1. Two point charges are located on the x-axis as follows: charge $q_1 = -4.0 \mu C$ is at $x = -2$ cm, charge $q_2 = +8.0 \mu C$ is at $x = 3$ cm. Where can a third charge be placed on the x-axis such that the net force on it is identically 0 N?

   (1) $-14.1$ cm  
   (2) $10.1$ cm  
   (3) $-3.2$ cm  
   (4) $2.1$ cm  
   (5) $-8.2$ cm

2. A $+2.5$ nC charge with mass $10^{-4}$ kg is suspended using a thin insulating wire with negligible mass as shown in Figure 1. A second $-2.5$ nC charge is located 1 cm to the left of the suspended charge. Find the angle (in degrees).

   (1) $29.9$  
   (2) $16.2$  
   (3) $4.5$  
   (4) $20.1$  
   (5) $24.2$

3. Two point charges $q_1 = +4.0 \mu C$ and $q_2$ are located at $(x, y) = (-a, 0)$ and $(0, 0)$ respectively (see Figure 2). If the electric field at $(x, y) = (0, a)$ is pointed to the right (parallel to the x-axis), what is the value of $q_2$ (in $\mu C$)?

   (1) $-1.4$  
   (2) $-2.8$  
   (3) $-5.6$  
   (4) $5.6$  
   (5) $2.8$
4. What is the electric field (in V/m) at point P located 25 cm from the center of the sphere in Figure 3? Assume the sphere has a charge of $-15\mu$C and the shell has a charge of $200\mu$C.

   (1) $2.2 \times 10^6$, inward  
   (2) $1.0 \times 10^7$, inward  
   (3) $1.4 \times 10^7$, outward  
   (4) $6.7 \times 10^6$, outward  
   (5) $9.7 \times 10^{-8}$, outward

5. Which of the electric field line configurations shown in Figure 4 is CORRECT?

   (1) B, E  
   (2) A, B, D  
   (3) A, D  
   (4) B  
   (5) E

6. Four 2 C charges are initially arranged as shown in Figure 5a. The charges are then rearranged to the final configuration shown in Figure 5b. Compute the change in potential energy (in J).

   (1) $-1.0 \times 10^{-10}$  
   (2) $-2.4 \times 10^9$  
   (3) $-4.6 \times 10^7$  
   (4) $4.6 \times 10^7$  
   (5) $9.0 \times 10^8$

7. A positively charged insulating rod is brought close to a neutral electroscope but they do not touch (see Figure 6). The electroscope is then grounded. After the ground is disconnected, the rod is moved away. Which of the following statements is true?

   (1) The overall charge on the electroscope is negative, and the foil is negatively charged.  
   (2) The overall charge on the electroscope is negative, and the foil is positively charged.  
   (3) The overall charge on the electroscope is zero, and the foil is neutral.  
   (4) The overall charge on the electroscope is positive, and the foil is positively charged.  
   (5) The overall charge on the electroscope is zero, and the foil is negatively charged.

8. A reitzon ($m = 2.6 \times 10^{-26}$kg, $q = +3.5 \times 10^{-18}$C) is launched with an initial velocity of $1.2 \times 10^7$ m/s toward an infinite conducting sheet of charge with charge density $+5.4\mu$C/m$^2$. How long (in s) does it take to stop?

   (1) $2.9 \times 10^{-7}$  
   (2) $4.3 \times 10^{-4}$  
   (3) $7.8 \times 10^{-12}$  
   (4) $9.6 \times 10^{-15}$  
   (5) $2.2 \times 10^{-9}$

9. The electric field at a point P in space is identically zero. Which of the following statements must be true?

   (1) Any charge placed at P will experience zero net force.  
   (2) The absolute electric potential at P is identically zero.  
   (3) A negative charge placed at P will accelerate in a direction opposite to that of a positive charge placed at P  
   (4) The electric field very near P is identically zero.  
   (5) There is no charge in the vicinity of P.

10. A parallel plate capacitor is connected to a battery and charged. The battery is then disconnected from the capacitor. The plates are then moved closer together. Which of the following statements is CORRECT?

