PHYS 1320 (Spring 2024) Sonnenfeld Online HW #2 Charges & Coulomb's Law

Problem 1: To start a car engine, the car battery moves N = ***4.25*** × 10^{21} electrons through the starter motor.
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Part (a) Write an expression for the magnitude of charge moved, Q, in terms of N and the fundamental charge e?
Expression :
$|Q|$ = ____

Select from the variables below to write your expression. Note that all variables may not be required.
α, **β**, **θ**, **a**, **d**, **e**, **g**, **h**, **j**, **k**, **m**, **N**, **P**, **S**, **t**

Part (b) Calculate the magnitude of the charged moved, Q, in coulombs?
Numeric : A numeric value is expected and not an expression.
$|Q|$ = ____

Problem 2: A 2.5 g copper penny is given a charge of ***-1.1*** nC.
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Part (a) Which statement best describes the numbers of protons and electrons in the penny when it is charged as indicated?
MultipleChoice :

1) The number of protons is equal to the number of electrons.
2) Electrons were removed, and the number of protons exceeds the number of electrons.
3) Electrons were added, and the number of protons exceeds the number of electrons.
4) Electrons were removed, and the number of electrons exceeds the number of protons.
5) Electrons were added, and the number of electrons exceeds the number of protons.
6) There is insufficient information to compare the numbers of protons and electrons.

Part (b) How many electrons were transferred in order to create the charge on the penny?
Numeric : A numeric value is expected and not an expression.
N_e = ____ electrons

Part (c) By what percentage do the transferred electrons change the mass of the penny? (Express your result as a positive percentage for an increase,

negative for a decrease.)
Numeric : A numeric value is expected and not an expression.
$\frac{\Delta m}{m}$ = ____ %

Problem 3: We have three identical metallic spheres A, B, C. Initially sphere A is charged with charge Q, while B and C are neutral. First, sphere A is brought into contact with sphere B and then separated from it. After that, sphere A is brought into contact with sphere C and then separated from it. Finally, sphere A is brought into contact with sphere B again, and then separated from it.
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What is final charge of sphere A?
MultipleChoice :

1) $Q/8$
2) $Q/2$
3) $3Q/8$
4) $Q/4$
5) Q

Problem 4: An insulating rod is negatively charged, and an electrically neutral conducting sphere is mounted on an insulating stand. The rod is brought near to the sphere on the right, but they never actually touch.
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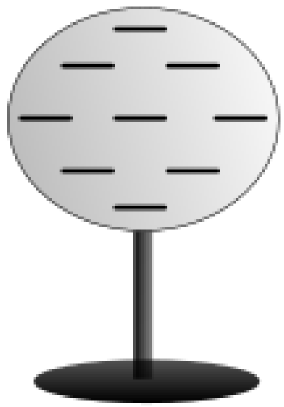
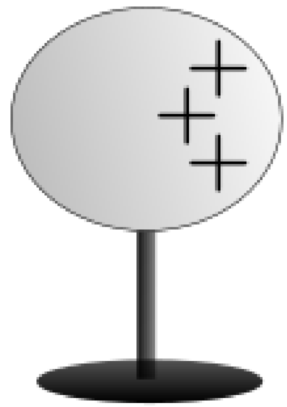
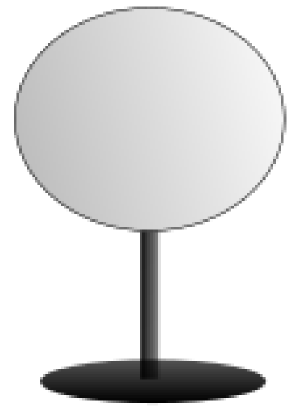
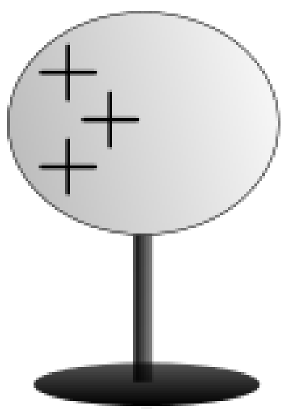
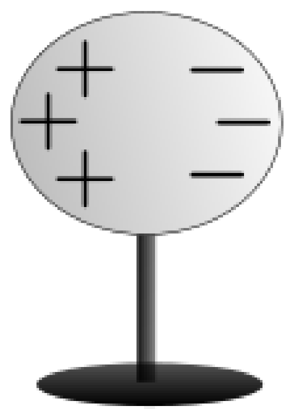
Select the image that best represents the resulting charge distribution on the conducting sphere.
SchematicChoice :

