Name:__Solutions_____ ID: _____

Physics 203

Midterm 2

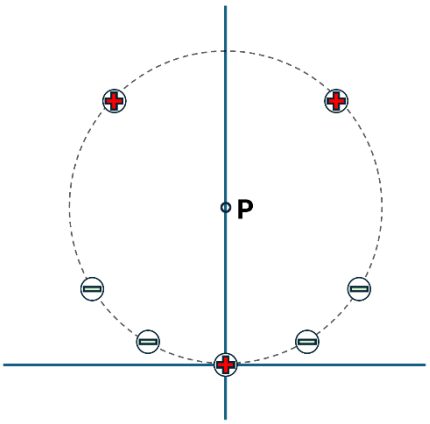
5/13/2026

Collaboration is not allowed. Allowed on your desk are: ten 8.5 x 11 inch doubled-sided sheets of notes that are bound together, non-communicating graphing scientific calculator, a page of scratch paper, writing utensils, a straight edge, and the exam. You will have 80 minutes to complete this exam.

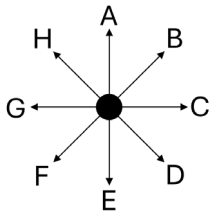
For questions 1 through 4 **fill in the square** next to all correct answers. A given problem may have more than one correct answer. Each correctly bubbled answer will receive two points. There are **5** correct answers in this section and only the first **5** filled in answers will be graded. There is no partial credit.

Question 1

Consider 3 positive charges and 4 negative charges, all with the same magnitude charge, fixed in place around a circle as shown in the figure. If an electron is placed in the center of the circle, at point **P**, in which direction does the net force acting on it point.

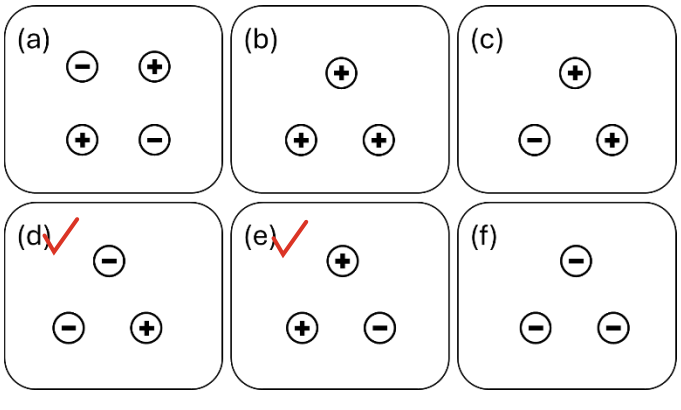


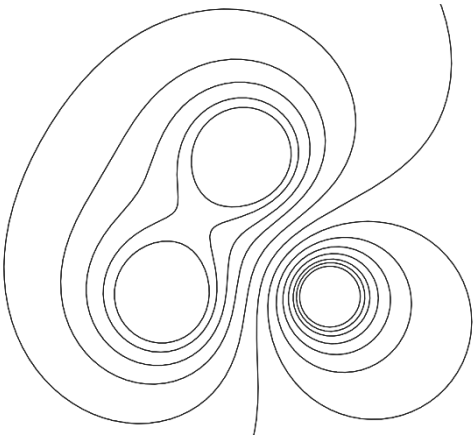
☑ (a) A
□ (b) B
□ (c) C
□ (d) D
□ (e) E
□ (f) F
□ (g) G
□ (h) H



Question 2

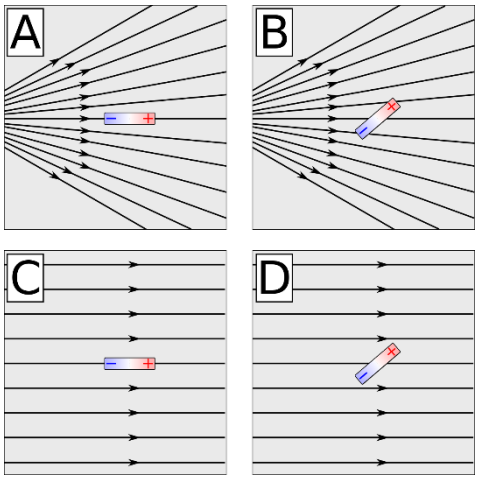
Which pictured charge configuration(s) could produce the provided electric potential field?





