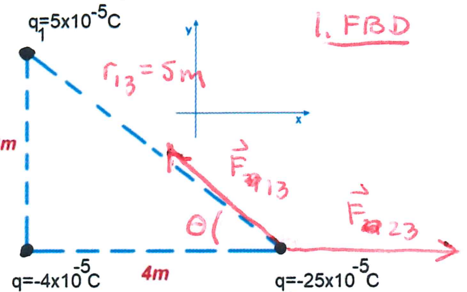
SOLUTIONS - PHYS 2210 - EXAM 2 - SPRING 2020

1. What is the correct ***force*** on point charge q_3 in the image below? Use $k=1\times10^{10}Nm^2/C^2$.

$\vec{F}_3 = \vec{F}_{13} + \vec{F}_{23}$

$\sin\theta = \frac{3}{5}$

$\cos\theta = \frac{4}{5}$



1. FBD

2. Magnitudes

$$F_{13} = \frac{k|q_1q_3|}{r_{13}^2} = \frac{(1\times10^{10}\frac{Nm^2}{C^2})(5\times10^{-5}C)(25\times10^{-5}C)}{(5m)^2} = 5N$$

$$F_{23} = \frac{k|q_2q_3|}{r_{23}^2} = \frac{(1\times10^{10}\frac{Nm^2}{C^2})(4\times10^{-5}C)(25\times10^{-5}C)}{(4m)^2} = \frac{25}{4}N$$

[✓ A.] $(\frac{9}{4}\hat{i}+3\hat{j})$N

B. $(\frac{13}{4}\hat{i}+3\hat{j})$N

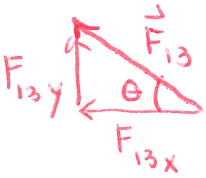
C. $(3\hat{i}+\frac{9}{4}\hat{j})$N

D. $(\frac{24}{5}\hat{i}+5\hat{j})$N

E. $(\frac{38}{5}\hat{i}-2\hat{j})$N

3. Components

$\longrightarrow F_{23x} = F_{23} = \frac{25}{4}N$

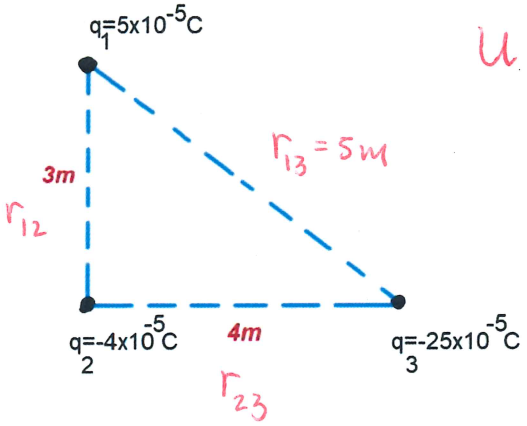


$F_{13x} = -F_{13}\cos\theta = -(5N)(\frac{4}{5}) = -4N$

$F_{13y} = F_{13}\sin\theta = (5N)(\frac{3}{5}) = 3N$

4. Add Components $\Rightarrow \vec{F}_3 = (\frac{25}{4}N - 4N)\hat{i} + 3\hat{j}\ N = \boxed{(\frac{9}{4}\hat{i}+3\hat{j})N}$

2. What is the ***electric potential energy*** of the charge configuration illustrated below? Use $k=1\times10^{10}Nm^2/C^2$.



$$U = \frac{kq_1q_2}{r_{12}} + \frac{kq_1q_3}{r_{13}} + \frac{kq_2q_3}{r_{23}}$$

$$U = \frac{(1\times10^{10}\frac{Nm^2}{C^2})(5\times10^{-5}C)(-4\times10^{-5}C)}{3m}$$

$$+ \frac{(1\times10^{10}\frac{Nm^2}{C^2})(5\times10^{-5}C)(-25\times10^{-5}C)}{5m}$$

$$+ \frac{(1\times10^{10}\frac{Nm^2}{C^2})(25\times10^{-5})(-4\times10^{-5}C)}{4m}$$

