I. Lecture questions (45 points total)

1. [3 pts] A uniform long wire has current I through it when it is connected to an ideal battery. The wire is then stretched (**keeping its volume constant**) until it is now twice its original length. The cross-section of the new wire is uniform along its entire length. If you connect the new wire to the same battery, what will be the current in the new wire?

   A. $\frac{1}{2}I$

   B. $\frac{1}{4}I$

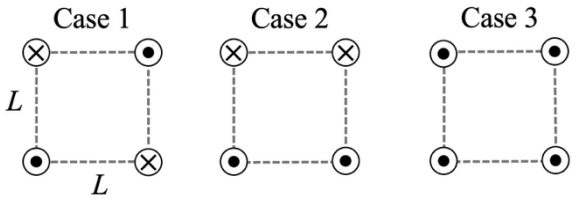
   C. I

   D. $2I$

   E. $4I$

Use the following scenario for the next two problems.

In each case shown at right, very straight wires carry the same amount of current I, either into or out of the page. A wire is located at each corner of a square with a side length of L.



2. [3 pts] In which case is the magnetic field at the center of the square the greatest?

   A. Case 1

   B. Case 2

   C. Case 3

   D. Case 1 and Case 2, which are equal.

   E. All cases are the same.

3. [3 pts] What is the force per unit length on the **upper left** wire in **Case 1** due to the other three wires?

   A. $0.35\frac{\mu_o I^2}{\pi L}$ toward the center of the square

   B. $0.35\frac{\mu_o I^2}{\pi L}$ away from the center of the square

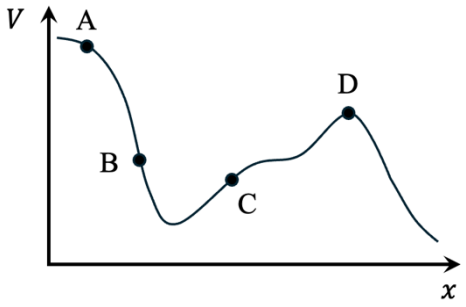
   C. $1.35\frac{\mu_o I^2}{\pi L}$ away from the center of the square

   D. $0.65\frac{\mu_o I^2}{\pi L}$ toward the center of the square

   E. $0.65\frac{\mu_o I^2}{\pi L}$ away from the center of the square

Use the following scenario for the next two problems.

A plot of the electric potential V vs position x is shown at right. (Note that point D is at a local maximum.)



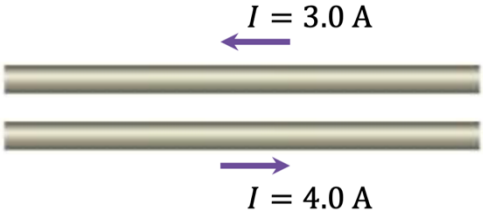
4. [3 pts] At which of the labelled points A-D is the x-component of the electric field negative?
   A. Point A
   B. Point B
   C. Point C
   D. Point D
   E. Point A and Point B

5. [3 pts] At which of the labeled points A-D is the magnitude of the x-component of the electric field, $|\vec{E}_x|$, the greatest?
   A. Point A
   B. Point B
   C. Point C
   D. Point D

6. [3 pts] A parallel-plate capacitor with plates separated by d is fully charged by a battery, which **remains connected** to the capacitor. The plates are then pulled apart until they are separated by a distance $2d$. What is the ratio of the final to initial electrostatic energies, $\frac{U_f}{U_i}$?
   A. ¼
   B. ½
   C. 1
   D. 2
   E. 4

Consider the following scenario for the next two questions.

7. [3 pts] Two long parallel wires separated by 0.12 m carry currents in opposite directions. The currents in the top and bottom wire are 3.0 A and 4.0 A, respectively. What is the magnitude of the magnetic force per unit length on the top wire?



   A. There is no magnetic force on the top wire.
   B. 5.0×10^{-6} N/m
   C. 4.0×10^{-5} N/m
   D. 6.7×10^{-6} N/m
   E. 2.0×10^{-5} N/m

8. [3 pts] What is the direction of the magnetic force **on the top wire**?
   A. Out of the page
   B. Into the page
   C. Toward the bottom of the page
   D. Toward the top of the page
   E. There is no magnetic force on the top wire.

