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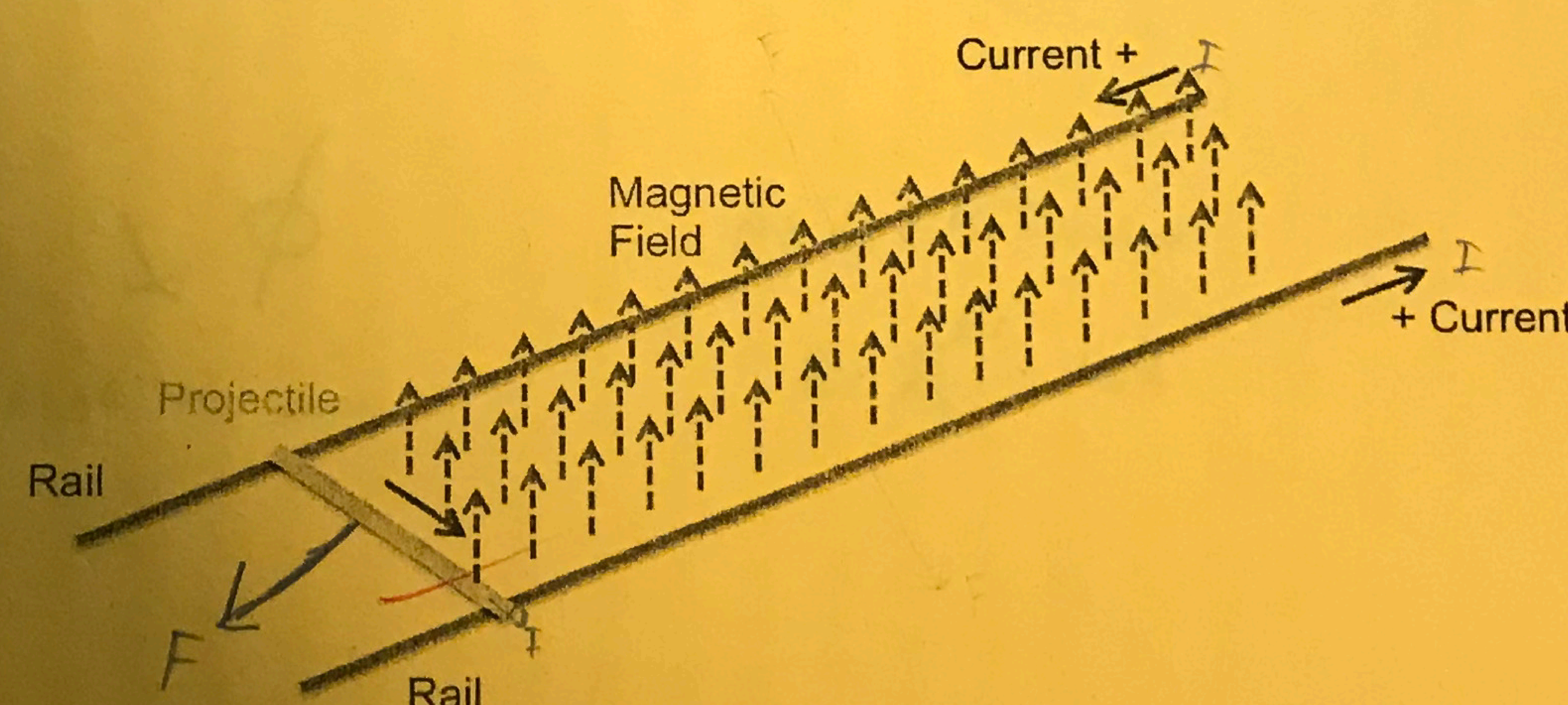
10/10

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.



(a) $F = I\vec{l} \times \vec{B}$ (shown in figure)

