Problem 5 (10 pts): At time t=0, the current through a 40.0mH inductor is 30.0 mA and is increasing steadily at the rate of 120 mA/s.

(10)

a) (5 pts) What is the energy stored in the inductor at time t=0?
b) (5 pts) How long does it take for the energy to increase by a factor 9 from the initial value?

a) $U = ?$ $t = 0$ $I_0 = 30.0 \times 10^{-3}$ A $\frac{dI}{dt} = .12$ A

$U = \frac{1}{2} L I^2$ $L_0 = 40.0 \times 10^{-3}$ H

$U = \frac{1}{2}(40.0 \times 10^{-3})(30.0 \times 10^{-3})^2$

+5

$U_0 = 1.8 \times 10^{-5}$ J

b) $9U_0 = \frac{1}{2} L_0 (I_0 + \frac{dI}{dt} t)^2$

$9U_0 = 1.62 \times 10^{-4}$ J

$\sqrt{\frac{18 U_0}{L_0}} = I_0 + \frac{dI}{dt} t$

$\frac{\sqrt{\frac{18 U_0}{L_0}} - I_0}{dI/dt} = t$

+5

$t = 0.5$

0.06

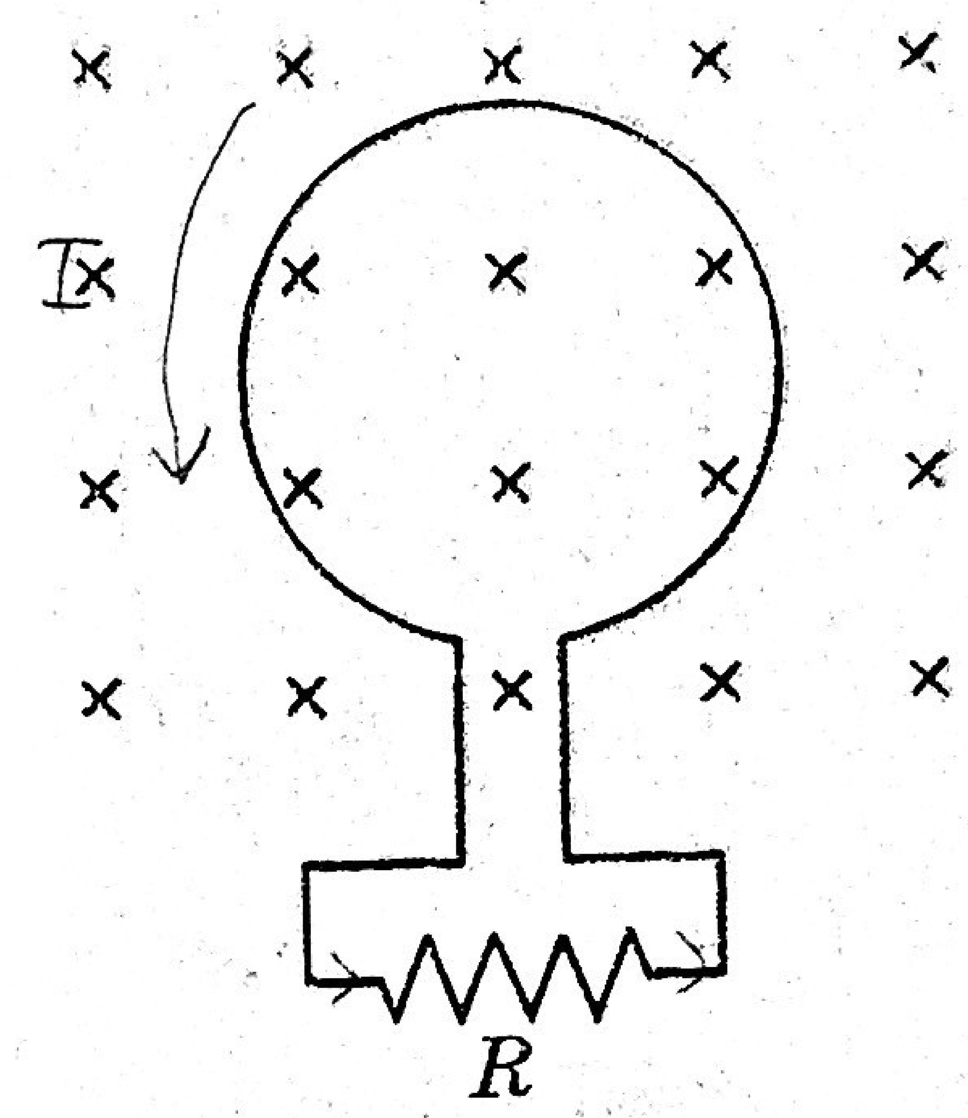
(7)

Problem 4 (10 pts): In the figure below, the magnetic flux through the loop perpendicular to the plane of the coil and directed into the paper is varying according to the relation

$$\Phi_m = 4t^2 + 7t + 1,$$

where Φ_m is in milli-webers, and t is in seconds.

a) (6 pts) What is the magnitude of the EMF induced in the loop when t=3.0 sec?
b) (4 pts) What is the direction of the current through resistor R at that time?