    (1) The voltage across the plates decreases  
    (2) The electric field between the plates increases  
    (3) The capacitance decreases  
    (4) The stored electrical energy increases  
    (5) The charge on plates increases
11. Four thin, flat parallel charged conducting sheets are arranged as shown in Figure 7. The plates have uniform charge densities of $+3\mu\text{C}/\text{m}^2$, $+6\mu\text{C}/\text{m}^2$, $-4\mu\text{C}/\text{m}^2$, and $+7\mu\text{C}/\text{m}^2$ respectively. What is the magnitude of force (in N) on a $-1\mu\text{C}$ charge placed at point P?

1. $3.4 \times 10^{-1}$  
2. $8.0 \times 10^{-1}$  
3. $8.9 \times 10^{-3}$  
4. $6.7 \times 10^{-1}$  
5. $1.1 \times 10^5$

12. In the above problem, which way does the charge move?

1. $-y$  
2. $+y$  
3. $+x$  
4. $-x$  
5. $+z$

13. Two protons initially separated by $10^{-6}$ m are traveling toward each other with velocities of $1.7 \times 10^4$ m/s. How close (in m) will they come to each other?

1. $4.8 \times 10^{-10}$  
2. $3.2 \times 10^{-9}$  
3. $9.8 \times 10^{-12}$  
4. $2.1 \times 10^{-7}$  
5. $5.4 \times 10^{-7}$

14. An insulating sphere has a uniform charge density $\rho$ and radius $R$ (See Figure 8). Using Gauss’s Law, which expression below correctly expresses the magnitude of the electric field at point P inside the sphere located $r$ away from the center? The volume of a sphere of radius $r = (4/3)\pi r^3$ and the surface area of a sphere is $4\pi r^2$. Hint: $Q = (\rho) \times$ (Volume)

1. $\rho r / 3\epsilon_0$  
2. $4\pi \rho r^3 / 3\epsilon_0$  
3. $\rho r^3 / 4\pi \epsilon_0$  
4. $4\pi \rho r^3 / \epsilon_0$  
5. Something else

15. Six point charges are arranged in a hexagon as shown in Figure 9. What is the direction (in degrees) of the electric field at the center of the hexagon?

1. 60  
2. 300  
3. 120  
4. 210  
5. 0

16. How much charge (in C) must be put on a 2.0 mF capacitor to have enough energy to operate a 25 W light bulb for 10 seconds?

1. 1.0  
2. 1.4  
3. 3.3  
4. 0.7  
5. 5.4

17. The graph in Figure 10 shows the potential (in V) as a function of distance. In what region is the magnitude of the electric field the smallest?

1. 2–3 m  
2. 1–2 m  
3. 0–1 m  
4. 3–4 m  
5. 4–5 m

18. A gatoron particle ($m = 6.5$ kg, $q = -9.6$ C) moves in a circular around a massive moron particle ($q = +3.5$ C) assumed to be fixed in space. If the speed of the gatoron is 200 m/s, find the radius of orbit (in m)

1. $1.2 \times 10^6$  
2. $4.7 \times 10^6$  
3. $3.2 \times 10^2$  
4. $2.9 \times 10^8$  
5. $7.6 \times 10^5$
19. An experiment is performed with three rods of unknown charge states. We find that rod A is repelled from rod B. Rod B is attracted to rod C. Rod A is attracted to rod C. Which of the following CAN be true?

(1) Rod A is positively charged, rod B is positively charged, rod C is negatively charged
(2) Rod A is positively charged, rod B is negatively charged, rod C is negatively charged
(3) Rod A is positively charged, rod B is a neutral conductor, rod C is negatively charged
(4) Rod A is negatively charged, rod B is positively charged, rod C is positively charged
(5) Rod A is a neutral conductor, rod B is positively charged, rod C is negatively charged

20. Make sure that your name, social security number, and EXAM CODE are correctly entered on your bubble sheet. Which of the following statements is correct? (This problem is graded, so answer it correctly.)

(1) I SWEAR THAT I HAVE CORRECTLY ENTERED THE ABOVE INFORMATION. IF I HAVEN'T, THIS QUESTION WILL BE MARKED WRONG!!! (No kidding.)
(2) The device has yet to be invented that can measure the magnitude of my hatred for this class.
(3) Physics? I thought this class was “Basketweaving 101”!
(4) Einstein proved that the laws of physics are relative; therefore, even though I bubbled the information in incorrectly in this universe, it is correct in some other universe. I deserve credit regardless.
(5) I’m changing my major to philosophy, so physics is the last thing on my mind.