Question 3

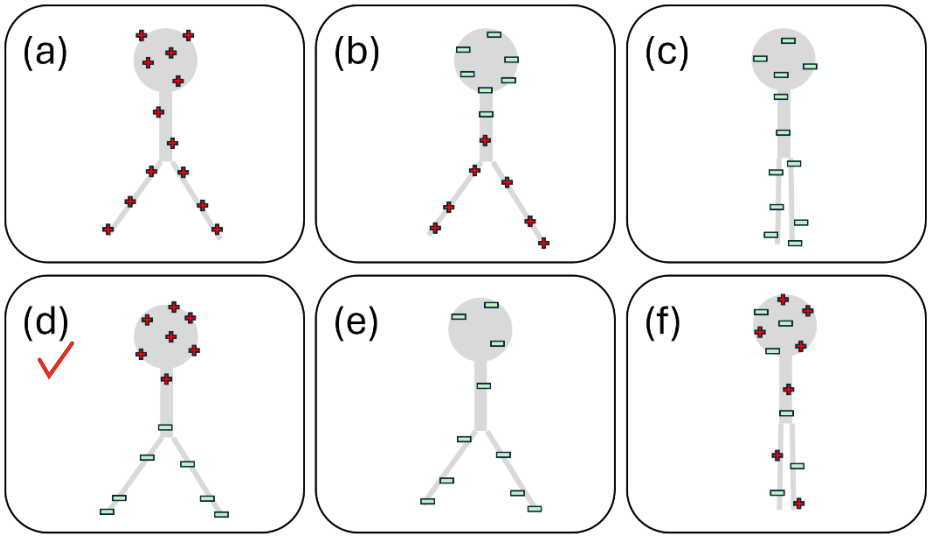
The following images are of a dipole in an electric field. Which case has both a **non-zero electric force** and a **non-zero torque**?



- ☐ (a) A
- ☑ (b) B
- ☐ (c) C
- ☐ (d) D

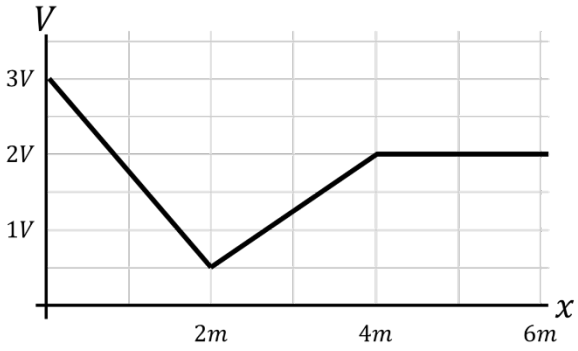
Question 4

A neutral Silver Surfer is attacked by a beam of electrons from Electro. The Silver Surfer escapes and retreats to hover over (but not touch) his favorite art installation, a giant electroscope outside the Electrical Engineering Department at State University. Which one of the following diagrams best describes the charge distribution on the electroscope while the Silver Surfer hovers above it. Note: this electroscope is made entirely of conducting materials, with a fixed spherical top and vertical base, along with two metal leaves that hang below and are free to pivot.



Question 5

(7 points) An object with mass $m = 1.5\ kg$ and net charge $q = -50\ \mu C$ starts with a velocity of $v_x = 50\frac{m}{s}\ \hat{x}$ at $x = 2\ m$. The electric potential as a function of position is shown in the figure.



(a) Make a prediction for whether the speed of the charge will be larger or smaller (than the initial speed) when it reaches $\mathrm{x = 5\ m}$. (Note, the correctness of your prediction will not be graded)

(b) What speed will it have when it reaches $\mathrm{x = 5\ m}$?