$\Phi = 4t^2 + 7t + 1$

a) $\mathcal{E}$ when $t = 3.0s$?

$\mathcal{E} = \frac{-d\Phi}{dt} = -\frac{d}{dt}(4t^2+7t+1)$

$\mathcal{E} = -3t+7$ } distribute (−)

$\mathcal{E} = -3(3)+7$

$|\mathcal{E}| = -17$ mWebers

$\mathcal{E} = 17$ mWebers

x3

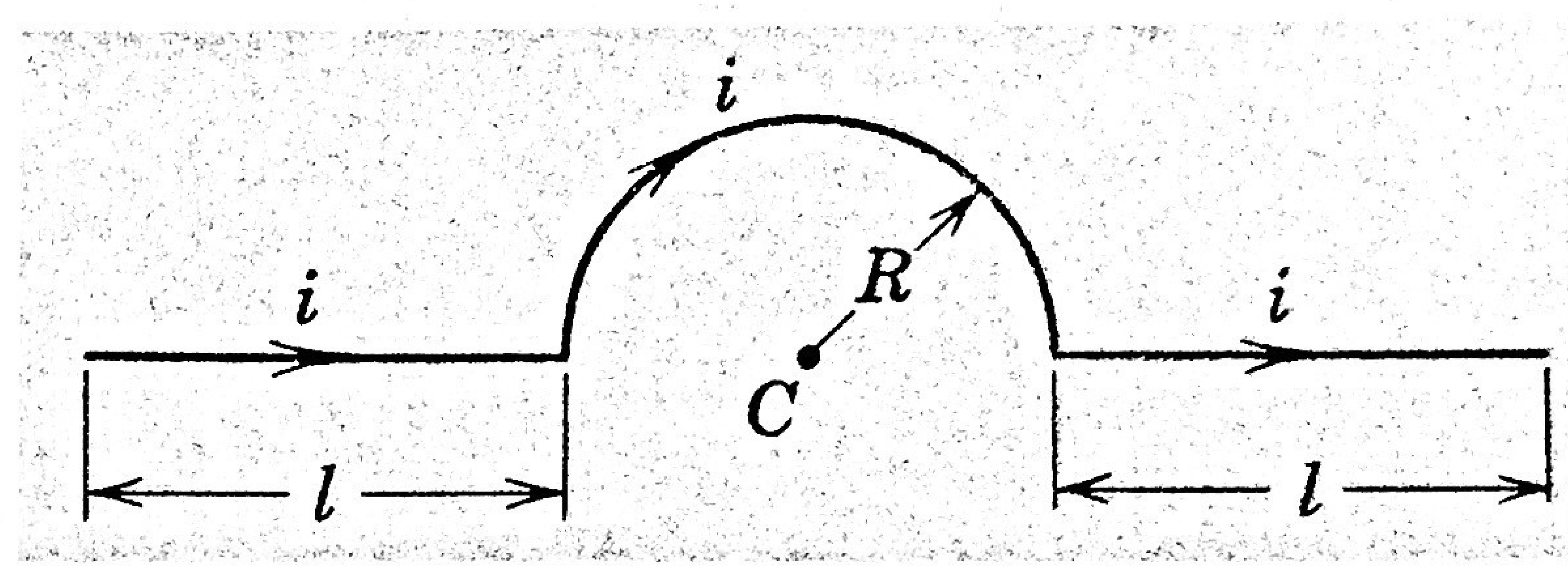
b) According to Lenz's Law, it will oppose the original $\vec{B}$ field. (since ?) Since original $\vec{B}$ field is pointing into the paper, the induced one will be pointing out ($\vec{B}$ is increasing). This means that the current through resistor R is going from left to right.

