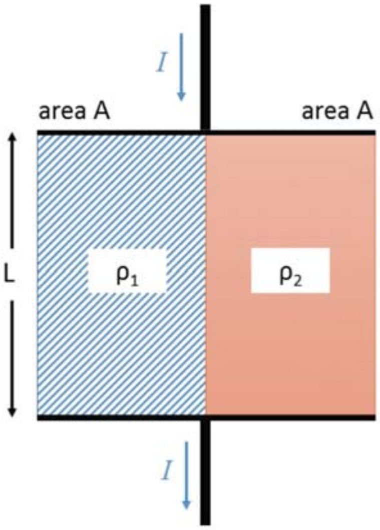
3) While the dielectric material goes into the capacitor gap, the potential energy stored in the capacitor

a. increases.
b. stays the same.
c. decreases.

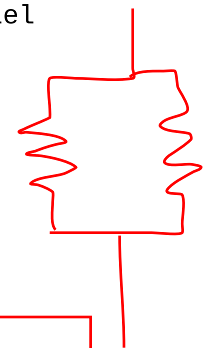
```
From the formula: U = Q^2/2C, so increasing C implies decreasing U.
Or
Physics intuition: due to induced charges on the material, the material
would be sucked into the gap, so if you hold the material, you are done
a work by the system. -> The system must lose energy!
```

The next two questions pertain to the situation described below.

A single resistor is made by attaching two blocks of different materials to two conducting plates, as shown in the figure.



This is basically a parallel
R circuit.



Cross Sectional Area of Blocks:

$A = 1.6 \times 10^{-4}\ \mathrm{m}^2$

R = ¥rho L/A

Length of Blocks:

$L = 0.125\ \mathrm{m}$

Recall
R = R1R2/(R1+R2)

Resistivities:

$\rho_1 = 3.5 \times 10^{-8}\ \Omega \cdot \mathrm{m}$

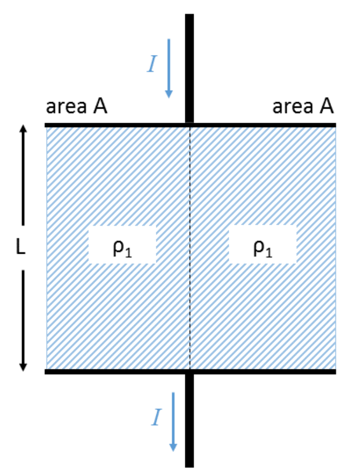
$\rho_2 = 5 \times 10^{-8}\ \Omega \cdot \mathrm{m}$

4) What is the total resistance R of the combined element?

a. $R = 6.7 \times 10^{-5}\ \Omega$
b. $R = 1.1 \times 10^{-5}\ \Omega$
c. $R = 2.7 \times 10^{-5}\ \Omega$
d. $R = 8.8 \times 10^{-7}\ \Omega$
e. $R = 1.6 \times 10^{-5}\ \Omega$

```
R = (rho1xrho2)/(rho1 + rho2) x(L/A)
  = (3.5x5/8.5) 10^{-8} x 0.125/1.6x10^{-4}
  = 0.1508 x10^{-4} ohms
```

5) The resistor is connected to a battery of V volts and the power dissipation is measured to be P_{before}.



Now, the block with resistivity ρ_2 is replaced with a block of resistivity ρ_1.

When the resistor is connected to the battery (with V volts) the power dissipation is measured to be P_{after}.

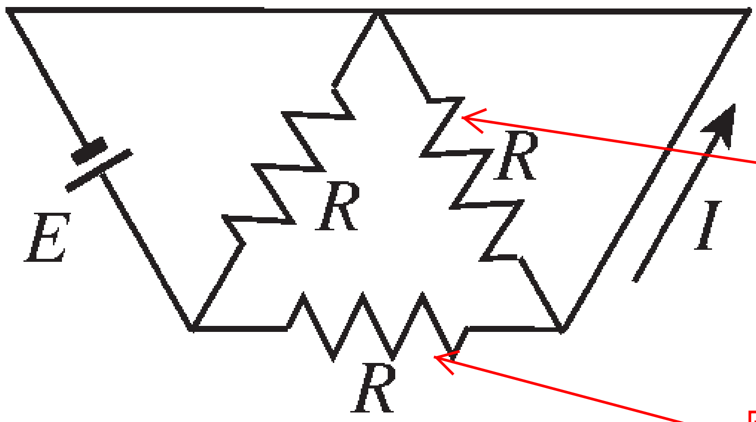
Choose the correct relationship between these two power dissipations from below.

