Five multiple choice questions, 8 points each. Choose the best or most nearly correct answer.

____ 1. The three wires shown carry identical currents $I$ in the directions indicated. For which of the three paths $a$, $b$, and $c$ is the line integral $\int B \cdot d\hat{s}$ equal to zero?

   [A] $a$ only
   [B] $a$ and $b$
   [C] $b$ and $c$
   [D] $a$, $b$, and $c$

____ 2. Two solenoids both have $n$ turns per meter. Solenoid 1 has radius $R$ and carries current $I$, producing a magnetic field $B_1$. Solenoid 2 has radius $2R$ and carries current $2I$, producing magnetic field $B_2$. What is the ratio $B_2/B_1$?

   [A] $\frac{1}{2}$
   [B] 1
   [C] 2
   [D] 4

____ 3. A long straight wire carries a constant current $I_0$. A conducting rectangular loop is pushed toward the wire as shown. The induced current in the loop is

   [A] ⬇️
   [B] ⬆️
   [C] ⊗
   [D] ⊘

____ 4. At a certain point in space and time, the electric and magnetic fields of an electromagnetic wave are given by $\vec{E} = (3 \times 10^3 \text{ V/m})\hat{i}$ and $\vec{B} = (10^5 \text{ T})\hat{k}$. What is the direction of the wave’s propagation?

   [A] $+x$
   [B] $-x$
   [C] $+y$
   [D] $-y$

____ 5. What is the best way to generate electricity using pigs?

   [A] Ignite them in large numbers and use the heat to generate steam to drive a turbine.
   [B] Densely pack pigs into a flywheel shape, spin it rapidly, and attach to a generator.
   [C] Convince pigs they’re lemmings. Show them a cliff. Install a watermill-type pig turbine at the bottom of the cliff.
   [D] Take a pig to a battery store and exchange it for a pair of AA batteries.

Note: no bacon was produced in the process of composing this question.
6. (40 points total) A planar square wire loop of side $L$ and mass $m$ is located a distance $D$ below a long straight horizontal wire that carries a current $I_w$ to the left, as shown in the figure.

(a) (10 points) You want to use the magnetic force between the straight wire and the loop to levitate the loop. To do this, current must flow in the loop. In what direction must the current in the loop flow?

Circle one:  $igcirc$  $igcirc$  $igcirc$

(b) (5 points) Segments ② and ④ do not contribute to the net force on the rectangular loop. Why?

Circle one: both forces are zero the forces cancel

(c) (10 points) If a current $I$ flows in the rectangular loop, find the magnitudes and directions of the forces exerted by the long straight horizontal wire on segments ① and ③ of the square loop.

(d) (15 points) Calculate the magnitude of the current $I$ in the loop that is necessary to hold the loop stationary at a distance $D$ below the straight wire.
7. (20 points total) Two concentric circular loops of wire carry the same magnitude current, \( I_0 \), but in opposite directions, as shown. The larger loop (labeled \( \odot \)) has radius \( 3R \) and the smaller loop (labeled \( \oplus \)) has radius \( R \). Use the Biot-Savart Law to derive an expression for the magnetic field at the center \( P \) of the two loops. Express your answer using unit vector notation in terms of the parameters given.

8. (20 points total) A long metal cylinder with diameter \( 2R \) carries a current \( I \) parallel to its axis of symmetry and distributed uniformly across the cylinder’s cross sectional area. Beginning with Ampere’s Law, derive an expression for the magnitude of the magnetic field outside the cylinder a distance \( d > R \) from the symmetry axis.
9. (40 points total) The figure shows a copper rod moving with velocity \( v \) parallel to a long straight wire carrying a current \( I \). \( a = 1 \) cm, \( b = 21 \) cm, \( v = 5.0 \) m/s, and \( I = 100 \) A.

(a) (10 points) Which end of the rod is at the higher electric potential?

circle one: Left Right Top Bottom

(b) (25 points) Find the magnitude of the electric field in the rod at its center. Put your answer in the box just above part c.

\[
E = 
\]

(c) (5 points) Is the electric field constant in the rod? Circle one: Yes No
A campfire is burning 12 meters away from you. You have a photometer and detect the campfire electromagnetic wave intensity to be $8 \text{ W/m}^2$. The campfire emits most of its radiation in the infrared with a frequency $4 \times 10^{14} \text{ Hz}$. (All solutions MUST start with OSE’s).

(a) (5 points) What is the wavelength of the infrared radiation?

(b) (15 points) Estimate the amplitudes of the electric and magnetic fields of the campfire electromagnetic radiation detected by the photometer.

(c) (10 points) Assuming the campfire radiates electromagnetic radiation radially outward above ground, what is the total power output of the campfire?

(d) (10 points) Estimate the radiation force that exerted on your shirt if you are wearing a totally absorbing black shirt with area $0.4 \text{ m}^2$ exposed to the radiation. Assume that the exposed area is perpendicular to the incident radiation.