Sample Exam 2 KEY

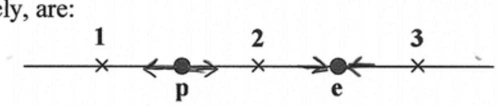
1. The magnitude of the electric field at a distance of 10 cm from an isolated point charge of 2.0×10^{-9} C is:

A. 1.8 N/C
B. 180 N/C
C. 18 N/C
D. 1800 N/C
E. none of these

$$|\vec{E}| = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2} = \frac{1}{4\pi(8.85\times10^{-12}\,\frac{C^2}{N\cdot m^2})}\frac{(2\times10^{-9}C)}{(0.10\ m)^2}$$

$$= 1798\ N/C$$

2. A proton **p** and an electron **e** are on the x axis. The directions of the electric field at points 1, 2, and 3 respectively, are:



$\leftarrow$ $\rightarrow$ $\leftarrow$

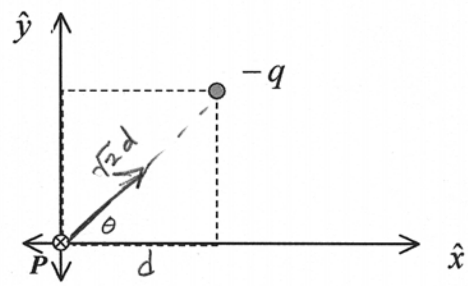
A. →,←,→
B. ←,→,←
C. ←,→,→
D. ←,←,←
E. none of the above

E due to p is larger than due to e^- because e^- is farther away

E due to e^- is larger than due to p because p is farther away

3. A charge is placed at the corner of a square of side *d* as shown in the diagram below. Using the *xy*-axis given, what is the electric field at point *P*?

A. $\left(\sqrt{2}q/16\pi\varepsilon_0 d^2\right)\hat{\mathbf{i}}$
B. $\left(q/4\pi\varepsilon_0 d^2\right)\hat{\mathbf{i}}$
C. $\left(\sqrt{2}q/16\pi\varepsilon_0 d^2\right)(\hat{\mathbf{i}}+\hat{\mathbf{j}})$
D. $\left(q/4\pi\varepsilon_0 d^2\right)(\hat{\mathbf{i}}+\hat{\mathbf{j}})$
E. $\left(\sqrt{2}q/8\pi\varepsilon_0 d^2\right)(\hat{\mathbf{i}}+\hat{\mathbf{j}})$



$\theta = 45°$

$$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{(\sqrt{2}d)^2}(\cos\theta\,\hat{x} + \sin\theta\,\hat{y})$$

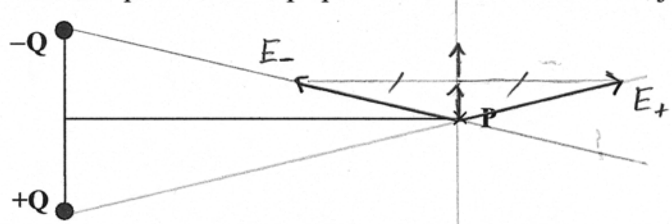
$$= \frac{1}{4\pi\epsilon_0}\frac{q}{2d^2}(\cos 45°\,\hat{x} + \sin 45°\,\hat{y})$$

$$= \frac{1}{4\pi\epsilon_0}\frac{q}{2d^2}\left(\frac{1}{\sqrt{2}}\hat{x} + \frac{1}{\sqrt{2}}\hat{y}\right) = \frac{q}{8\sqrt{2}\pi\epsilon_0 d^2}(\hat{x}+\hat{y})$$

multiply top and bottom by $\sqrt{2}$

$$\Rightarrow \sqrt{2}q/16\pi\epsilon_0 d^2\,(\hat{x}+\hat{y})$$

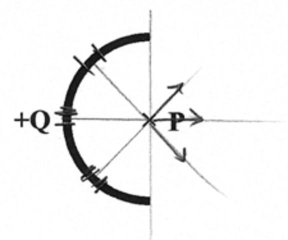
4. The diagram shows a positive charge Q and a negative charge $-Q$ with the same magnitude. The electric field at point P on the perpendicular bisector of the line joining them is:



Horizontal components cancel
Vertical components add

A. ↑
B. ↓
C. →
D. ←
E. zero

5. Positive charge Q is uniformly distributed on a semicircular rod. What is the direction of the electric field at point P, the center of the semicircle?