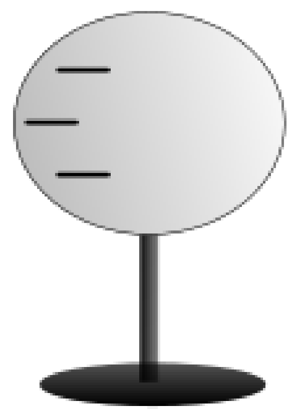


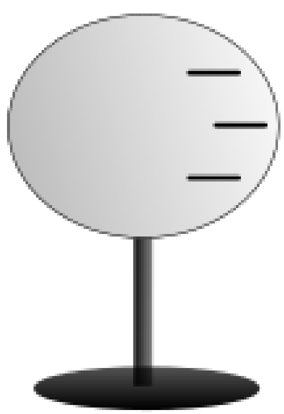


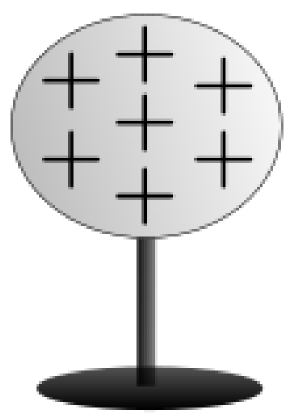


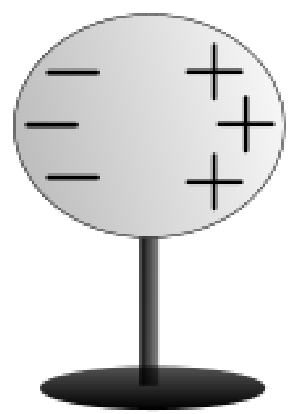












Problem 5: Consider the situation in the figure below; a neutral conducting ball hangs from the ceiling by an insulating string, and a charged insulating rod is going to be placed nearby.

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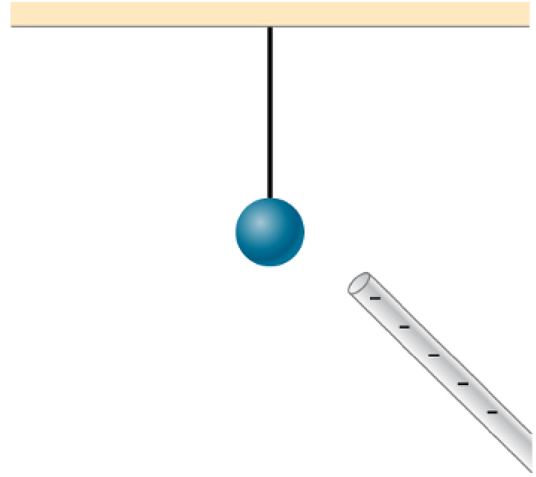

Part (a) First, if the rod was not there, what statement best describes the charge distribution of the ball?
MultipleChoice :

1) The positive and negative charges are separated from each other, but we don't know what direction the ball is polarized.
2) The positive and negative charges are evenly distributed everywhere in the ball.
3) Since it is a conductor, all the charges are on the outside of the ball.
4) The ball is neutral, so it has no positive or negative charges anywhere.

Part (b) Now, when the rod is moved close to the ball, what happens to the charges on the ball?
MultipleChoice :

1) Negative charge is draw from the ground (via the string), so the ball acquires a net negative charge.
2) There is a separation of charges in the ball; the positive charges move towards the side closer to the rod, and the negative charges move to the opposite side.
3) Nothing happens to the charges in the ball.
4) Positive charge is draw from the ground (via the string), so the ball acquires a net positive charge.
5) There is a separation of charges in the ball; the negative charges move towards the side closer to the rod, and the positive charges move to the opposite side.

