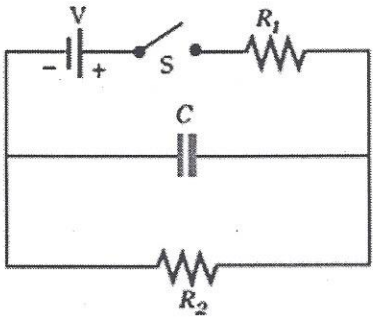
Name _____ Student ID _____ Score _____
*last* *first*

**I. RC Circuit.** An ideal battery of 100.0 V is connected to two resistors and a capacitor, as shown. Let $R_1 = 200$ Ohm, $R_2 = 300$ Ohm, and $C = 5.00$ μF. Initially, the switch has been open for a long time. Then, at time $t = 0$, the switch is closed.




**1.** (4 pts) What is the current **in the battery** just after the switch is closed?

| 0.50 A | 0.33 A | 0.20 A | 0.83 A | 0.42 A |
|---|---|---|---|---|
| **A** | **B** | **C** | **D** | **E** |

**2.** (3 pts) What is the current **in the battery** a long time after the switch is closed?

| 0.50 A | 0.33 A | 0.20 A | 0.83 A | 0.42 A |
|---|---|---|---|---|
| **A** | **B** | **C** | **D** | **E** |

**3.** (5 pts) What is the current **in resistor $R_2$** as a function of time? [For each choice, current values are given in Amps, time values in seconds.]

**A.** $0.50\, e^{-t/0.001}$

**B.** $0.33\left(1 - e^{-t/0.0015}\right)$

**C.** $0.20\, e^{-t/0.0025}$

**D.** $0.20\left(1 - e^{-t/0.0006}\right)$

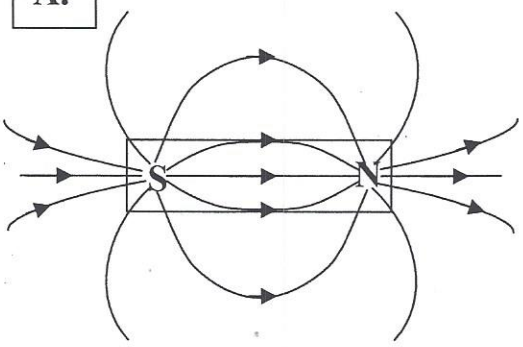
**E.** $0.83\left(1 - e^{-t/0.0006}\right)$

Name _____ Student ID _____ Score_____
*last* *first*

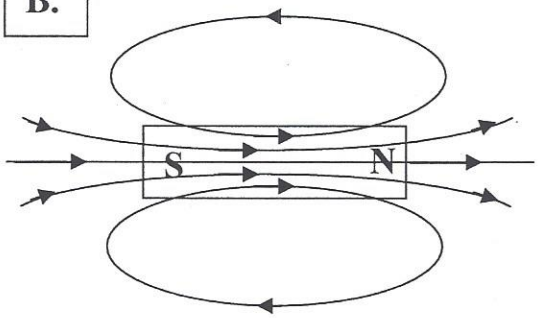
## II. Basic Electricity & Magnetism

**4.** (4 pts) The five figures illustrate possible magnetic field lines for the magnetic field near a bar magnet (magnetic dipole). **Choose the figure that best represents this magnetic field.** Note: all "N" ends are on the **right side** of each figure.