(c) Compare your prediction with what you found in part (b). Do they match? If they do, use sign sensemaking to explain your prediction. If they do not, use sign sensemaking to explain why the speed increased or decreased.

a) Speed will increase — i-f b/c $-\Delta$

b) $\Delta U^E = q\,\Delta V = -\Delta KE = \frac{1}{2}mv_i^2 - \frac{1}{2}mv_f^2$

$$v_f^2 = v_i^2 - \frac{2q\Delta V}{m}$$

$$v_f^2 = (50\,m/s)^2 - \frac{2(-50\times10^{-6}\,C)(2V - 0.5\,V)}{1.5\,kg}$$

$v_f = 50.000001\ m/s$ (or $50.0\ m/s$) ← very small + contribution

c) They match!

A negative charge will have a decrease in electric potential energy if it experiences an increase in voltage

$U^E = q\,V$ (−) ↑ ↓

• A decrease in U^E will give an increase in KE b/c no other energy types are relevant.

$$\underbrace{\Delta U^E}_{(-)} = -\underbrace{\Delta KE}_{(+)}$$

Question 6

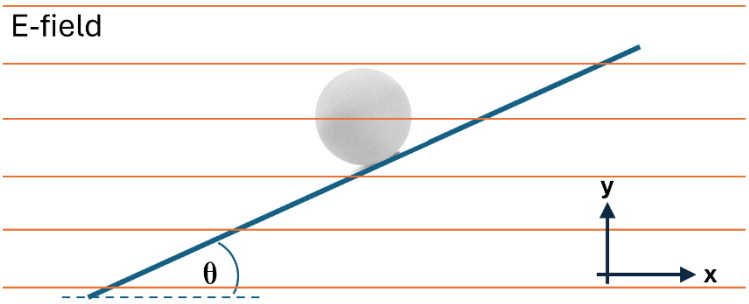
(12 points) A small positively charged Styrofoam ball with a mass, m, is in equilibrium on a frictionless inclined plane due to a uniform external horizontal electric field.

(a) Draw a free-body diagram of the ball. Label the forces and include the reference angle.

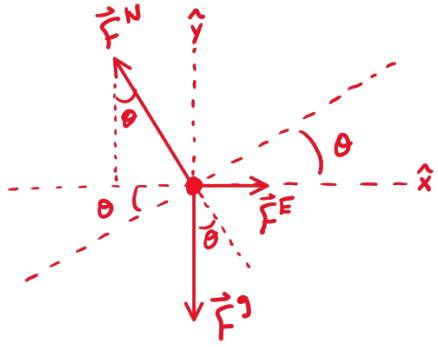
(b) What must be the direction of the external electric field? Explain.

(c) Symbolically write out Newton's 2nd law equation for the ball in both the x- and y-direction. Use the coordinate system in the figure. Your answer should use only the symbols **E**, **g, m, q, θ,** and numbers like 3 or ½.

(d) If the electric field has a magnitude of **510 V/m**, and m is **2.2 grams**, how much charge resides on the ball?



(a) FBD



(b) positive charge, $\vec{F} = q\vec{E} \Rightarrow \vec{F}$ & $\vec{E}$ must point the same direction. B/c the normal force has a negative x-component, F^E, and therefore $\vec{E}$, must point in the $+\hat{x}$ direction. Problem statement says horizontal $\vec{E} \Rightarrow E_y = 0$.

(c) x

$\Sigma f_x = ma_x^{\,0}$

$+|F^E| - |F_x^N| = 0$

$+qE - F^N \sin\theta = 0 \rightarrow F^N = \frac{qE}{\sin\theta}$

y

$\Sigma f_y = ma_y^{\,0}$

$-|F^g| + |F_y^N| = 0$

$-mg + F^N \cos\theta = 0 \rightarrow F^N = \frac{mg}{\cos\theta}$

$\frac{qE}{\sin\theta} = \frac{mg}{\cos\theta} \Rightarrow q = \frac{mg}{E}\tan\theta$