Since V is given, we should use
P = V^2/R

a. $P_{\mathrm{after}} > P_{\mathrm{before}}$
b. $P_{\mathrm{after}} < P_{\mathrm{before}}$
c. $P_{\mathrm{after}} = P_{\mathrm{before}}$

```
Since rho1 < rho2, new R is less than the old R, so P goes up.
```

6) In the resistor network shown in the figure, what is the current I?



Assume that all the resistors are identical with resistance $R = 3.75\ \Omega$ and battery $E = 12$ V.

No voltage across this R, so nocurrent flows through it; you can remove it.

The voltage across this R is E, so I = E/R.

a. $I = 1.3$ A
b. $I = 0.64$ A
c. $I = 6.4$ A
d. $I = 3.2$ A
e. $I = 3.8$ A

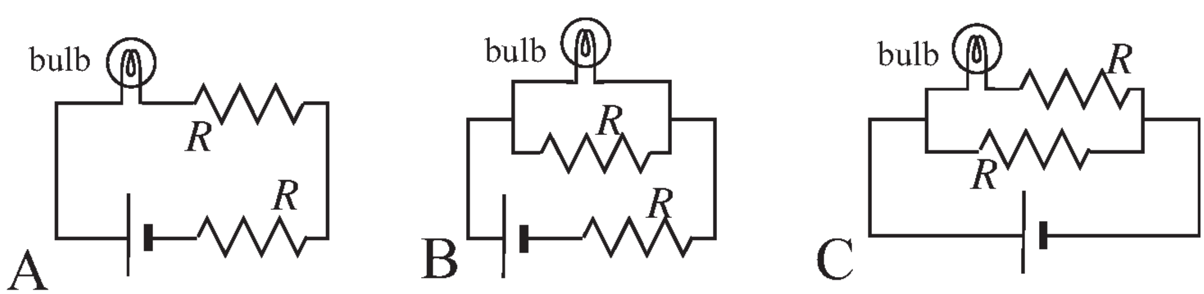
I = 12/3.75 = 3.2 A.

7) You are making a circuit with the following components:

Two identical resistors $R = 20\ \Omega$
A light bulb with resistance $R_{bulb} = 1\ \Omega$
A battery with a positive E.

Which of the following circuit connections gives the brightest bulb output (i.e., highest power dissipation at the light bulb)?

P = I^2R, so larger I gives bigger P, brighter bulb.