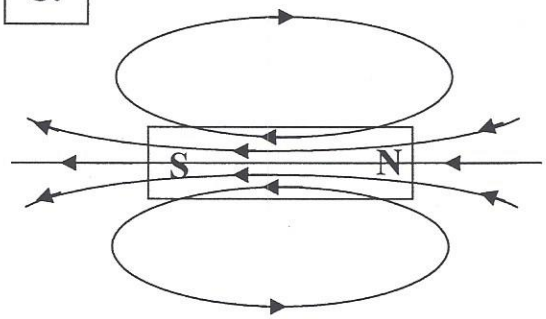
**A.**



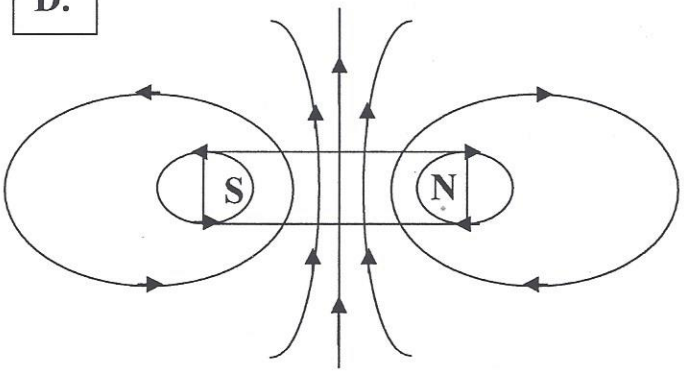

**B.**



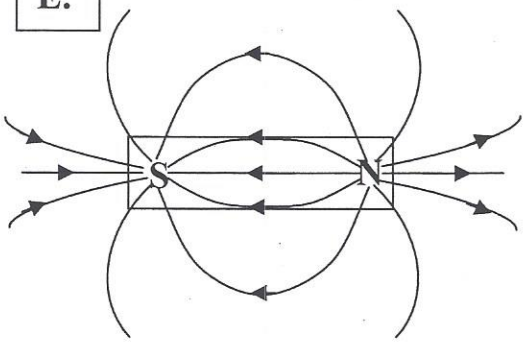

**C.**




**D.**



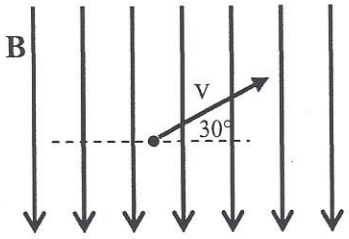

**E.**



Name _____ Student ID _____ Score _____
*last* *first*

## III. Magnetic Forces and Torques

A proton is launched inside a large region of space (about a cubic meter) with a uniform magnetic field B = 2.4 T that points directly down the page, as shown. The proton has mass = $1.67\times10^{-27}$ kg, and initial velocity v = $3.0\times10^{7}$ m/s as shown. It moves in a curved path.

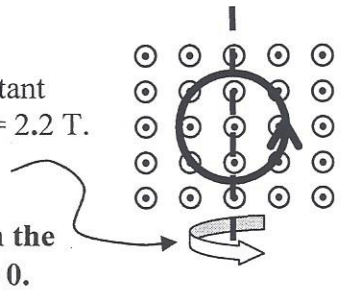



**5.** (4 pts) Which choice best represents the maximum width (diameter) of the proton's path?

| 26 cm | 13 cm | 0.071 mm | 11 cm | 15 cm |
|---|---|---|---|---|
| **A** | **B** | **C** | **D** | **E** |

**6.** (4 pts) Which choice best describes the proton's path, looking up the page as shown?

**A.** Circle ⊥ to the page, clockwise, tilted 30° off horizontal.
**B.** Circle ⊥ to the page, counterclockwise, tilted 30° off horizontal.
**C.** Moves up the page following a counterclockwise helix.
**D.** Moves up the page following a clockwise helix.
**E.** Moves up the page in a parabola.



A circular loop of radius 8.0 cm, with 120 turns of wire, carries constant current I = 3.0 A in a uniform outward magnetic field of strength B = 2.2 T. The current flows counterclockwise, and the loop rotates as shown.
**The figure shows the loop at time $t = 0$.**
**Questions 7 and 8 are to be answered at a later time $t$ (> 0), when the loop has rotated an additional 45° from the position shown at $t = 0$.**

**7.** (4 pts) Which choice best represents the magnitude of torque exerted on the loop by the magnetic field at time $t$ ?

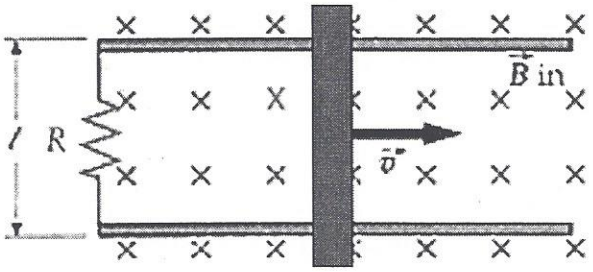
| 11 N•m | 8.0 N•m | 23 N•m | 5.6 N•m | 16 N•m |
|---|---|---|---|---|
| **A** | **B** | **C** | **D** | **E** |

**8.** (3 pts) Which choice best represents the direction of torque on the loop at time $t$ ?

**A.** In the direction of the rotation of the loop.
**B.** Opposite the direction of rotation of the loop.
**C.** Out of the page and 45° to the right (perpendicular to the plane of the loop).
**D.** Out of the page and 45° to the left (parallel to the plane of the loop).
**E.** Into the page and 45° to the left (perpendicular to the plane of the loop).

Name _____ Student ID _____ Score_____
*last* *first*

**IV. Motional EMF** A thin conducting rod of length $l = 20$ cm is sliding to the right with a speed of 6.0 m/s along conducting rails that are connected by a resistor R = 4.0 Ohm. The whole system lies inside a uniform magnetic field **B** which is directed into the page and has a magnitude of 1.2 Tesla. The resistances of the rod and the rails are negligible.