9. [3 pts] Two wires with the same cross-sectional areas and lengths but made of materials with different conductivities are connected as shown. The combination is then connected to a battery. Which of the following are **the same** for both wires?

   i. Current
   ii. Current density
   iii. Electric field

   A. i. and ii.
   B. i. and iii.
   C. ii. and iii.
   D. All of them.
   E. None of them.

Use the following scenario for the following two questions.

A parallel-plate capacitor is fully charged by connecting it to a battery. **The battery remains connected.** When a **single change** described in the following questions is made, what would happen to the electric field strength in the gap, E, and the amount of charge on the positively charged plate, q?

10. [3 pts] The area of the capacitor plates is reduced.

    A. E remains the same, and q decreases.

    B. E decreases, and q decreases.

    C. E increases, and q remains the same.

    D. E increases, and q increases.

    E. E remains the same, and q increases.

11. [3 pts] A dielectric material with a dielectric constant $\kappa > 1$ is inserted in the gap of the capacitor.

    A. E remains the same, and q decreases.

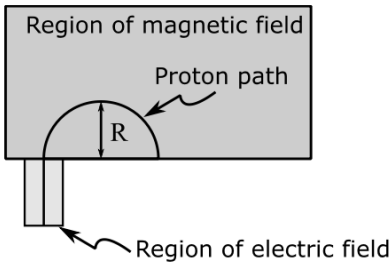
    B. E decreases, and q decreases.

    C. E increases, and q remains the same.

    D. E increases, and q increases.

    E. E remains the same, and q increases.

12. [3 pts] A proton is accelerated from rest through a potential difference V and then enters a uniform magnetic field perpendicular to its path. The field deflects the particle into a circular arc of radius R. If the potential difference is tripled to $3V$, what will be the radius of the circular arc?



    A. $9R$

    B. $3R$

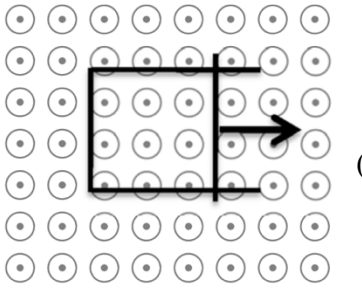
    C. $\sqrt{3}R$

    D. $R/\sqrt{3}$

    E. $R/9$

Use the following scenario for the following two questions.

Three sides of a square are made of one piece of copper wire, which is kept stationary. A crossbar, which is in contact with the first piece of wire, is being made to move to the right with **decreasing** speed.



13. [3 pts] Does the induced current in the loop flow clockwise or counterclockwise?

    A. The induced current flows clockwise.

    B. The induced current flows counterclockwise.

    C. There is no induced current.

14. [3 pts] Is the induced emf in the square increasing, decreasing, or remaining steady? Consider absolute values only.

    A. The induced emf is increasing.

    B. The induced emf is decreasing.

    C. The induced emf is remaining steady.

    D. There is no induced emf.

15. [3 pts] A solenoid with a radius of 0.35 m has 30000 windings over a length of 1.4 m. The magnetic field inside the solenoid is 0.27 T. What is the current in the windings?

    A. 0 A

    B. 2.5 A

    C. 5.0 A

    D. 7.2 A

    E. 10 A

II. Lab Questions (15 points total)

16. [3 pts] In Lab A4, students take three force measurements between two exotic particles. The force measurement device is a digital scale that reads to one-hundredth of a newton (0.01 N). Their measurements are shown at right. If σ_r represents the random uncertainty and σ_i represents the instrumental uncertainty, which option below is closest to the ratio σ_r/σ_i?