Part (c) Which of the following statements is correct about the force being applied to the ball when the rod is nearby?
MultipleChoice :

1) There is no force on the ball from the rod, because they are not touching each other.
2) The ball is attracted to the rod.
3) There is no force on the ball from the rod, because the force of gravity and the string cancel it out.
4) There is no force on the ball from the rod, because the ball is neutral.
5) The ball is repelled by the rod.

Problem 6: Suppose a speck of dust in an electrostatic precipitator has N_p = ***4.75*** $\times 10^{17}$ protons in it and carries a net charge of Q = ***-43*** nC. Let q_e represent the charge of an electron.

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Part (a) Enter an expression for the number of electrons N_e in the speck of dust in terms of the charge of an electron, q_e, and other variables from the problem statement.
Expression :
N_e = ____

Select from the variables below to write your expression. Note that all variables may not be required.
α, β, θ, a, d, g, h, j, k, m, N_p, P, Q, q_e, t

Part (b) How many electrons are in the speck of dust?
Numeric : A numeric value is expected and not an expression.
N_e = ____

Problem 7: Two balloons have equal and opposite charges. Balloon one has $N = 10^9$ excess electrons. The balloons are separated by d = **2.6** m and each electron has a negative charge of $e = 1.602 \times 10^{-19}$ C.
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Part (a) What is the charge on balloon two, Q_2, in C?
Numeric : A numeric value is expected and not an expression.
Q_2 = ____

Part (b) What is the magnitude of the force (in N) of balloon one on balloon two using the variables provided and the Coulomb constant k ($k = 8.988 \times 10^9$ N m^2/C^2).
Numeric : A numeric value is expected and not an expression.
F_{12} = ____

Problem 8: Three charges are located as shown in the figure, with values q_1 = **3.9** × 10^{-16} C, q_2 = -**1.1** × 10^{-16} C, q_3 = **6.75** × 10^{-16} C. The charges are separated by d_1 = **2.3** × 10^{-6} m and d_2 = **2.5** × 10^{-6} m.
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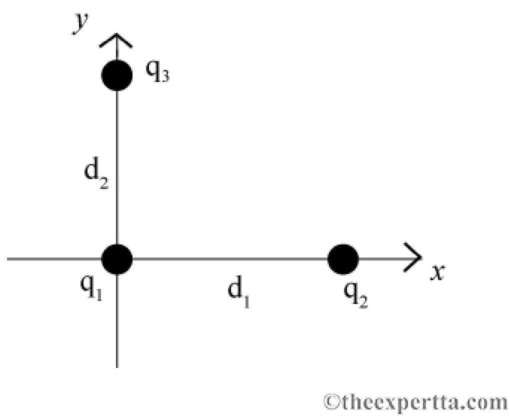

Part (a) What is the force of q_2 on q_1 in the x direction, F_x? Give your answer in newtons, and recall $k = 8.988 \times 10^9$ N m^2/C^2.
Numeric : A numeric value is expected and not an expression.
F_x = ____

Part (b) What is the force of q_3 on q_1 in the y direction, F_y? Give your answer in newtons.
Numeric : A numeric value is expected and not an expression.
F_y = ____

Problem 9: Three charged particles lie in the *xy* plane at an angle of θ relative to the *x*-axis. Charge q_1 is located at the origin, q_2 is a distance r from q_1, and q_3 is a distance $3r$ from q_1. The charges each have magnitude of q, but $q_1 = q_2 = +q$, and $q_3 = -q$. Charges q_1 and q_3 are fixed, and q_2 can move. However, q_1 and q_2 are connected by an ideal, neutral spring of spring constant k_s. The spring is initially not stretched. Let Coulomb's constant be k_e. q_1 and q_2 are positive and q_3 is negative.
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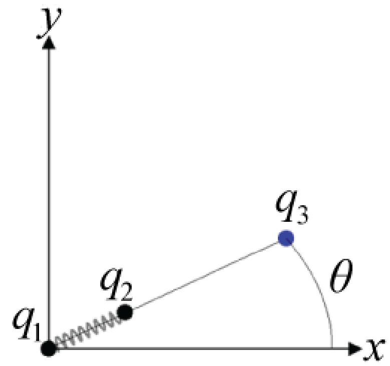

