Closed book. No work needs to be shown for multiple-choice questions.

1. The electric field is given by $E = E_0(y/b)^2$ in the $z$ direction. Find the magnitude of the flux through a square of side $a$ in the $xy$ plane. (Hint: the precise location of the square in $xy$ plane is not important. For simplicity, however, it is a good idea to put one of the corners in the origin.)

   a. $E_0$
   b. $E_0(a/b)$
   c. $E_0(a^2/3)$
   d. $E_0a^4/(3b^2)$
   e. $E_0a^4/(9b^2)$

2. A charge of $20 \times 10^{-6} \text{ C}$ is at a position $(x=12 \text{ m}, y=0)$ and a charge of $-10 \times 10^{-6} \text{ C}$ is at a position $(x=12 \text{ m}, y=5 \text{ m})$. What is the magnitude of the force at a charge of $-4 \times 10^{-6} \text{ C}$ at the origin?

   a. $40.56 \times 10^{-9} \text{ N}$
   b. $40.56 \times 10^{-3} \text{ N}$
   c. $3.12 \times 10^{-6} \text{ N}$
   d. $40.56 \times 10^{-3} \text{ N}$
   e. $3.12 \times 10^{-3} \text{ N}$

3. Charges of $12.0 \mu \text{ C}$ and $-18.0 \mu \text{ C}$ are placed at two corners of an equilateral triangle with sides of $0.10 \text{ m}$. At the third corner, what is the magnitude of the electric field created by these two charges?

   a. $13.5 \times 10^6 \text{ N/C}$
   b. $9.3 \times 10^6 \text{ N/C}$
   c. $4.7 \times 10^6 \text{ N/C}$
   d. $14.3 \times 10^6 \text{ N/C}$
   e. $6.6 \times 10^5 \text{ N/C}$

4. A long, thin wire carries a uniform line charge density $\lambda = -6.8 \mu \text{ C/m}$. It is surrounded by a thick concentric cylindrical shell of inner radius $2.5 \text{ cm}$ and outer radius $3.5 \text{ cm}$. What uniform charge density in shell will result in zero electric field outside of the shell?

   a. $3.6 \text{ mC/m}^3$
   b. $1.8 \text{ mC/m}^3$
   c. $5.4 \text{ mC/m}^3$
   d. $2.7 \text{ mC/m}^3$
   e. $0.9 \text{ mC/m}^3$
5. An isolated charged point particle produces an electric field with magnitude $E$ at a point 2 m away. A point at which the field magnitude is $E/4$ is:

   a. 1 m away from the particle.
   b. 2 m away from the particle.
   c. 4 m away from the particle.
   d. 6 m away from the particle.
   e. 8 m away from the particle.

6. A semicircular loop of radius $a$ carries a positive charge $Q$ distributed uniformly over its length. Find the electric field at the center of the loop.

   a. $k_e Q / (\pi a^2)$
   b. $2k_e Q / (\pi a^2)$
   c. $k_e Q / (2\pi a^2)$
   d. $k_e Q / (a^2)$
   e. $2k_e Q / (a^2)$

7. Two charged particles are arranged as shown. In which region could a third particle, with charge +1C, be placed so that the net electric force on it is zero?

   a. I only
   b. I and II only
   c. III only
   d. I and III only
   e. II only

8. Two identical conducting balls of mass 10 grams are hung from thin threads of length 120 cm and carry the same charge $q$. Assume the angle the threads make from the vertical is $\theta = 20^\circ$. What is the value of each charge?

   a. $5.2 \times 10^{-5}$ C.
   b. $1.6 \times 10^{-6}$ C.
   c. $4.5 \times 10^{-6}$ C.
   d. $8.2 \times 10^{-7}$ C.
   e. Not enough information is given to solve this problem.
Recall that

\[ k_c = \frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9 \text{N.m}^2/\text{C}^2 \]

and

\[ \varepsilon_0 = 8.85 \times 10^{-12} \text{C}^2/(\text{N.m}^2) \]