+4

Problem 3 (10 pts): The wire shown below carries current *I*. What is the magnetic field ***B*** (magnitude and direction) at the center C of the semicircle arising from:

9

a) (3 pts) each straight segment of length *l*
b) (5 pts) the semicircular segment of radius *R*, and
c) (2 pts) the entire wire.



a) each l segment

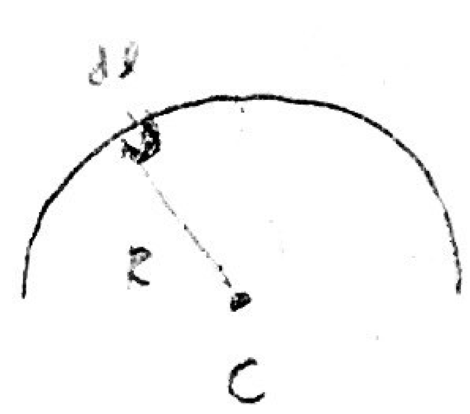
$B = \frac{\mu_0}{4\pi} \int \frac{I\, dl \sin\theta}{r^2}$

$r = 180$ $r = (180)\sin\theta$

There is no angle between C and l so $\sin\theta = 0$, which means the $\vec{B}$ at both l's $= \boxed{0}$

+3

b)



$B = \frac{\mu_0}{4\pi} \int \frac{I\, dl \sin\theta}{r^2}$

$dl = \pi r$

$\sin\theta = 1$

b/c semicircle because $\theta = 90°$ always

$B = \frac{\mu_0}{4\pi} \frac{I \pi r (1)}{r^2}$ $\boxed{\frac{\mu_0 I}{4r}}$

+4

c) $B_{wire} = B_l + B_{semicirc} = 0 + \frac{\mu_0 I}{4r} = \boxed{\frac{\mu_0 I}{4r} \text{ (total } \vec{B})}$

+2

10/10

Problem 2 (10 pts): Electromagnetic rail guns work using Lorentz force to launch high velocity projectiles, by means of a sliding armature that is accelerated along a pair of conductive rails carrying a very large current.

Model such a device by assuming that a metal wire slides without friction on two rails spaced by 0.5 m apart, as in the figure below. The wire carries a projectile, and the combined mass of wire plus projectile is 0.8 kg. Assume there is a constant magnetic field of 0.25 T everywhere between the rails (this is a simplification), and a constant current of $7\text{x}10^4$ amps flows from the generator G along one rail, across the wire, and back down the other rail.

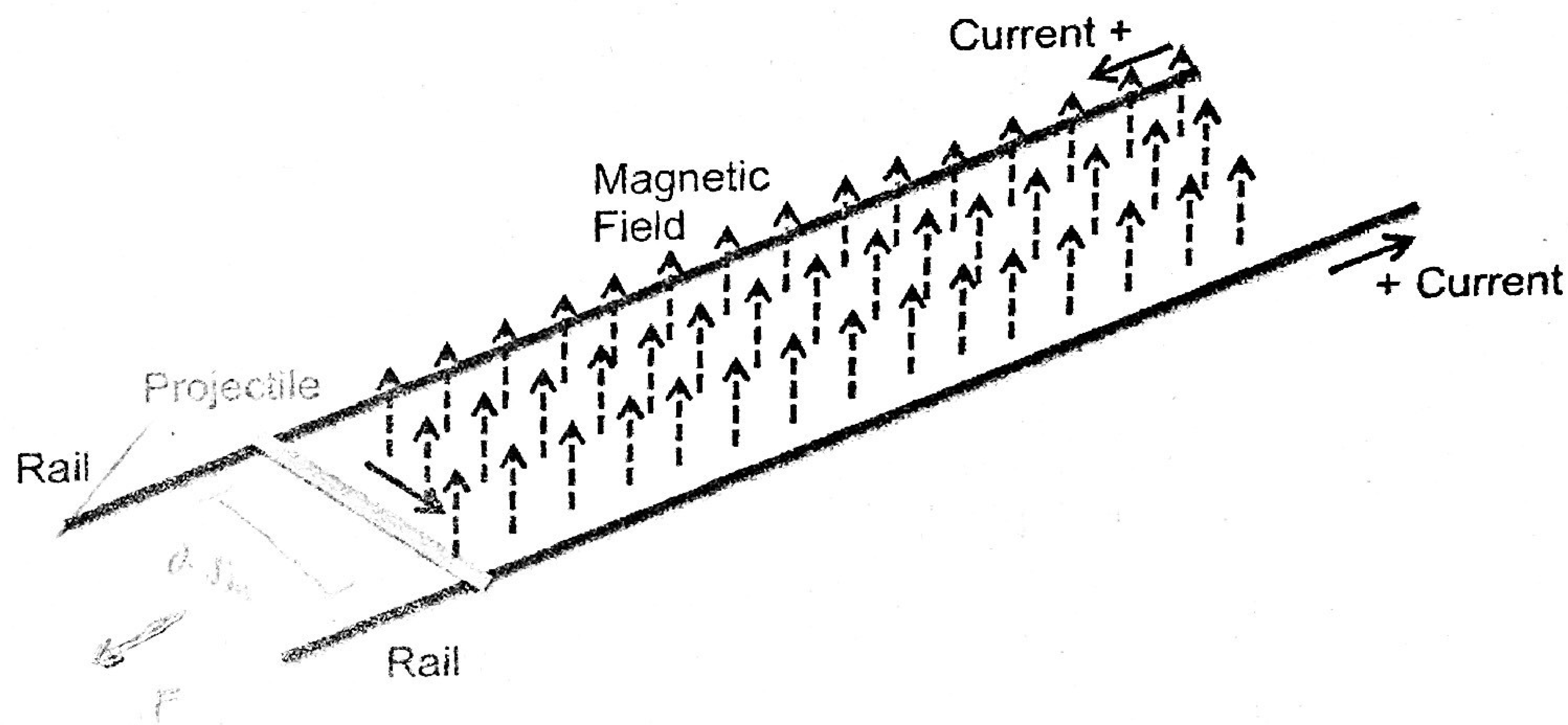
a) (2 pts) Indicate the direction of force F on the wire on the diagram below.
b) (4 pts) Find the magnitude of the force on the wire.
c) (4 pts) Find the velocity v after 0.20 sec, assuming it to be at rest at t=0.