Small chunks of the semicircle each produce small amounts of $\vec{E}$ @ point P. All vertical components cancel in pairs. Horizontal components add to right.

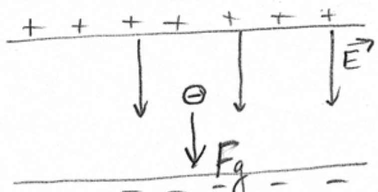
A. ↑
B. ↓
C. ←
D. →
E. ↗

6. A point charge of 0.02 C is placed in an electric field of 400 N/C $\hat{\mathbf{i}}$. What is the force on the charge?

$$\vec{F} = q\vec{E} = 0.02\,C\left(400\,\tfrac{N}{C}\hat{i}\right)$$
$$= 8N\hat{i}$$

A. $8.0\,\text{N}\,\hat{\mathbf{i}}$
B. $-8.0\,\text{N}\,\hat{\mathbf{i}}$
C. $8.0\times10^{-6}\,\text{N}\,\hat{\mathbf{i}}$
D. $2.0\times10^{4}\,\text{N}\,\hat{\mathbf{i}}$
E. $-2.0\times10^{4}\,\text{N}\,\hat{\mathbf{i}}$

7. A charged oil drop with a mass of 3.0×10^{-3} kg is held suspended by a downward electric field of 60 N/C. The charge on the drop is:



1st charge must be negative to be suspended.

2nd $F_g = F_e$

A. 2.0×10^{3} C
B. -2.0×10^{3} C
C. 4.9×10^{-4} C
D. -4.9×10^{-4} C
E. 1.8 C

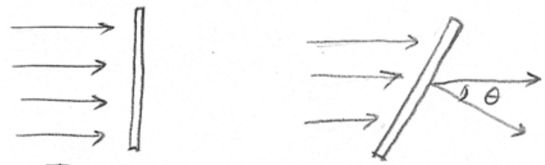
$$4.9\times10^{-4}C = q = \frac{mg}{E} = \frac{(3\times10^{-3}kg)(9.8 m/s^2)}{(60 N/C)} \qquad mg = qE$$

8. A total charge of 6.3×10^{-8} C is distributed uniformly throughout a 2.7 cm radius sphere. The volume charge density is:

A. 3.7×10^{-7} C/m^3
B. 6.9×10^{-6} C/m^3
C. 6.9×10^{-6} C/m^2
D. 2.5×10^{-4} C/m^3
E. 7.6×10^{-4} C/m^3

$$\rho = \frac{\text{charge}}{\text{volume}} = \frac{q}{4/3\pi r^3}$$
$$= \frac{6.3\times10^{-8}C}{\frac{4}{3}\pi(0.027m)^3} = 7.64\times10^{-4}\frac{C}{m^3}$$

9. When a piece of paper is held with one face perpendicular to a uniform electric field the flux through it is 25 N $\cdot$ m^2/C. When the paper is turned so that the field makes an angle of 25° with the normal to the paper, the flux through the paper is:



A. 0
B. 12 N $\cdot$ m^2/C
C. 21 N $\cdot$ m^2/C
D. 23 N $\cdot$ m^2/C
E. 25 N $\cdot$ m^2/C

$$\Phi = 25\frac{N\cdot m^2}{C} = \vec{E}\cdot\vec{A} = EA\cos\theta$$

$$\Phi = \underbrace{EA}_{25}\cos\theta = 25\cos25^\circ = 22.66\ N\cdot m^2/C$$

10. A 5.0 μC point charge is placed within the confines of a cube. The total electric flux through all sides of the cube is:

A. 0
B. 7.1×10^4 N $\cdot$ m^2/C
C. 9.4×10^4 N $\cdot$ m^2/C
D. 1.4×10^5 N $\cdot$ m^2/C
E. 5.6×10^5 N $\cdot$ m^2/C

$$\Phi = \oint \vec{E}\cdot d\vec{A} = Q/\epsilon_0$$
$$= \frac{5\times10^{-4}C}{8.85\times10^{-12}\ C^2/N\cdot m^2}$$
$$= 5.6497\times10^{5}\frac{N\cdot m^2}{C}$$
$$\approx 5.6\times10^{5}\frac{N\cdot m^2}{C}$$

11. 10 C of charge is placed on a spherical conducting shell. A –3 C point charge is placed at the center of the shell's cavity, isolated from the shell. The net charge on the inner surface of the shell is:

A. –7 C
B. –3 C
C. 0 C
D. +3 C
E. +7 C

Gaussian sphere
$E=0$ in conductor
$\therefore q_{enc} = 0$ also
q_{inner} + point charge $= 0$

12. Charge is distributed uniformly along a long straight wire. The electric field 2.0 cm from the wire is 20 N/C. The electric field 4.0 cm from the wire is:

A. 120 N/C
B. 80 N/C
C. 40 N/C
D. 10 N/C
E. 5.0 N/C

Gaussian cylinder

$\oint \vec{E}\cdot d\vec{A} = Q_{enc}/\epsilon_0$

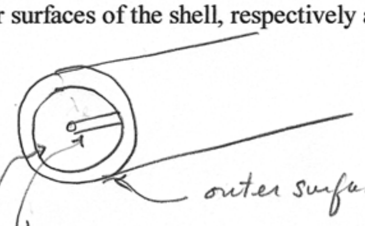
$E(2\pi r l) = \lambda l/\epsilon_0$

$E_1 = \dfrac{\lambda}{2\pi\epsilon_0 r_1}$, $E_2 = \dfrac{\lambda}{2\pi\epsilon_0 r_2}$ $\Big\}$ $\dfrac{E_2}{E_1} = \dfrac{r_1}{r_2}$

$E_2 = \dfrac{r_1}{r_2} E_1 = \left(\dfrac{2.0\text{cm}}{4.0\text{cm}}\right)(20\,\text{N/C}) = 10\,\text{N/C}$

13. A long line of charge with λ_l charge per unit length runs along the axis of a conducting cylindrical shell that carries a charge per unit length of λ_c. The charge per unit length on the inner and outer surfaces of the shell, respectively are:

A. λ_l and λ_c
B. $-\lambda_l$ and $\lambda_c + \lambda_l$
C. $-\lambda_l$ and $\lambda_c - \lambda_l$
D. $\lambda_l + \lambda_c$ and $\lambda_c - \lambda_l$
E. $\lambda_l - \lambda_c$ and $\lambda_c + \lambda_l$



outer surface?

λ_l

$-\lambda_l$, must be opposite λ_l

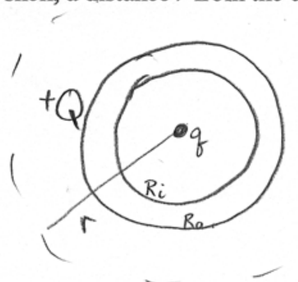
$\dfrac{q_{inner}}{l} + \dfrac{q_{outer}}{l} = \lambda_c$

$-\lambda_l + \lambda_{outer} = \lambda_c$

$\lambda_{outer} = \lambda_c + \lambda_l$

14. Positive charge Q is placed on a conducting spherical shell with inner radius R_1 and outer radius R_2. A point charge q is placed at the center of the cavity. The magnitude of the electric field at a point outside the shell, a distance r from the center, is:

A. $Q/\left(4\pi\varepsilon_0 R_1^2\right)$
B. $Q/\left\{4\pi\varepsilon_0\left(R_1^2 - r^2\right)\right\}$
C. $q/\left(4\pi\varepsilon_0 r^2\right)$
D. $(q+Q)/\left(4\pi\varepsilon_0 r^2\right)$
E. $(q+Q)/\left\{4\pi\varepsilon_0\left(R_1^2 - r^2\right)\right\}$



Gaussian surface @ r

$\oint \vec{E}\cdot d\vec{A} = \dfrac{Q_{enc}}{\epsilon_0}$

$E(4\pi r^2) = \dfrac{(Q+q)}{\epsilon_0}$

$E = \dfrac{(Q+q)}{4\pi\epsilon_0 r^2}$

15. A 5.0-cm radius conducting sphere has a charge density of 2.0×10^{-6} C/m^2 on its surface. The electric potential at its surface, relative to the potential far away, is:

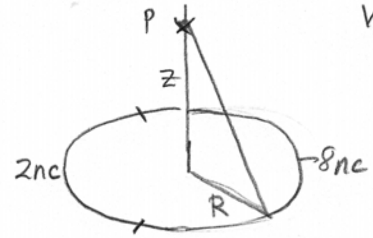
A. 1.1×10^4 V
B. 2.2×10^4 V
C. 2.3×10^5 V
D. 3.6×10^5 V
E. 7.2×10^6 V

$$V = \frac{1}{4\pi\epsilon_0}\int \frac{dq}{r} \Rightarrow \frac{\sigma A}{4\pi\epsilon_0 r} = \frac{\sigma(4\pi r^2)}{4\pi\epsilon_0 r}$$

$$= \frac{\sigma r}{\epsilon_0} = \frac{(2\times10^{-6}\,C/m^2)(0.05\,m)}{8.85\times10^{-12}\,C^2/N\cdot m^2} = 11300\,V = 1.1\times10^4\,V$$

16. A non-conducting ring of radius 1.0 m is charged with 2.0 nC on one-third of its circumference and –8.0 nC on the other two-thirds. If V at infinity is zero, find the potential at a point 2.0 meters above the ring on the central axis.