(d) $q = 4.23 \times 10^{-5} \tan\theta$ C

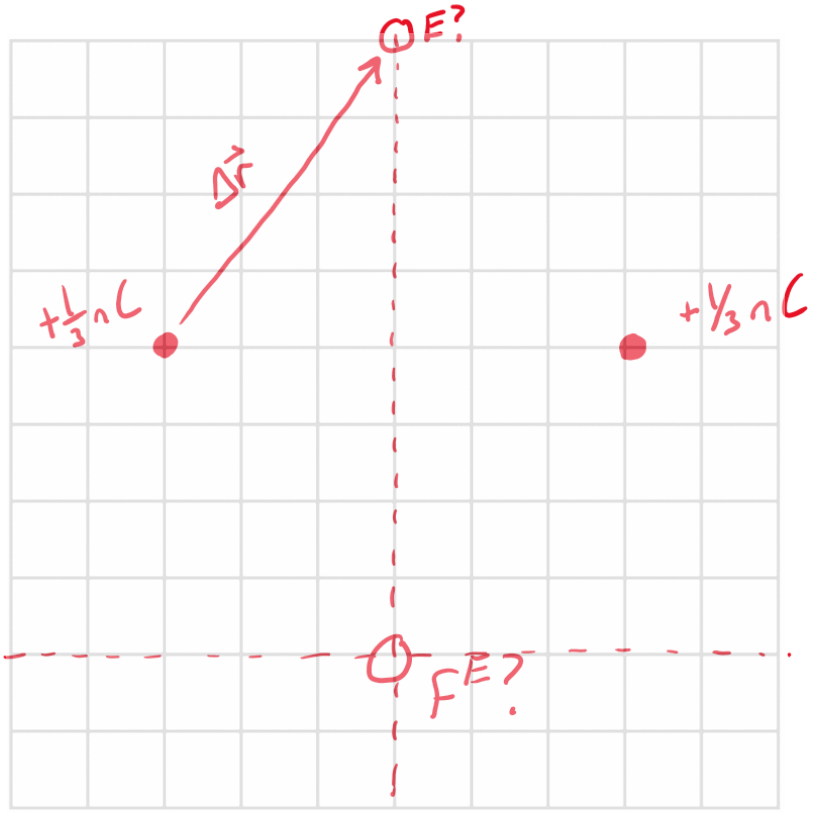
if $\theta = 35^\circ \Rightarrow q = 29.6\ \mu C$

Question 7

(10 points) There is one point charge at location **<3, 4, 0> m** and another point charge at **<-3, 4, 0> m**, both have charge of **+1/3 nC**.

(a) What is the net electric field vector at **<0, 8, 0> m**?

(b) What is the electric force vector on a **-2/3 nC** test charge placed at **<0, 0, 0> m**?



$\Delta\vec{r}_1 = \langle +3, +4 \rangle$

$|\Delta\vec{r}_1| = \sqrt{3^2+4^2} = 5$

$\Delta\hat{r}_1 = \frac{\langle 3, 4 \rangle}{5} = \langle \frac{3}{5}, \frac{4}{5} \rangle$

$\vec{E}_1 = (9\times10^9)\frac{(\frac{1}{3}\times10^{-9})}{25}\langle \frac{3}{5}, \frac{4}{5} \rangle \frac{N}{C}$

$= 0.12 \langle \frac{3}{5}, \frac{4}{5} \rangle \frac{N}{C}$

from symmetry:

$\vec{E}_2 = 0.12 \langle -\frac{3}{5}, \frac{4}{5} \rangle \frac{N}{C}$

↓ not a unit vector!

$\Rightarrow \vec{E}_{tot} = 0.24 \langle 0, \frac{4}{5} \rangle \frac{N}{C}$

$$\vec{E}_{tot} = \frac{24}{125}\langle 0, 1 \rangle \frac{N}{C} = 0.192 \frac{N}{C} +\hat{y}$$

b) by symmetry $\vec{E}_{tot}$ at $\langle 0,0,0 \rangle = 0.192 \frac{N}{C}(-\hat{y})$

$\vec{F} = q\vec{E} = (-\frac{2}{3}\times10^{-9} C)(-0.192 \frac{N}{C}\hat{y})$

$$= +\frac{16}{125}\times10^{-9}\ N\ \hat{y} = \langle 0, 1.28\times10^{-10} \rangle N$$