(b) $|F| = IlB\sin\theta$, $\theta = 90°$

$F = (7\times10^4\,A)(.5\,m)(.25\,T)$

$F = 8750\,N$

(c) $F = Blv$

$\frac{F}{Bl} = v$

$\frac{8750\,N}{(.5m)(.25T)} = 70{,}000\,m/s$

$F = ma$

$\frac{F}{m} = a$

$\frac{8750\,N}{.8\,kg} = 10937.5\,m/s^2$

$a = \frac{v}{t}$

$at = v$

$v = 2187.5\,m/s$

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

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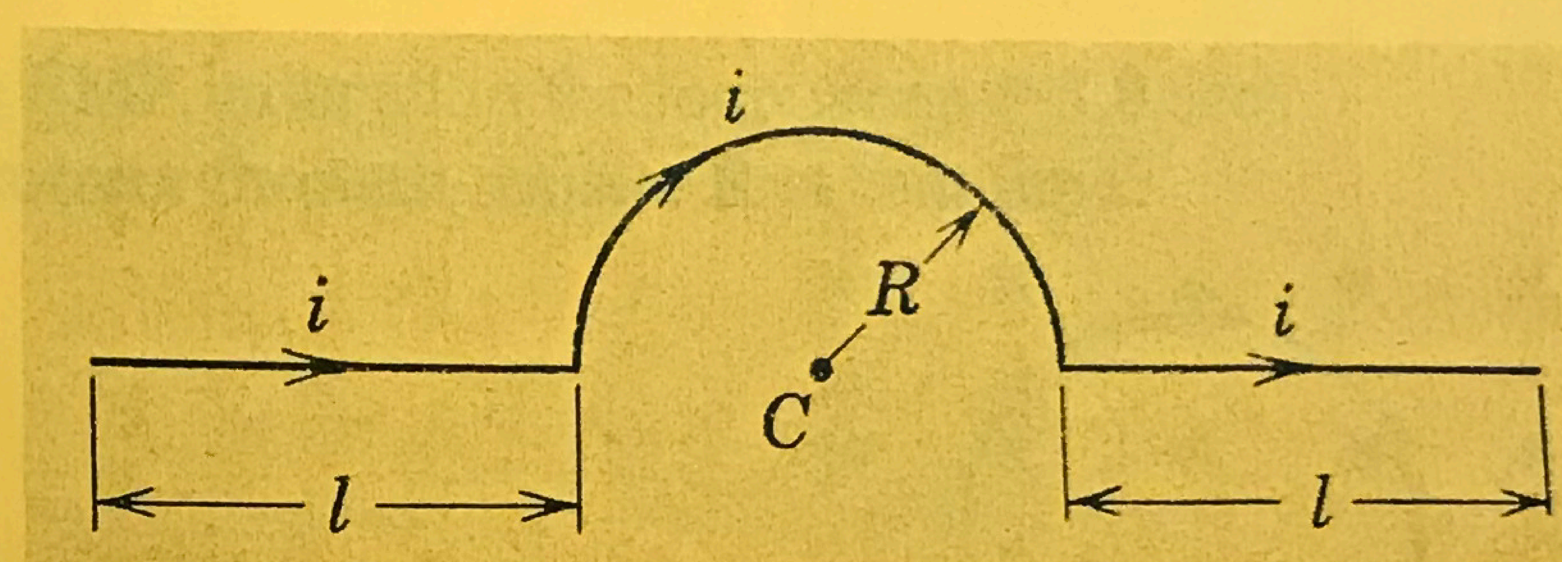
a) (3 pts) each straight segment of length l
b) (5 pts) the semicircular segment of radius R, and
c) (2 pts) the entire wire.



in class

(a) B in long straight wire ✗ ∅

$B = \frac{\mu_0 I}{2\pi R}$ out of the paper

$\oint B \cdot dl = \mu_0 I_{enclosed}$

$B \cdot l \Big|_R^{R+l} = \mu_0 I$

(b) B (at center of current loop) ✗ 2

$B = \frac{\mu_0 I}{2R}$ out of the paper

✗ 2

(c) $B_{total} = \frac{\mu_0 I}{2R}\left(1 + \frac{1}{\pi}\right)$ out of the paper

units = Teslas

direction of B is out of the paper

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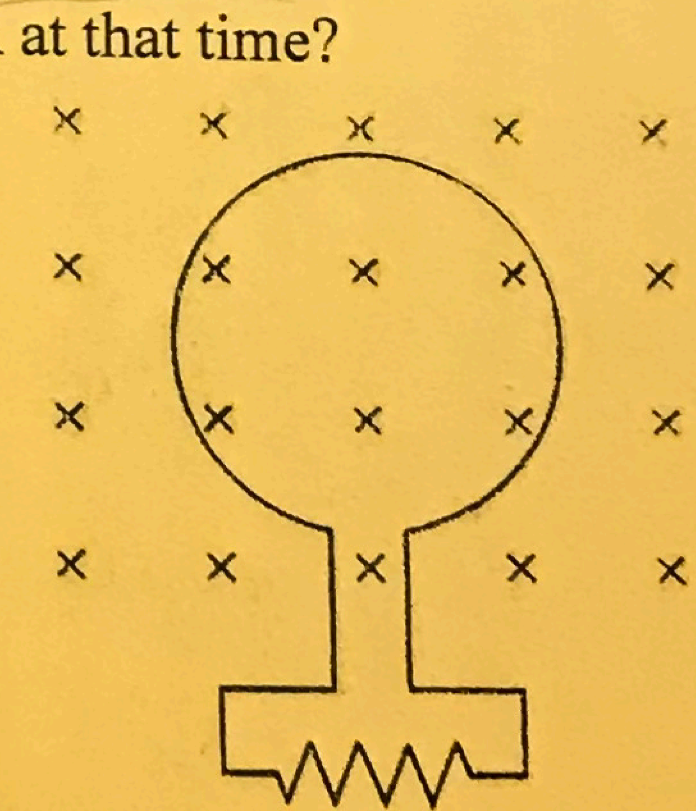
(10)

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

$$\Phi_m = 4t^2 + 7t + 1, \quad mW/s$$

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?



(a) $N=1$

$|\mathcal{E}| = \left|-N\frac{d\Phi}{dt}\right|$

$\mathcal{E} = 1 \cdot \frac{d\Phi}{dt}$

$\frac{d\Phi}{dt} = 8t + 7$

$\mathcal{E}(3) = (8(3) + 7) = 31 \; mW/s^2$

$\mathcal{E}(3) = 31 \; mV$

+6

(b) counter clockwise to resist induced change

+4

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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.

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?

10

$L = 40\,mH$

$I(0) = 30.0\,mA$

$\frac{dI}{dt} = 120\,mA/s$

(a) $U = \frac{1}{2}LI^2$

$U = \frac{1}{2}(.040\,H)(.030\,A)^2 = 1.8\times10^{-5}\,J$

+5

(b) $9U = \frac{1}{2}L(3I)^2$

30 → 90
mA/s mA/s

in .5 s, the current will become 30 mA + 60 mA = 90 mA

$U = \frac{1}{2}(.040\,H)(.090\,A)^2$

$U = 1.62\times10^{-4}$

$\frac{1.62\times10^{-4}}{1.8\times10^{-5}} = 9$ (factor of 9)

+5

so it will take 0.5 sec