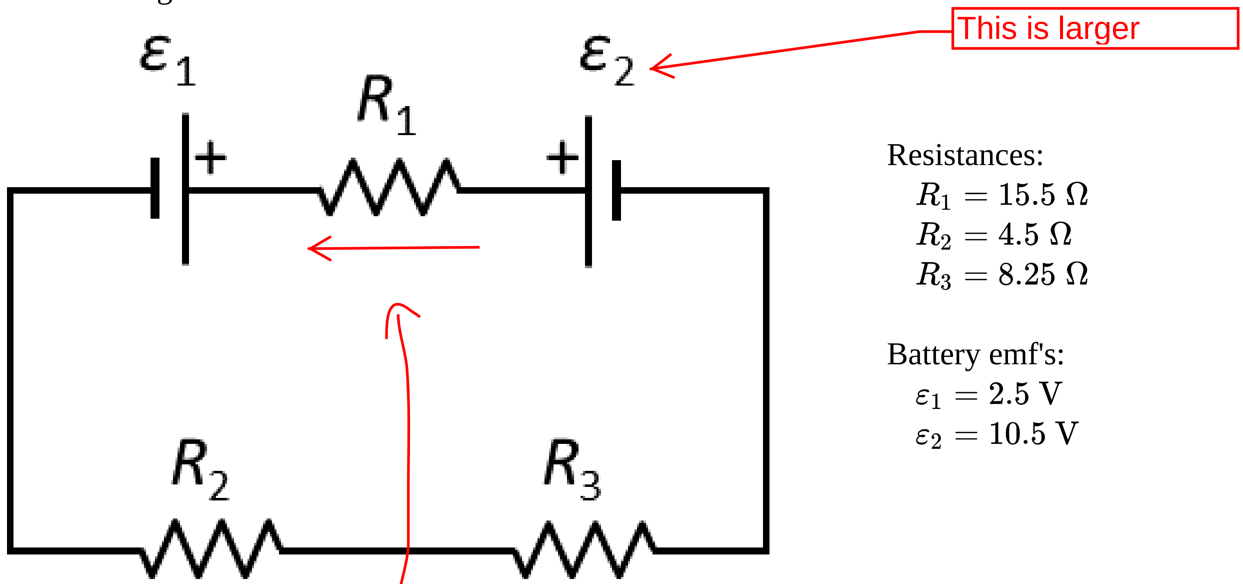


A I = E/41 This is obviously out,
B and C are very close.
B total R = 20 + 20/21= 440/21 -> I through bulb = E(21/440)(20/21)= E/22
C I = E/21
Thus, the bulb in C is the brightest.

a. B
b. C
c. A

The next two questions pertain to the situation described below.

The following circuit contains three resistors and two batteries.



Resistances:
$R_1 = 15.5\ \Omega$
$R_2 = 4.5\ \Omega$
$R_3 = 8.25\ \Omega$

Battery emf's:
$\varepsilon_1 = 2.5$ V
$\varepsilon_2 = 10.5$ V

8) What is the magnitude of the current $|I|$ flowing through resistor R_1?

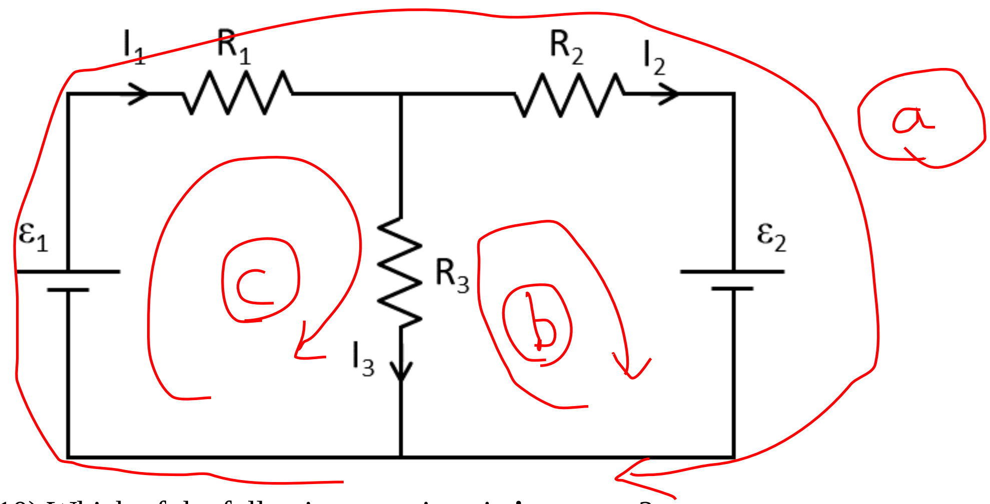
```
I = total emf/totalR
  = 8/(15.5+4.5+8.25) = 8/28.25 = 0.283
```

a. $|I| = 0.4$ A
b. $|I| = 0.28$ A
c. $|I| = 1.1$ A
d. $|I| = 3.3$ A
e. $|I| = 0.46$ A

9) In what direction does the positive current I through resistor R_1 flow?

a. right
b. left
c. cannot be determined

Consider the circuit below.



10) Which of the following equations is ***incorrect*** ?

If the Kirchhoff's loop rule is applied to the loops a - c, you get something like the candidate formula.