A. +8.0 V
B. +32 V
C. -24 V
D. -54 V
E. -72 V



$$V_p = \frac{1}{4\pi\epsilon_0}\frac{q_1+q_2}{\sqrt{R^2+z^2}}$$

$$= \frac{1}{4\pi(8.85\times10^{-12})}\frac{(2-8)\times10^{-9}\,c}{\sqrt{(1m)^2+(2m)^2}}$$

$$= -24V$$

17. A circular arc of plastic rod has a radius of 0.50 m and a uniform negative charge distribution of –5.0 pC/m. What is the electric potential at point P?

A. 0.14 V
B. -0.14 V
C. 0.090 V
D. -0.090 V
E. 0 V

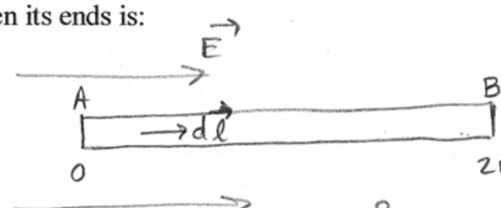
$$V_p = \frac{q}{4\pi\epsilon_0 r} = \frac{\lambda(\pi R)}{4\pi\epsilon_0 R}$$

$$= \frac{\lambda}{4\epsilon_0} = \frac{-5\times10^{-12}\,C/m}{4(8.85\times10^{-12})}$$

$$= -0.14\,V$$

18. A 2.0-meter stick is parallel to a uniform 200 N/C electric field. The magnitude of the potential difference between its ends is:

A. 0
B. 1.6×10^{-17} V
C. 3.2×10^{-17} V
D. 100 V
E. 400 V



$$V_B - V_A = -\int_A^B \vec{E}\cdot d\vec{l} = -\int_A^B E\,dl\cos 0°$$

$$= -E\int_A^B dl = -EL = -(200\,N/c)(2m)$$

$$= -400V \quad |-400V| = 400V$$

don't worry about sign here, ΔV has to be oriented correctly to accelerate the e^-

19. An electron is accelerated from rest through a potential difference of 100V. Its final speed is:

A. 100 m/s
B. 3.0×10^{6} m/s
C. 5.9×10^{6} m/s
D. 3.5×10^{13} m/s
E. 1.5×10^{16} m/s

$$\Delta V = \frac{W_{ext}}{q} = \frac{\Delta K}{q} = \frac{\frac{1}{2}m(v_f^2 - v_i^2)}{q}, \quad v_i^2 \to 0$$

$$v_f = \sqrt{\frac{2q\Delta V}{m}} = \sqrt{\frac{2(1.6\times10^{-19}C)(100V)}{9.1\times10^{-31}kg}}$$

$$= 5.9\times10^{6} m/s$$

20. If 500 J of work are required to carry a 40 C charge from one point to another, the magnitude of the potential difference between these two points is:

A. 12.5 V
B. 20,000 V
C. 0.08 V
D. 500 V
E. depends on the path

$$\Delta V = \frac{W_{ext}}{q} = \frac{500J}{40C} = 12.5V$$

21. A 5.5×10^{-8} C charge is fixed at the origin. A -2.3×10^{-8} C charge is moved from x = 3.5 cm on the x axis to y = 3.5 cm on the y axis. The change in potential energy of the two-charge system is:

A. 3.2×10^{-4} J
B. -3.2×10^{-4} J
C. 9.3×10^{-3} J
D. -9.3×10^{-3} J
E. 0

$$\Delta U = U_f - U_i = \frac{q}{4\pi\epsilon_0}\left\{\frac{q_f}{r_f} - \frac{q_i}{r_i}\right\}$$

$$= \frac{q q_f}{4\pi\epsilon_0}\left\{\frac{1}{3.5cm} - \frac{1}{3.5cm}\right\}$$

$$0 !$$

no change in distance from q.

