Name: ...........................Yibin Pan................................ Section: .......................... 

TA (please circle):
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Instructions:

1. Don’t forget to write down your name and section number.

2. Show your work. A reasonable amount of work is required to receive full credit.

3. Be aware that intermediate steps earn points even if the final answer is incorrect.

4. Erase (or cross out) any mistakes or you will be marked down. Grading is based on everything you have written down.

5. Both the magnitude and direction of vector quantities need to be specified for full credit.

Fundamental constants:

\[ \varepsilon_0 = (4\pi k_p)^{-1} = 8.85 \times 10^{-12} \text{ C}^2/(\text{N} \cdot \text{m}^2) \]
\[ \mu_0 = 4\pi \times 10^{-7} \text{ T} \cdot \text{m} / \text{A} \]
\[ c = 3 \times 10^8 \text{ m/s} \]
\[ m_p = 1.67 \times 10^{-27} \text{ kg} \]
\[ m_e = 9.11 \times 10^{-31} \text{ kg} \]
\[ q_p = -q_e = 1.6 \times 10^{-19} \text{ C} \]

Scores:

Problem 1 __________/30  Problem 2 __________/25
Problem 3 __________/15  Problem 4 __________/30

Total __________
Problem 1 (30 points):

a) The magnetic field generated by a current carrying solenoid is shown in figure 1.1, indicate on the graph the “north” end of the solenoid (2 points); also indicate the direction of the current (3 points).

b) Mark on the graph the direction of the magnetic force on each current segment in figure 1.2. (3 points), also indicate the direction of the total force on the 7 current segments (2 points).

c) What is the sign of the charge of the particle in figure 1.3? (5 points)
   Positive

d) Mark on the graphs the “south” end of each solenoid in figure 1.4. (5 points)

e) Are the two solenoids in figure 1.4 attractive or repulsive to each other? (5 points)
   Attractive

f) The bar magnet in figure 1.5 “before” is to be cut into two pieces in the middle. Which of the “after” configurations represents the resulting magnets? (5 points)
Problem 2 (25 points):
For the RC circuit shown in the figure.

a) What is the time constant of the circuit when switch S is closed? (5 points).
\[ R_{eq} = \frac{1}{(1/10 + 1/10 + 1/20)} = 4 \text{ K}\Omega, \quad \tau = R_{eq}C = 0.004 \text{ s} \]

b) Initially, the switch S is open and there is no charge on the capacitor. At t=0, S is closed. How long does it take to charge the capacitor to 80% of full charge? (5 point).
\[ Q = Q_{max} (1 - e^{-t/\tau}) = 0.8Q_{max}, \quad t = -\tau \ln 0.2 = 6.4 \times 10^{-3} \text{ s} \]

c) What is the full charge on the capacitor long after S is closed? (5 points)
\[ Q_{max} = \varepsilon C = 5 \times 10^{-6} \text{ Coulombs} \]

d) What is the current passing the switch S at t=0? (5 points)
\[ I_0 = \frac{\varepsilon}{R_{eq}} = 1.25 \times 10^{-3} \text{ A} \]

e) At t=0, what is the total power consumed in the circuit? (5 points)
\[ P(t=0) = I_0 \varepsilon = 6.25 \times 10^{-3} \text{ W}, \quad \text{or} \quad P(t=0) = I_0^2 R_{eq} = 6.25 \times 10^{-3} \text{ W} \]
Problem 3 (15 points):
A proton is emitted in the middle of a magnetic field of 1 Tesla as shown below. The speed of the proton is 0.01c, where c is the speed of light. (You may find all required constants on the cover page of the test.)

a) Illustrate on the graph the trajectory of the proton inside the B field. (5 points)

b) Convince yourself that the proton is to move circularly; what is its circular frequency? (5 points). (hint: what is the radius?)
   \[ r = \frac{mv}{qB}, \quad T = \frac{2\pi r}{v} = \frac{2\pi m}{qB}, \quad f = \frac{1}{T} = \frac{qB}{2\pi m} = \text{s}^{-1} \]

c) If the initial speed of the proton is doubled (i.e. 0.02c), what is the circular frequency? (5 points)
   Same, T (or f) is independent of v, this is the basic principle for Cyclotron to work.
Problem 4 (30 points): In figure 4.1, the infinite straight wire carries a current of 10.0Amps.

![Fig. 4.1](image1)

**a)** Use Ampere’s Law to find the magnetic field B produced by the straight current at point A. (10 points)

Draw a “Ampere’s” loop as shown. By symmetry: \( \int B \cdot d\vec{s} = \int Bds = B2\pi r = \mu_0 I \)

\[ B = \frac{\mu_0 I}{2\pi r} = 2 \times 10^{-4} \text{ T} \]

In the remaining questions of this problem, ignore the magnetic field produced by the current loop.

**b)** Now a square current loop carrying 0.1 Amp is added as shown in figure 4.2. Indicate on the graph the direction of the magnetic force on each segment of the current loop. Write “0” if the force is zero on a segment. (5 points)

**c)** What is the magnitude of the magnetic force on segment 1? (5 points)

\[ \vec{F}_B = I\vec{L} \times \vec{B} @ 90^\circ = I L B = 4 \times 10^{-7} \text{ N} \]

**d)** What is the combined force on segments 2 and 4? (5 points)

0
e) Now a second infinite straight current of 10.0 Amps is added as shown in figure 4.3, what is the magnetic force on segment 1? (5 point)

By same argument, \( F_{B2} = 1.33 \times 10^{-7} \) to the left

So \( F = F_{B1} + F_{B2} = 2.66 \times 10^{-7} \) N to the right.

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