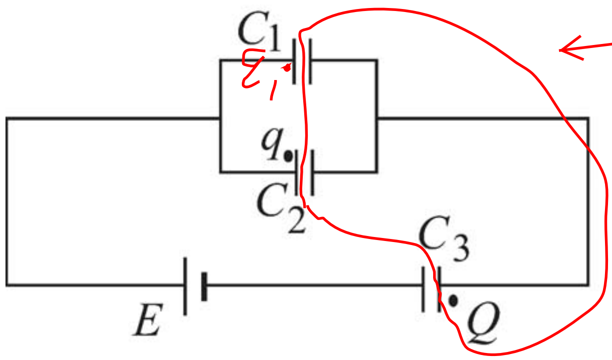
a. $\varepsilon_1 - \varepsilon_2 - I_1 R_1 - I_2 R_2 = 0$
b. $\varepsilon_2 - I_2 R_2 - I_3 R_3 = 0$
c. $\varepsilon_1 - I_1 R_1 - I_3 R_3 = 0$

```
loop a: e1 -I1R1 - I2R2 - e2 = 0, so a is correct.
loop b: +I3R3 - I2R2 - e2 = 0, so b is wrong.
loop c: e1 - I1R1 - I3R3 = 0, so c is correct.
```

The next two questions pertain to the situation described below.

Consider the following capacitor circuit:

Charge conservation tells us that the total charge inside the circle is zero.



Capacitances:
$C_1 = 5.3\ \mu\text{F}$
$C_2 = 8.6\ \mu\text{F}$

Battery:
$E = +45$ V

11) The charge q in the figure is 35 μC. What is the <u>magnitude</u> of the charge Q?

a. $|Q| = 57\ \mu\text{C}$
b. $|Q| = 35\ \mu\text{C}$
c. $|Q| = 14\ \mu\text{C}$

```
q/C2 = q1/C1, so q1 on C1 = (C1/C2)q = (5.3/8.6)x35 = 21.569 microC.
Therefore,
      q + q1 and -Q add up to zero.
Hence,
      |Q| = q + q1 = 35 + 21.6 = 56.6 microC.
```

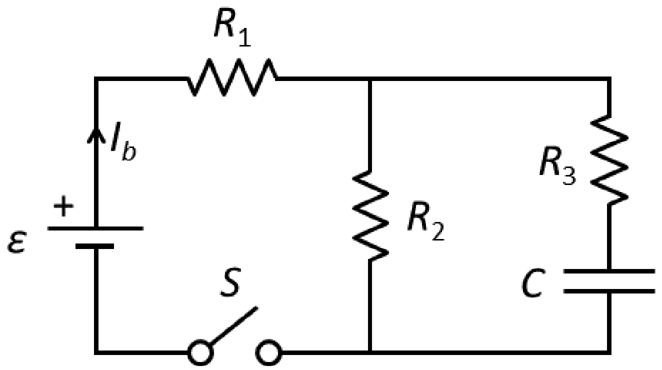
12) The sign of charge Q on capacitor C_3

a. cannot be determined.
b. is positive.
c. is negative.

```
Note that Q is on the plate with a higher voltage, so it must be
positive.
```

The next four questions pertain to the situation described below.

Consider the following RC circuit. Initially, the capacitor is *uncharged*.



Resistances:
$R_1 = 4.2\ \Omega$
$R_2 = 8.7\ \Omega$
$R_3 = 12.2\ \Omega$

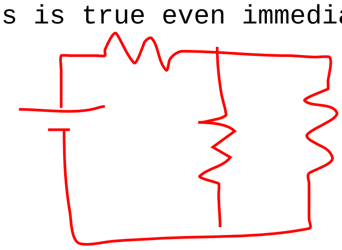
Capacitance:
$C = 5.5\ \mu\text{F}$

Battery emf:
$\varepsilon = 2.5$ V

13) At $t = 0$ the switch S is closed. What is the current out of the battery I_b immediately after closing the switch?