A. -20/9 J

B. 13/3 J

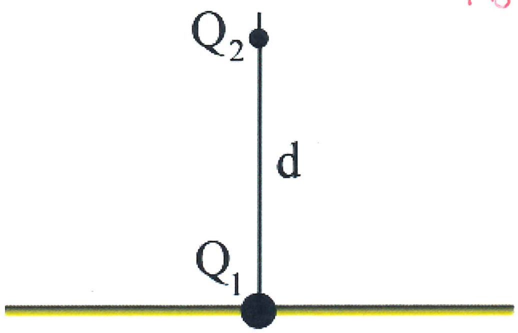
[✓ C.] -20/3 J

D. 170/3 J

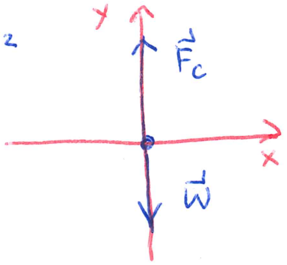
E. 20/3 J

$$U = -\frac{20}{3}J - 25J + 25J = \boxed{-\frac{20}{3}J}$$

3. A positively charged particle Q_1 is held fixed at the origin. A second charge Q_2 of mass m is floating a distance d above charge Q_1. The net force on Q_2 is equal to zero. You may assume this system is close to the surface of the Earth. In terms of the variables given including g, the acceleration due to gravity, what is a correct expression for the distance, d?



FBD Q_2



$$F_c = w$$

$$\frac{kQ_1Q_2}{d^2} = mg$$

$$\boxed{d = \sqrt{\frac{kQ_1Q_2}{mg}}}$$

A. $\frac{kQ_1Q_2}{mg}$

[✓ B.] $\sqrt{\frac{kQ_1Q_2}{mg}}$

C. $\sqrt{\frac{kQ_2}{mg}}$

D. $\sqrt{\frac{kQ_1}{mg}}$

E. 0

4. Charge q_1 = 2 μC is located at $\vec{r}_1 = (3\hat{i} + 5\hat{j})\text{m}$. A second charge q_2 = −10 μC is located at $\vec{r}_2 = (-\hat{i} + 2\hat{j})\text{m}$. What is the magnitude of the force of charge 2 on charge 1? Use $k=1\text{x}10^{10}\text{Nm}^2/\text{C}^2$.

$$r = |\vec{r}_2 - \vec{r}_1| = |(-4\hat{i} - 3\hat{j})| \text{ m}$$

$$r = \sqrt{16m^2 + 9m^2} = 5m$$

$$F_{21} = \frac{k|q_1 q_2|}{r^2} = \frac{(1\times10^{10}\frac{Nm^2}{C^2})(2\times10^{-6}C)(10\times10^{-6}C)}{(5m)^2}$$

$$\boxed{F_{12} = \frac{4}{5}\times10^{-2} N}$$

[✓ A.] 4/5 x 10^{-2} N

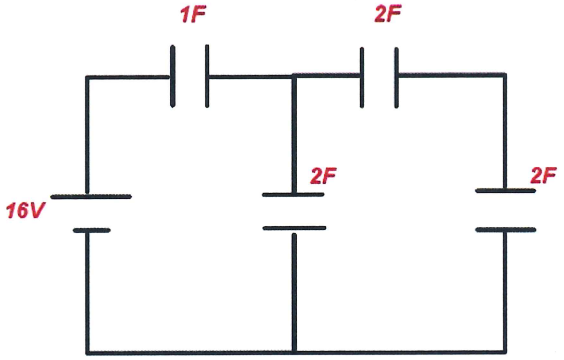
B. 1/5 x 10^{-2} N

C. 5x10^{-2} N

D. 20/51 x 10^{-2} N

E. 10/51 x 10^{-2} N

5. What is the ***energy*** stored in the capacitor of capacitance 1F in the circuit illustrated below?



$C_1 = \left(\frac{1}{2F}+\frac{1}{2F}\right)^{-1} = 1F$ ← series

$C_2 = 2F + 1F = 3F$ ← parallel

$C_{eq} = \left(\frac{1}{1F}+\frac{1}{3F}\right)^{-1} = \frac{3}{4}F$ ← series

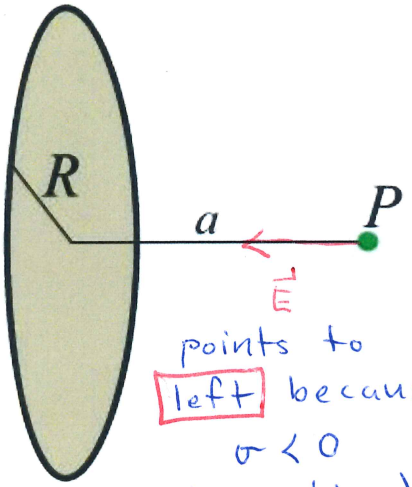
charge on 1F is also total charge →

$Q = C_{eq}\Delta V = \left(\frac{3}{4}F\right)(16V) = 12C$

$U = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}\frac{(12C)^2}{1F} = \boxed{72J}$