Trial	Force (N)
1	0.86
2	0.89
3	0.94

A. 2

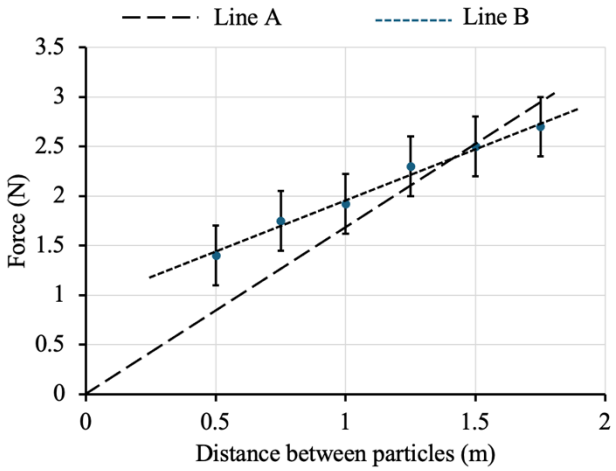
B. 4

C. 5

D. 8

E. 12

17. [4 pts] In a lab similar to Lab A4, a lab team explores the forces exerted between two exotic particles in a VR simulation. They make a plot of the force versus the distance between the two particles, as shown at right, and draw two best-fit lines, line A and line B. Which of the following statements is true, based on the rules stated in this course?



i. Their data is consistent with a model represented by line A.

ii. Their data is consistent with a model represented by line B.

iii. With line A, you could test a model that the force is proportional to the distance between the particles.

iv. With line B, you could test a model that the force is proportional to the distance between the particles.

A. i. only

B. i. and iii.

C. i. and iv.

D. i., ii., and iv.

E. i., ii., and iii.

18. [4 pts] In Lab A4, a group creates three particles and paints them with different colors: blue, green, and yellow. The group members observe the following interactions between two particles when you place each pair under identical conditions. Assume that they can duplicate the green particle and observe the interaction between two identical green particles for the first interaction (Green – Green).

- Green-Green: attract
- Green-Blue: no interaction
- Green-Yellow: repel
- Blue-Yellow: repel

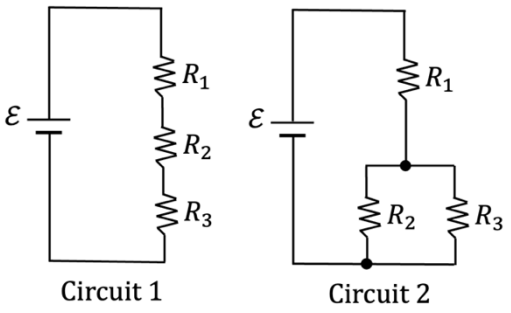
Use the information above to determine (1) whether the **green** and **yellow** particles are of the **same** type or are of **different** types, and (2) whether the **green** and **blue** particles are of the **same** type or are of **different** types.

Which of the choices (A to D) in the table below describes the nature of the particles?

Particles	**Choice A**	**Choice B**	**Choice C**	**Choice D**
Green and Yellow	Different types	Same type	Same type	Different types
Green and Blue	Different types	Different types	Same type	Same type

19. [4 pts] A lab group makes the measurements in circuits 1 and 2 shown in the tables at right. The batteries in both circuits are identical. Rank the resistance of resistors, R_1, R_2 and R_3, from largest to smallest, based on the student's measurements.

A. $R_1 > R_2 > R_3$
B. $R_1 > R_3 > R_2$
C. $R_2 > R_3 > R_1$
D. $R_2 > R_1 > R_3$
E. $R_3 > R_2 > R_1$



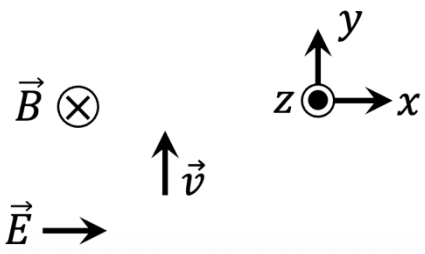
Circuit 1	
V_{R_1}	(0.50 ± 0.05) V
V_{R_3}	(1.00 ± 0.05) V

Circuit 2	
$i_{battery}$	(13.6 ± 0.1) mA
i_{R_2}	(5.5 ± 0.1) mA

III. Lecture Free Response (25 points total)

Questions 20 and 21 are related to the following scenario.