Initially, C has no charge, so there is no voltage across it.
This is true even immediately after the switch is closed.

a. $|I_b| = 0.68$ A
b. $|I_b| = 1.8$ A
c. $|I_b| = 0.27$ A
d. $|I_b| = 1.9$ A
e. $|I_b| = 0.19$ A



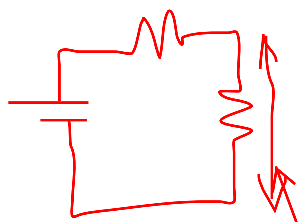
effectively at t=0+

2.5/(4.2 + 8.7x12.2/20.9)= 0.269

14) What is the current out of the battery I_b a long time ($t \to \infty$) after closing the switch S?

After a long tie C is full, so no current can go through R3.

a. $|I_b| = 0.27$ A
b. $|I_b| = 0.68$ A
c. $|I_b| = 0.19$ A
d. $|I_b| = 1.9$ A
e. $|I_b| = 1.8$ A



2.5/(4.2+8.7)= 0.193

15) A long time after closing the switch S, how does the voltage across the capacitor V_C compare to the battery emf ε?

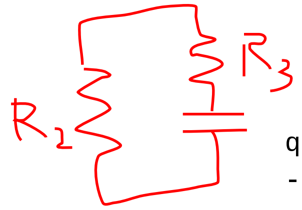
This is Vc = voltage across R2

a. $V_C > \varepsilon$
b. $V_C < \varepsilon$
c. $V_C = \varepsilon$

16) A long time after closing the switch, the switch is reopened. How much time does it take for the capacitor to lose half its charge?

The circuit is effectively

a. $t = 96\ \mu$s
b. $t = 80\ \mu$s
c. $t = 35\ \mu$s



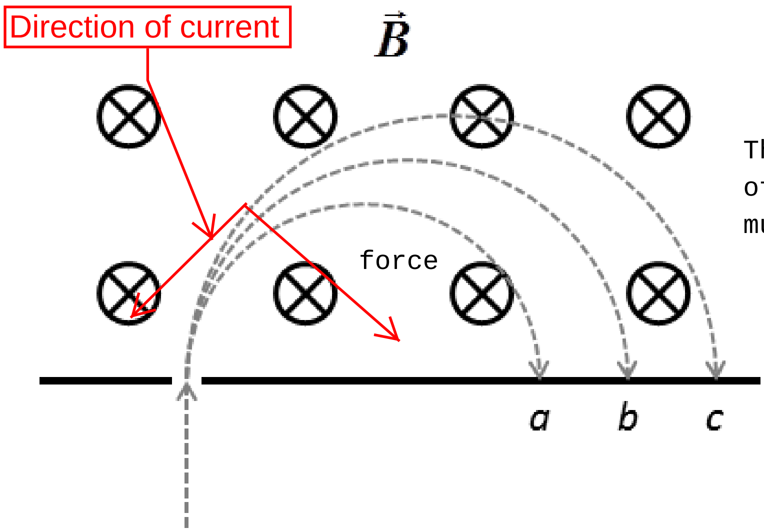
tau = C(R2+R3) = 5.5 x 20.9
= 114.95.
q(t) = q_0 e^{-t/tau) = q_0/2
-> t = tau log 2 = 114.95 x 0.693
= 79.68

The next two questions pertain to the situation described below.

Consider a beam of identical particles with the same charge Q and mass m.

The beam enters a region containing a uniform $\vec{\mathbf{B}}$ field pointing into the page.

After entering the magnetic field region, particles from the beam travel along the dotted trajectories shown in the figure.



The direction of the current is opposite of the velocity direction, so the charge must be negative.

17) What is the sign of the charge of the particles?

a. positive
b. the sign cannot be determined
c. negative

18) Particles moving along which trajectory have the largest speed?