A. 22 J
B. 144 J
C. 6 J
[✓ D. 72 J]
E. 3 J

6. A uniformly charged solid disk of radius R = 3 m carries a uniform charge density of σ = $-30\varepsilon_0$ C/m^2. A point P is located a distance a = 4 m from the center of the disk and perpendicular to the face of the disk. What is the electric field strength E and the direction of the electric field, respectively, at point P?



points to $\boxed{\text{left}}$ because $\sigma < 0$ (negative)

$E = \frac{\sigma}{2\varepsilon_0}\left(1 - \frac{z}{\sqrt{z^2+R^2}}\right)$

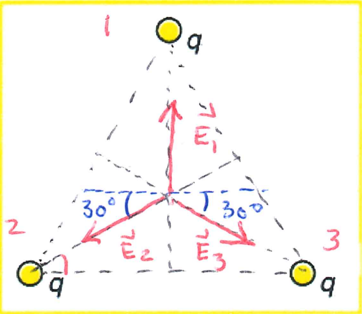
$E = \frac{+30\varepsilon_0}{2\varepsilon_0}\left(1 - \frac{4m}{\sqrt{16m^2+9m^2}}\right)$

$E = 15\left(1-\frac{4}{5}\right)$ N/C

$\boxed{E = 3 \text{ N/C}}$

A. 30 N/C to the left
B. 3 N/C to the right
[✓ C. 3 N/C to the left]
D. 15 N/C to the left
E. 15 N/C to the right

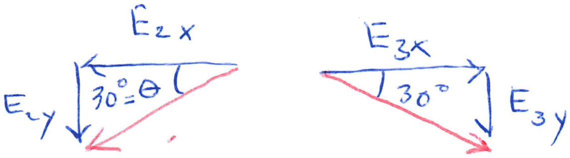
7. In the figure, three point charges of charge q=-150x10^{-10}C are located at the corners of an equilateral triangle 3m on a side. Find the ***electric field*** at the center of the triangular configuration of charges. Use k=1x10^{10}Nm^2/C^2, $\sin(30^\circ)=\cos(60^\circ)=1/2$, and $\cos(30^\circ)=\sin(60^\circ)=\sqrt{3}/2$



1. FBD

2. Magnitudes

$$E_1 = E_2 = E_3 = \frac{kq}{r^2}$$



3. Components

★ Notice x-components cancel by symmetry!

$$E_{1y} = E_1 = \frac{kq}{r^2}$$

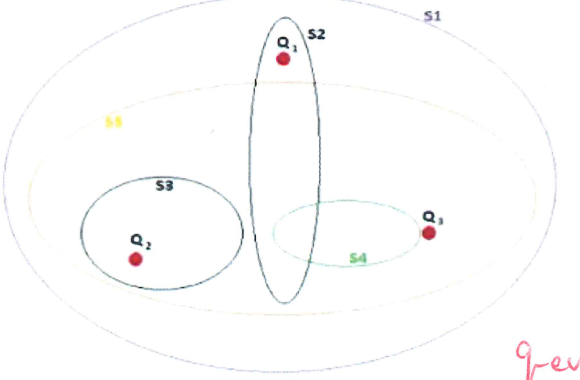
$$E_{2y} = -E_2\sin(30^\circ) = -\frac{1}{2}E_2 = -\frac{kq}{2r^2}$$

$$E_{3y} = -E_3\sin(30^\circ) = -\frac{1}{2}E_3 = -\frac{kq}{2r^2}$$

[✓ A. 0]
B. $(25\hat{j})$N/C
C. $(-25\sqrt{3}\hat{i}+50\hat{j})$N/C
D. $(50\hat{i}+50\hat{j})$N/C
E. $(50\sqrt{3}\hat{i}-50\hat{j})$N/C

4. Add Comps $E_y = \frac{kq}{r^2} - \frac{kq}{2r^2} - \frac{kq}{2r^2} = \boxed{0}$

8. Three electric charges, $Q_1 = 3\varepsilon_0$, $Q_2 = \varepsilon_0$, and $Q_3 = -8\varepsilon_0$ (units are Coulombs) are presented in the figure, along with 5 surfaces, S1 through S5. What is the net electric flux through surface S5?