Part (a) Choose the best expression for the net electrostatic force on q_2, in terms of the given variables.
Expression :
F = ____

Select from the variables below to write your expression. Note that all variables may not be required.
cos(α), **cos(φ)**, **cos(θ)**, **sin(α)**, **sin(φ)**, **sin(θ)**, **γ**, **(**, **)**, **i**, **j**, **k$_e$**, **n**, **q**, **r**

Part (b) Because the force on q_2 is nonzero, it will begin to move from rest. In which direction will it move?
MultipleChoice :

1) It will move toward q_3.
2) It will not move.
3) There is not enough information.
4) It will move out of the *xy* plane.
5) It will move toward q_1.
6) It will move along the +*x* direction.
7) It will move along the +*y* direction.

Part (c) When q_2 begins to move, it will stretch the spring. Choose the equation for the force vector from the spring, $\mathbf{F}_s$, due to stretching the spring a distance of Δr.
SchematicChoice :

$\vec{F}_s = -k_s(\cos\theta\,\hat{\imath} + \sin\theta\,\hat{\jmath})$ $\vec{F}_s = -k_s\Delta r(\sin\theta\,\hat{\imath} + \cos\theta\,\hat{\jmath})$ $\vec{F}_s = -\frac{1}{2}k_s(\Delta r)^2(\cos\theta\,\hat{\imath} + \sin\theta\,\hat{\jmath})$

$\vec{F}_s = -k_s\Delta r(\cos\theta\,\hat{\imath} + \sin\theta\,\hat{\jmath})$ $\vec{F}_s = -k_s\Delta r(\hat{\imath} + \hat{\jmath})$ $\vec{F}_s = -\Delta r(\cos\theta\,\hat{\imath} + \sin\theta\,\hat{\jmath})$

Part (d) When q_2 is at its equilibrium position, the forces acting on it will be balanced. Which of the expressions below correctly shows the electrostatic force on q_2 when the charge has reached its equilibrium position?

MultipleChoice :

1) $\mathbf{F} = k_q\, q^2\, (1/(r-\Delta r)^2 + 1/(2r-\Delta r)^2)\, (\cos(\theta)\, \mathbf{i} + \sin(\theta)\, \mathbf{j})$
2) $\mathbf{F} = k_e\, q^2\, (1/(r+\Delta r)^2 + 1/(3r-\Delta r)^2)\, (\cos(\theta)\, \mathbf{i} + \sin(\theta)\, \mathbf{j})$
3) $\mathbf{F} = k_e\, q^2\, (1/(r+\Delta r)^2 + 1/(2r-\Delta r)^2)\, (\sin(\theta)\, \mathbf{i} + \cos(\theta)\, \mathbf{j})$
4) $\mathbf{F} = k_e\, q^2\, (1/(r+\Delta r)^2 + 1/(2r-\Delta r)^2)\, (\cos(\theta)\, \mathbf{i} + \sin(\theta)\, \mathbf{j})$
5) $\mathbf{F} = k_e\, q^2\, (1/(r-\Delta r)^2 + 1/(2r+\Delta r)^2)\, (\cos(\theta)\, \mathbf{i} + \sin(\theta)\, \mathbf{j})$
6) $\mathbf{F} = k_e\, q^2\, (1/(r+\Delta r)^2 + 1/(2r+\Delta r)^2)\, (\cos(\theta)\, \mathbf{i} + \sin(\theta)\, \mathbf{j})$

Problem 10: Free charges do not remain stationary when close together.

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To illustrate this, calculate the magnitude of the instantaneous acceleration in, meters per second squared, of two isolated protons separated by ***1.7*** nm.

Numeric : A numeric value is expected and not an expression.

a = ____