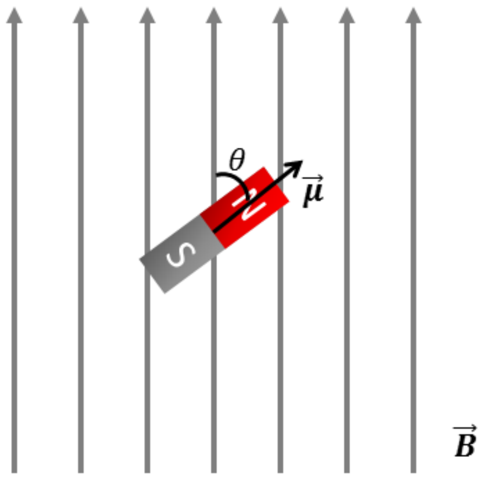
a. trajectory b
b. trajectory c
c. trajectory a

r= mv/qB

m, q, B are the same, so large v means larger r.

The next two questions pertain to the situation described below.

A bar magnet sits at an angle in a magnetic field as shown in Figure A. Assume the bar magnet is a magnetic dipole.

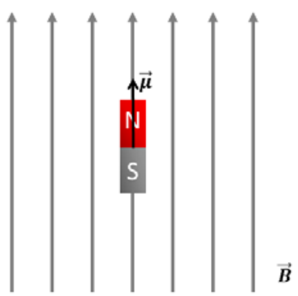


Angle between the dipole moment and the magnetic field:
$\theta = 60^{\circ}$

The magnitude of the magnetic field:
$\vec{B} = 0.83$ T

Figure A

19) When the bar magnet is <u>aligned with the magnetic field</u>, as shown in Figure B, $U_{dip} = -4.25$ J.



U = -mu|B|
tau = mu B sin phi

Figure B

What is the magnitude of torque $|\tau|$ experienced by the bar magnet in Figure A.

a. $|\tau| = 3.68$ N · m
b. $|\tau| = 2.13$ N · m
c. $|\tau| = 7.36$ N · m

Therefore, |tau| = |U|sin theta = 4.25 sin 60 = 3.68 N.m

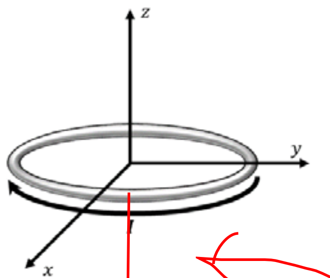
20) What is the <u>magnitude</u> of the magnetic moment of the bar magnet?

a. $|\mu| = 1.76$ A · m^2
b. $|\mu| = 4.43$ A · m^2
c. $|\mu| = 5.12$ A · m^2
d. $|\mu| = 3.53$ A · m^2
e. $|\mu| = 3.05$ A · m^2

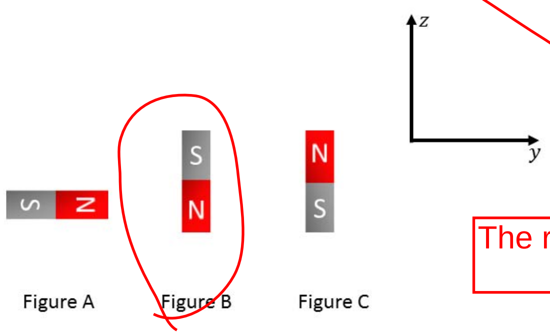
mu = |U|/|B| = 4.25/0.83 = 5.12

The next two questions pertain to the situation described below.

A loop of wire carries a current I and sits in the xy-plane as shown in the figure.



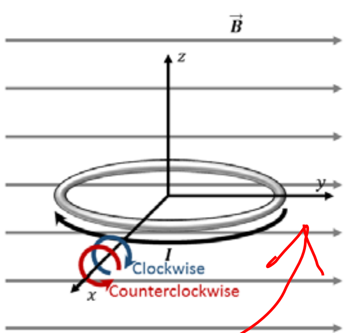
21) Which figure best describes the **direction** of the magnetic dipole moment produced by this current loop?



The right-handed screw rule

a. Figure A
b. Figure C
c. Figure B

22) The current loop is placed in a magnetic field as shown.