$$\phi_E = \frac{q_{enc}}{\varepsilon_0}$$

$$q_{enc} = Q_2 + Q_3$$

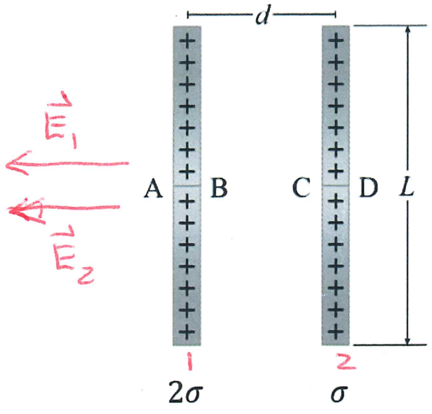
$$q_{enc} = \varepsilon_0 - 8\varepsilon_0 = -7\varepsilon_0$$

$$\phi_E = \frac{-7\varepsilon_0}{\varepsilon_0} = \boxed{-7\,\frac{N}{C}m^2}$$

A. 4 Nm^2/C
B. -4 Nm^2/C
C. 7 Nm^2/C
D. 1 Nm^2/C
[✓ E. -7 Nm^2/C]

9. Two large rectangular sheets of charge of side L are separated by a distance d (d << L) have surface charge densities illustrated below. What is the magnitude of the electric field at point A in the figure?

$E_{plane} = \frac{\sigma}{2\varepsilon_0}$



$E_x = E_{1x} + E_{2x}$

$E_x = \frac{2\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \boxed{\frac{3\sigma}{2\varepsilon_0}}$

A. $\frac{\sigma}{2\varepsilon_0}$

B. $\frac{2\sigma}{\varepsilon_0}$

C. 0

[✓ D.] $\frac{3\sigma}{2\varepsilon_0}$

E. $\frac{\sigma}{\varepsilon_0}$

10. An infinite conducting cylindrical shell of outer radius r_1 and inner radius r_2 initially carries a surface charge density σ. A thin wire, with linear charge density λ, is inserted along the shells' axis. The shell and the wire do not touch and there is no charge exchanged between them. What is the electric field strength E ***inside the cavity*** for $r<r_2$?

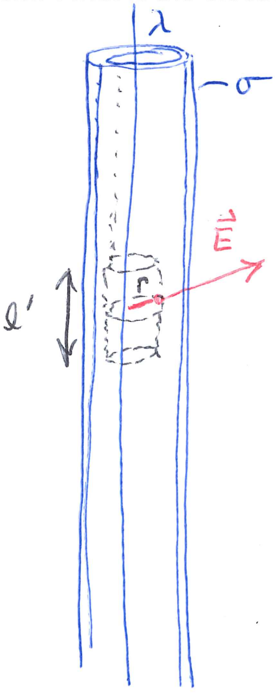
A. 0

[✓ B.] $\frac{\lambda}{2\pi\varepsilon_0 r}$

C. $\frac{\sigma r_1}{\varepsilon_0 r}$

D. $\frac{\sigma+\lambda}{2\pi\varepsilon_0 r^2}$

E. $\frac{2\pi r_1\sigma+\lambda}{2\pi\varepsilon_0 r}$



$\oint \vec{E} \cdot d\vec{A} = \frac{q_{enc}}{\varepsilon_0}$

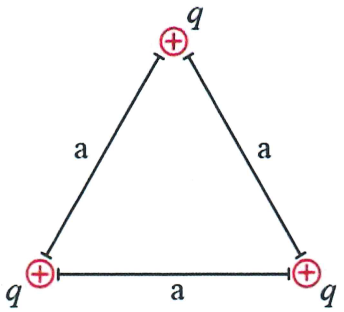
$E(2\pi r \ell') = \frac{q_{enc}}{\varepsilon_0}$

$q_{enc} = \lambda \ell'$

$E(2\pi r \cancel{\ell'}) = \frac{\lambda \cancel{\ell'}}{\varepsilon_0}$

$\boxed{E = \frac{\lambda}{2\pi\varepsilon_0 r}}$

11. Consider the arrangement of three small charged spheres, each of mass 1 kg, shown in the figure. The spheres have equal charges of 6x10^{-5}C and are positioned on the vertices of an equilateral triangle, with side length a = 3m. If these spheres are released at precisely the same time, how fast, in meters per second, will they be moving when they are infinitely far away form each other? Use k=1x10^{10}Nm^2/C^2.