**9.** (4 pts) What is the induced **emf** in the circuit?

| 0.84 V | 1.44 V | 1.66 V | 2.00 V | 3.64 V |
|---|---|---|---|---|
| **A** | **B** | **C** | **D** | **E** |

**10.** (4 pts) What is the induced current in the circuit?

**A.** 0.21 A clockwise
**B.** 0.21 A counterclockwise
**C.** 0.36 A clockwise
**D.** 0.36 A counterclockwise
**E.** 0.50 A counterclockwise

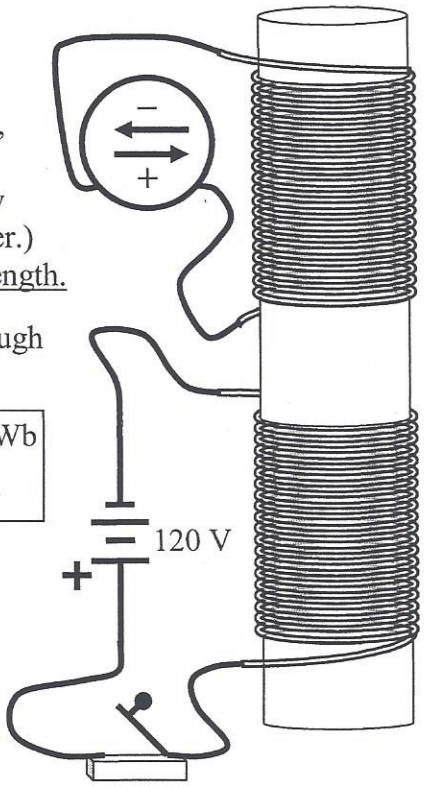
**11.** (4 pts) What force is exerted by the (external) magnetic field on the rod?

**A.** 0.032 N to the left
**B.** 0.064 N to the left
**C.** 0.064 N to the right
**D.** 0.086 N to the left
**E.** 0.128 N to the right

Name _____ Student ID _____ Score_____
*last* *first*

**V. Electromagnetic Induction.**

Two similar solenoid coils are wound on a common cylindrical iron core as shown. Each has 1200 turns of wire, diameter 20 cm, length 60 cm, and resistance R = 6.0 Ω. The lower solenoid is connected to a battery, the upper to an ammeter (the arrows show current directions that cause + and – current readings on the meter.) Assume the iron does not increase the applied magnetic field strength.




**12.** (4 pts) Which choice best represents the maximum flux through a single coil near the center of the lower solenoid?

| $9.5\times10^{-4}$ Wb | $5.0\times10^{-2}$ Wb | $6.3\times10^{-3}$ Wb | $2.1\times10^{-2}$ Wb | $1.6\times10^{-3}$ Wb |
|---|---|---|---|---|
| **A** | **B** | **C** | **D** | **E** |

**13.** (4 pts) At which of the following times will the ammeter (shown at upper left of diagram) show a **negative** reading?

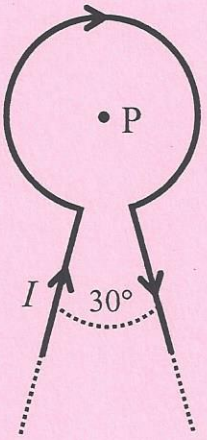
**A.** Immediately after the switch is initially closed.
**B.** One minute later when the switch remains closed.
**C.** Two minutes later, when the switch is suddenly opened.
**D.** Both A and B.
**E.** Both A and C.

**14.** (4 pts) After a while the battery begins to wear out. As a result, the flux through each coil of the lower solenoid is reduced by $1.5\times10^{-4}$ Wb during a time $\Delta t = 0.20$ s. Which choice best represents the average magnitude of EMF induced in the upper solenoid during this short time?

| 36 mV | 1.80 V | 0.45 V | 0.18 V | 0.90 V |
|---|---|---|---|---|
| **A** | **B** | **C** | **D** | **E** |

Name _____ Student ID _____ Score_____
*last* *first*

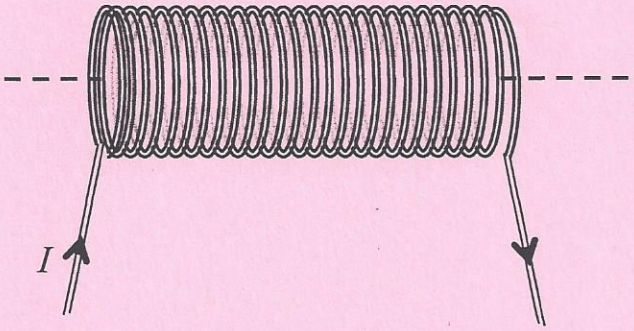
**VI. Magnetic Field Due to Current.** A wire of length 10.0 m is bent at its midpoint into a circular arc of radius 2.00 cm with two equal-length straight "legs" (full length not shown) that extend radially away from the arc. A steady current $I = 3.00$ Amps is supplied by a battery (not shown). Note that the arc covers 330°, 30° less than a complete circle.




**15.** [10 pts] Compute ***B*** (magnitude and direction) at point P. Show your work and explain briefly so that the grader can follow your computation.

**16.** [4 pts] By what percentage does your value differ from that at the center of a full circular loop with the same radius and current?

The same 10.0-m wire is instead bent into a solenoid of radius 2.00 cm, length 32.0 cm and 76 turns. The same steady 3.00 A current flows through this device. **Figure NOT to scale.**




**17.** [5 pts] Would you choose Ampere's Law or the Biot-Savart Law to compute the magnitude of ***B*** at a point near the geometric center of this solenoid? Explain.

**18.** [6 pts] Find ***B*** (magnitude and direction) at the geometric center of the solenoid.


C