Notes: You should have (7) pages, with (12) problems, plus the formula sheet. Work problems in space provided, showing your work where required to receive credit.

Useful information (see also the formula sheet):

Uniform acceleration results:
\[ x = x_o + v_o t + \frac{1}{2} a t^2, \quad v^2 = v_o^2 + 2ax, \quad v = v_o + at \]
(1) [17 points] The figure shows three point charges, with $Q$ a constant. The charges $(-Q)$ are located at $\pm d$ on the $x$ axis. The charge $+2Q$ is located at position $(-d/2)$ on the $y$ axis.

(a) Find the force on the $(+2Q)$ charge, in terms of $Q$ and $d$. What is the direction?

(b) Find the electric potential at a point $(+d)$ on the $y$ axis.

(c) Find the energy required to move the charge on the right to a point far away, if the other two charges remain fixed. Assume that $Q = 2.5 \, \mu C$, and $d = 4.0 \, \text{cm}$ for this part.

(2) [5 points] An electromagnetic wave has an electric field with peak value 250 N/C. What is the average intensity of the wave?
(3) [10 points] The resistors are arranged as shown.
(a) With $R_1$, $R_2$, and $R_3$ constants, find the net resistance of this circuit.

(b) If all three resistors each have $R = 10\,\Omega$, $V_a = 15\,V$, and $V_b = 40\,V$, find the power dissipated in $R_3$.

(4) [7 points] Given a charged particle moving as shown,
(a) what must be the direction of the uniform magnetic field inside of the box, assuming there are no electric fields, and that gravity can be neglected?

   (i) up out of the paper
   (ii) down into the paper
   (iii) to the right (→)
   (iv) to the left (←)
   (v) in the plane of the paper, at an angle 45° from the lower left to the upper right

(b) Along the path of the charge, which of the following is correct?
   (i) The speed of the particle steadily increases.
   (ii) The speed increases and decreases, oscillating at the cyclotron frequency.
   (iii) The particle traces an arc of a circle.
   (iv) The particle's path is a parabola.
   (v) The particle's kinetic energy increases by $(B^2)/2\mu_o$, which is the energy density of the magnetic field in the box.
(5) [7 points] A magnetic field is directed perpendicular to the plane of a 0.15-m × 0.30-m rectangular coil comprised of 120 loops of wire. To induce an average emf of −1.2 V in the coil, the magnetic field is increased from 0.1 T to 1.5 T during a time interval Δt. Determine Δt.

(6) [6 points] Frank's Aggie ring which is 2.2 cm high is placed 35 cm away from a converging lens having a focal length of 20 cm. Find the height of the image. Is this a real or virtual image?

(7) [4 points] Choose the incorrect statement, regarding the steady-state behavior of the illustrated circuit.

(a) There will be no voltage drop across the ideal inductor.
(b) There will be no voltage drop across C.
(c) Power will be dissipated only in the resistor R_2.
(d) Current from the battery will equal ε/R_2.
(e) There will be nonzero magnetic flux in L.
(8) [12 points] A solid insulating sphere has radius \( R \), and a uniform volume charge density \( \rho \) of positive charge in it.

(a) Use Gauss’ Law to find the electric field at points both inside and outside the sphere. You must show the method here, indicating how the result is obtained.

(b) Find a general relation for the electric potential at points outside the sphere, relative to infinity.

(9) [7 points] A long, solid cylindrical wire carries a uniform current density \( J \). Find the magnetic field inside the wire, far from the ends. For credit you must show how your result comes from a basic law. Which law did you use?
(10) [7 points] In this circuit, the capacitor is initially uncharged. $V_B = 10 \, \text{V}$, $C = 3.0 \, \mu\text{F}$, and $R = 4500 \, \Omega$. If the switch is closed at $t = 0$, find the voltage across the resistor at $t = 2.0 \, \text{ms}$.

![Circuit Diagram]

(11) [9 points] Two long, parallel wires separated by a distance $d$ carry currents in opposite directions as shown in the figure. The top wire carries a current of 6 A. Point C is at the midpoint between the wires and point O is a distance 0.5$d$ below the lower wire as in the figure. The total magnetic field at point O is zero.

(a) Find the current in the lower wire.

![Wire Diagram]

(b) What is the direction of the magnetic field at C?
(12) [9 points] (a) If the capacitor value is \( C \), and the area is \( A \), find the electric field in the gap, if the voltage \( V \) is applied as shown. (Your answer should be in terms of \( C \), \( A \), and \( V \).) The shaded parts are metal plates; assume that these can be treated as very wide and flat.

(b) Inside either of the metal plates, which of the following will be true:

(i) The electric potential will be zero.
(ii) The charge density will be a constant value.
(iii) The electric field will be a constant vector pointing towards the center of the gap.
(iv) The electric field will be zero.
(v) The electric flux will be constant.