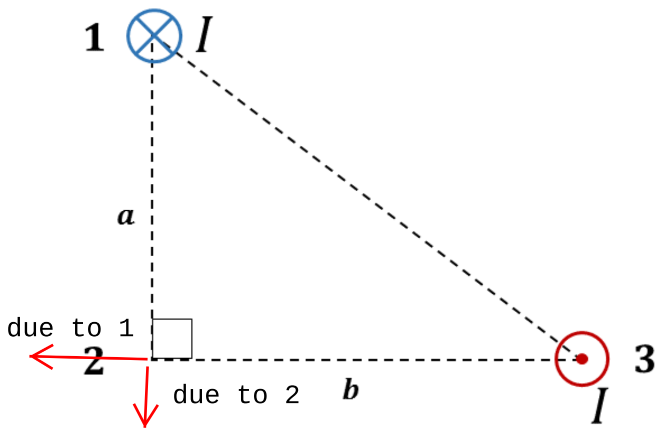
mu to B right-handed screw rule

The loop will

a. not rotate.
b. rotate counterclockwise around the x-axis.
c. rotate clockwise around the x-axis.

The next two questions pertain to the situation described below.

Two long, straight wires are placed on the vertices of a right triangle as shown in the figure.



The lengths of the sides of the triangle are:

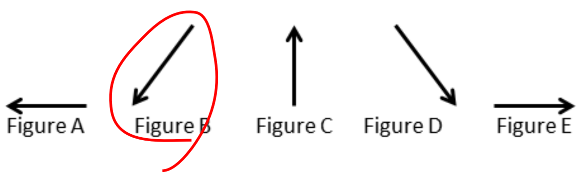
$a = 6.7$ m
$b = 9.1$ m

The magnitude of the current carried by each wire is:

$I = 2.2$ A

|B| = mu_0 I/2 pi r
+
right-handed screw rule to determine the direction of B.

23) Which vector best describes the **direction** of the magnetic field at vertex **2**?



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

24) What is the **magnitude** of the magnetic field at vertex **2**?

a. $|\vec{B}| = 2.2 \times 10^{-7}$ T
b. $|\vec{B}| = 8.2 \times 10^{-8}$ T
c. $|\vec{B}| = 1.5 \times 10^{-8}$ T

```
B due to A = mu_0I/2pi x r = 2x10^{-7}x2.2/6.7 = 0.6567 x10^{-7} T
B due to B = = 2x10^{-7}x2.2/9.1 = 0.4835 x 10^{-7} T
Therefore, Pythagoras tells us
sqrt(0.6567^2 + 0.4835^2)x10^{-7} = 0.815 x 10^{-7} T
```

You are going to make a $|\vec{B}| = 1.7$ T MRI magnet from copper wire. Assume an MRI magnet is a solenoid.

The solenoid has the following parameters:
Length: $L = 2.2$ m
Diameter: $d = 0.65$ m

The wire has the following parameters:
Cross-sectional area: $A = 3.3 \times 10^{-7}$ m^2
Resistivity: $\rho_{Cu} = 1.86\ \Omega \cdot \mathrm{m}$

The magnitude of the current carried by the magnet wire:
$I = 140$ A

B = mu_0 nI = mu_0 (N/L)I

25) What is the resistance of your magnet?

R = rho L/A

a. $R = 2.4 \times 10^{15}\ \Omega$
b. $R = 2.4 \times 10^{11}\ \Omega$
c. $R = 10^{20}\ \Omega$

```
Since B, and I are given, from B = mu_0 nI ->
n = 1.7/4pi x10^{-7} x140
 = 9662.9 = N/2.2 -> N = 21258.553
The total wire length = pi d x N
 = 43410.71 m
R = 1.86 length/3.3x10^{-7}
 =2.4467x10^11 ohms
```

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

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

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

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

Interference and diffraction

Double-slit interference: $d\sin\theta = m\lambda$ $\qquad d\sin\theta = \left(m + \frac{1}{2}\right)\lambda$ $\qquad m = 0, \pm1, \pm2, \cdots$

Single-slit diffraction: $a\sin\theta = m\lambda$ $\qquad m = 0, \pm1, \pm2, \cdots$

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

Quantum mechanics

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

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

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

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

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

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

Nuclear physics and radioactive decay

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

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

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

Constants and unit conversion

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

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

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

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

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

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