$l = .5$

$m = 0.8$ kg

$B = 0.25$

$I = 7\times10^4$ A



a) $F = I\bar{l} \times B$

F is pointing into the

left

b) $F = I\bar{l} \times \vec{B}$

$F = (7\times10^4)(.5)(0.25)$

F = 8750 N

c) F = ma

$a = \frac{8750}{0.8} = 10938 \ m/s^2$

$a = \frac{dx^2}{dt}$ $v = \frac{dx}{dt}$

$v = \int_0^{0.20} 10938 \, dt$ $v = 10938 \Big|_0^{0.20} =$ 2187.6 m/s

10/10

Problem 1 (10 pts): The current in a long solenoid of radius 5 cm and 1200 turns per meter is varied with time at a rate of 4000 A/s. A coil with twelve loops of radius 7 cm and resistance 1.1 Ω surrounds the solenoid. Find the electrical current induced in the loop.

$\frac{dI}{dt} = 4000$

$r_1 = .05m$

$n_1 = 1200$

$N_2 = 12$

$r_2 = .07$

$R_2 = 1.1$

$B = \mu_0 n I$

$\mathcal{E}_1 = \frac{-d\Phi}{dt}$

$\mathcal{E}_1 = \frac{-d}{dt} \mu_0 n I \cdot \pi r^2$

$\mathcal{E}_1 = \mu_0 \frac{dI}{dt} \pi r^2$

$\mathcal{E}_1 = (4\pi \times 10^{-7})(4000)\pi(.05)^2$

$\mathcal{E}_1 = 3.9 \times 10^{-5}$ V $= \Phi_{21}$

$\mathcal{E} = IR$

$I = \mathcal{E}/R$

$\Phi_{12} = \mu_0 n I \pi r^2$

I

$M = \frac{N_2 \Phi_{21}}{I_1} \rightarrow M = \frac{N_2 \mu_0 n I_1 \pi r^2}{I_1}$

$M = N_2 \mu_0 n \pi r^2$

$M = 1.42 \times 10^{-4}$ H

$|\mathcal{E}_2| = -M \frac{dI_1}{dt}$

$|\mathcal{E}_2| = (1.42 \times 10^{-4})(4000) = 0.568$ V

$\mathcal{E}_2 = I_2 R_2$

$I_2 = \frac{\mathcal{E}_2}{R_2} = \frac{(0.568)}{1.1} = 0.52$ A

Name: Christian Rodriguez

Student ID #: 804789345

(show your student ID card when handing in your exam)

Signature:

31 October 2017

Physics 1C Midterm #1

Version B

- **Do not open this exam until instructed to begin.** You have 50 minutes to complete this exam.
- Remember to write down each step of your calculation, box your answers so we can find them, and display physical quantities in SI units unless told otherwise.
- The graded exams will be returned on Thursday.

Score :

1. 10 /10 points
2. 10 /10 points
3. 9 /10 points
4. 9 /10 points
5. 10 /10 points

Total ________ /50 points