$$U_i + \overset{rest}{\cancel{K_i}} = \overset{0}{\cancel{U_f}} + K_f$$

$$U_f = U(r\to\infty) = 0$$

$$K_f = \frac{1}{2}mv^2 + \frac{1}{2}mv^2 + \frac{1}{2}mv^2 = \frac{3}{2}mv^2$$

$$U_i = \frac{kq^2}{a} + \frac{kq^2}{a} + \frac{kq^2}{a} = \frac{3kq^2}{a}$$

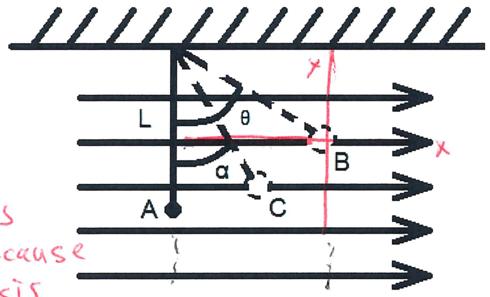
$$K_f = U_f$$

$$\frac{3}{2}mv^2 = \frac{3kq^2}{a} \Rightarrow v = \sqrt{\frac{2kq^2}{ma}}$$

$$v = \sqrt{\frac{2(1\times10^{+10}\frac{Nm^2}{C^2})(6\times10^{-5}C)^2}{(1kg)(3m)}} = \boxed{\sqrt{24}\ m/s}$$

A. $\sqrt{12}$ m/s
B. 10 m/s
[✓ C.] $\sqrt{24}$ m/s
D. $\sqrt{8}$ m/s
E. 2 m/s

12. A small ball with charge q = 2C is suspended from the ceiling by a string of length L = 3 m and is initially at rest. A uniform horizontal electric field E of magnitude 10 V/m is applied to the ball-string system. The ball then begins to move. Ignore air resistance. Suppose point B is the highest point the ball can reach. Take $\theta = 53.1^0$ as the angle of the string with the vertical direction at point B. Find the ***change of electrical potential energy*** ΔU from point A to point B. Use $\cos(53.1^\circ) = 0.6$ and $\sin(53.1^0) = 0.8$.



x_A is negative because left of y axis →

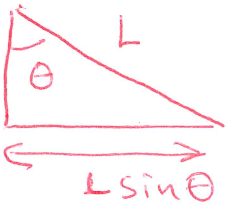
$x_A = -L\sin\theta$ $x_B = 0$

$$U = qEx + U_0$$

$$U_B = qE(0) + U_0$$

$$U_A = qE(-L\sin\theta) + U_0$$

$$\Delta U = U_B - U_A = -qEL\sin\theta$$



A. -36J
[✓ B.] -48J
C. -60J
D. -20J
E. -15J

$$\Delta U = -(2C)(10\frac{V}{m})(3m)\sin(53.1)^\circ$$

$$\boxed{\Delta U = -48J}$$

13. Suppose you have an electric field between two parallel conducting plates separated by 1 cm and having a potential difference (voltage) between them of 2 × 10^4 V. What is the electric field strength between the plates?

$$E = \frac{\Delta V}{d} = \frac{2\times10^{+4}\,V}{0{,}01m} = \boxed{200\times10^{+4}\ N/c}$$

A. $7\text{x}10^5$ N/C
B. $4\text{x}10^4$ N/C
[✓ C.] $200\text{x}10^4$ N/C
D. $2\text{x}10^4$ N/C
E. $20\text{x}10^4$ N/C

14. The electric field strength for three charge configurations have the following dependence with position r far away from the distribution:

1. 1/r dependence → line
2. $1/r^2$ dependence → sphere, point
3. $1/r^3$ dependence → dipole

What is the correct matching of charge distribution to position dependence?

A.
1. uniformly charged sphere
2. uniformly charged infinite line
3. electric dipole

B.
1. uniformly charged sphere
2. electric dipole
3. uniformly charged infinite line

[✓ C.]
1. uniformly charged infinite line
2. uniformly charged sphere
3. electric dipole

D.
1. electric dipole
2. uniformly charged sphere
3. uniformly charged infinite line

E. 1. electric dipole
2. uniformly charged infinite line
3. uniformly charged sphere

15. Suppose you want a capacitor bank with a total capacitance of 128 F and you possess numerous 2 F capacitors. What is the smallest number you could connect together to achieve your goal?

A. 8
B. 128
C. 12
D. 256
[✓ E. 64]

$C_{eq} = NC$ ← connect in parallel

$N = \frac{C_{eq}}{C} = \frac{128 F}{2 F} = \boxed{64 \text{ capacitors}}$