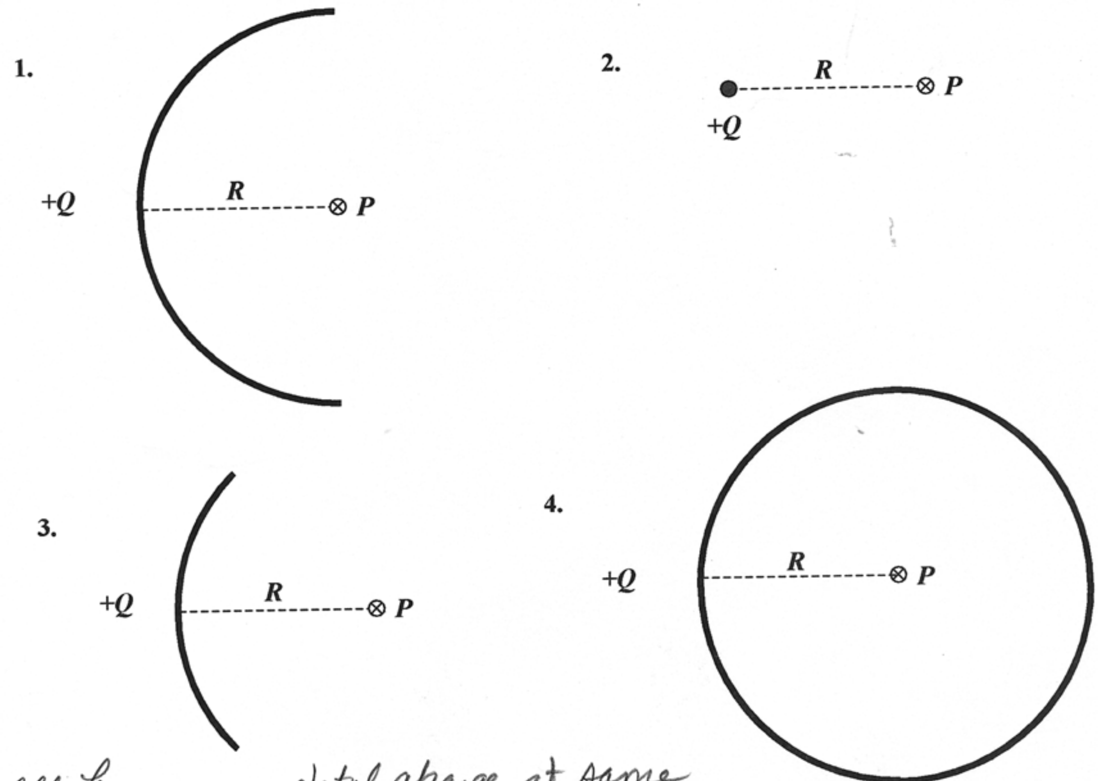
22. Three charges lie on the x axis: 1×10^{-8} C at $x = 1$ cm, 2×10^{-8} C at $x = 2$ cm, and 3×10^{-8} C at $x = 3$ cm. (Assume 2 significant digits of accuracy.) The potential energy of this arrangement, relative to the potential energy for infinite separation, is:

A. 7.9×10^{-2} J
B. 8.5×10^{-4} J
C. 1.7×10^{-3} J
D. 0.16 J
E. zero

$$U = W_{ext} = \frac{1}{4\pi\epsilon_0}\left\{\frac{q_1q_2}{r_{12}} + \frac{q_1q_3}{r_{13}} + \frac{q_2q_3}{r_{23}}\right\}$$

$$= \frac{1}{4\pi\epsilon_0}\left\{1\times10^{-8}\left(\frac{2\times10^{-8}}{0.01} + \frac{3\times10^{-8}}{0.02}\right) + \frac{2\times10^{-8}(3\times10^{-8})}{0.01}\right\}$$

$$= 8.5\times10^{-4} J$$



all have same total charge at same distance from P $\therefore$ $V = \frac{1}{4\pi\epsilon_0}\frac{Q}{R}$ is same for all

23. Rank the arrangements above according to the magnitude of the electric potential at the center of curvature, largest first.

A. 1, 2, 3, 4
B. 4, 1, 3, 2
C. 2, 3, 1, 4
D. all arrangements are the same
E. none of the above

Can you do the same for electric field?

Answers:
1. D
2. B
3. C
4. A
5. D
6. A
7. D
8. E
9. D
10. E
11. D
12. D
13. B
14. D
15. A
16. C
17. B
18. E
19. C
20. A
21. E
22. B
23. D