There is both a **uniform** magnetic field $\vec{B} = -B\hat{z}$ and a **uniform** electric field $\vec{E} = E\hat{x}$. These fields fill all of space. You observe that a particle with positive charge $+Q$ moves in a straight line with a constant velocity vector $\vec{v} = v_y\hat{y}$.



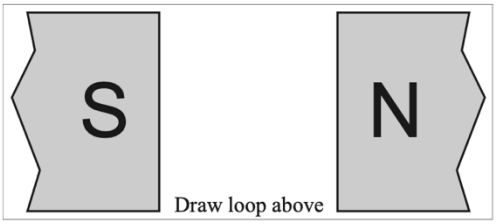
20. [6 pts] State the forces acting on the particle and the **direction** of those forces. **Explain briefly**. (You may ignore gravity.)

21. [8 pts] Use your answer to question 20 and your knowledge about the motion of the particle to determine v_y in terms of B, E, and Q. Show your work and explain your reasoning.

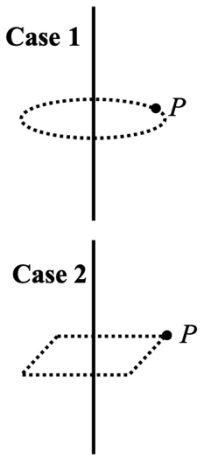
22. [6 pts] A small current loop is placed between opposite poles of two large magnets as shown in the cross-sectional diagram at right.

Cross-sectional diagram

How must the loop be oriented so as to **maximize** the net torque? Sketch a cross-sectional diagram (like the one at right) to indicate your answer. Explain.



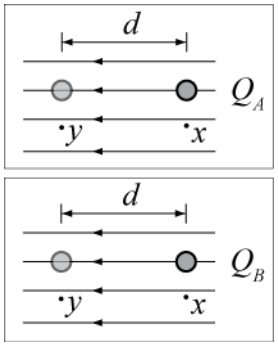
23. [5 pts] You wish to calculate the magnetic field at point *P* near a very long current-carrying wire using Ampère's Law. In the two cases shown, two different closed loops, one square and one circular, are centered on the wire and pass through point P.



In which case(s), if any, could Ampère's Law be used to calculate the magnetic field at point *P*? **Explain**. (You do not need to calculate the field.)

IV. Tutorial Questions (15 points total)

Two particles with the ***same*** positive charge, Q_A and Q_B are released from rest at point x in separate uniform electric fields that point in the negative x-direction. There is no interaction between the two charges. Both charges move through a distance d to the left. (Ignore any gravitational forces.)

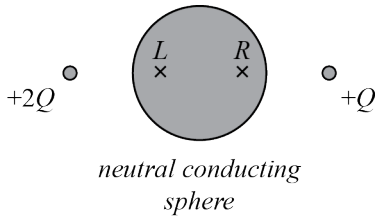


24. [4 pts] Is the value of $V_x - V_y$ *positive, negative, or zero*? If not enough information is given, state so explicitly. Explain.

It is known that the mass of Q_A is half as large as the mass of Q_B. When both charges have moved from point x to point y, the speed of Q_A is measured to be twice the speed of Q_B.

25. [4 pts] Is the magnitude of the electric field strength in which particle A is present *greater than, less than,* or *equal to* magnitude of the electric field strength in which particle B is present? Explain.

Two point charges are placed equidistant on either side of a neutral conducting sphere, as shown at right. The left charge is more positively charged than the right. Points L and R are locations that are equidistant from the center of the sphere.



Let $\Delta V_{L\to R}$ be the electric potential difference from point L to point R.

26. [4 pts] Immediately after the point charges are placed (before charges in the conductor have had time to move), is $\Delta V_{L\to R}$, positive, negative, or zero? If there is not enough information, state so explicitly. Explain your reasoning.

27. [3 pts] The point charges are held in place as the charge distribution on the sphere stabilizes. After a long time, is $\Delta V_{L\to R}$ positive, negative, or zero? If there is not enough information, state so explicitly. Explain your reasoning.