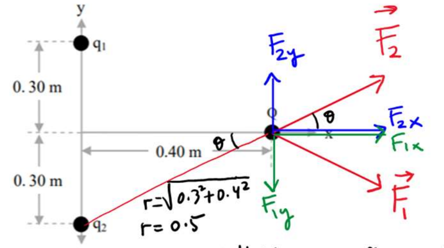
Q1 M2-142-01

Three charges, q1 = q2 = 2.0 µC and Q = 4.0 µC, are fixed in their places as shown in Figure 1. Find the net electrostatic force on Q due to q1 and q2. [$\hat{\imath}$ and $\hat{\jmath}$ are the unit vectors in the direction of x and y, respectively

A) (0.46 $\hat{\imath}$) N
B) (0.17 $\hat{\imath}$) N
C) (0.46 $\hat{\imath}$+ 0.17 $\hat{\jmath}$) N
D) (0.17 $\hat{\imath}$– 0.46 $\hat{\jmath}$) N
E) (0.17 $\hat{\imath}$+ 0.32 $\hat{\jmath}$) N



$F \equiv F_1 = F_2 = \frac{k|q_1||Q|}{r^2} = \frac{9\times10^9(2\times10^{-6})(4\times10^{-6})}{(0.5)^2} = 0.22\,N$

$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 = (F_{1x}+F_{2x})\hat{\imath} + (F_{1y}+F_{2y})\hat{\jmath}$

$\vec{F}_{net} = (F\cos\theta + F\cos\theta)\hat{\imath} + (F\sin\theta - F\sin\theta)\hat{\jmath}$ → 0

$\vec{F}_{net} = 2F\cos\theta\,\hat{\imath} = 2(0.22)\left(\frac{0.4}{0.5}\right)\hat{\imath} = (0.46\,N)\,\hat{\imath}$

cosθ

Q2 M2-112-02

Consider three distant spheres with charges Q_{1i} = 1C, Q_{2i} = 2C, and Q_{3i} = 3C. We allow these three charges to touch each other for a short time and then we separate them. The new charges of these spheres become Q_{1f} = q, Q_{2f} = 0.5q, and Q_{3f} = 1.5q. Find the value of q.

A) 2 C
B) 1 C
C) 3 C
D) 6 C
E) 4 C

Total charge is conserved

$Q_{1i}+Q_{2i}+Q_{3i} = Q_{1f}+Q_{2f}+Q_{3f}$

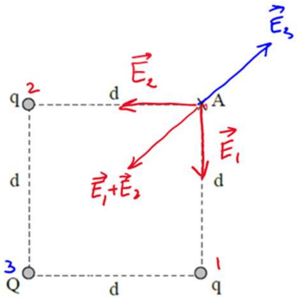
$1+2+3 = q + 0.5q + 1.5q$

$6 = 3q \Rightarrow q = 2\,C$

Q3 M2-112-04

Three point charges are located at the corners of a square as shown in Figure 2. Find the value of Q if the electric field at the corner A is zero. Take q = – 7.00 µC

A) 19.8 µC
B) 14.0 µC
C) 9.90 µC
D) 4.95 µC
E) 2.54 µC



$E_3 = \frac{k|Q|}{r^2} = \sqrt{E_1^2+E_2^2} = \sqrt{\left(\frac{k|q|}{d^2}\right)^2+\left(\frac{k|q|}{d^2}\right)^2} = \sqrt{2}\,\frac{k|q|}{d^2}$

d^2+d^2

$\frac{k|Q|}{2d^2} = \sqrt{2}\,\frac{k|q|}{d^2} \Rightarrow |Q| = 2\sqrt{2}\,|q| = 19.8\,\mu C$

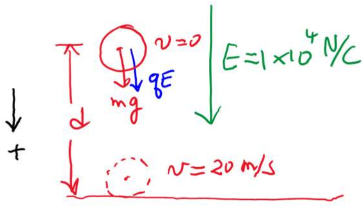
Since $\vec{E}_3$ point away from Q, Q must be a positive charge

$Q = +19.8\,\mu C$

Q4 **M2-122-02**

A positively charged sphere of mass 1.00 g falls from rest from a height of 5.00 m, in a uniform electric field of magnitude 1.00×10^4 N/C and is directed vertically downward. The sphere hits the ground with a speed of 20.0 m/s. What is the charge on the sphere?

A) + 3.02 μC
B) − 1.00 μC
C) + 5.23 μC
D) − 5.23 μC
E) + 1.00 μC



$v^2 = v_0^2 + 2a\Delta y$

$v^2 = 2\left(\frac{F}{m}\right)d = 2\left(\frac{mg+qE}{m}\right)d$

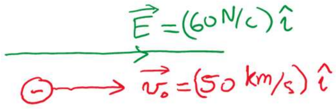
$q = \left(\frac{v^2}{2d} - g\right)\frac{m}{E} = \left(\frac{20^2}{2(5)} - 9.8\right)\frac{1\times10^{-3}}{1\times10^{4}}$

$q = 3.02\,\mu C$

Q5 **M2-132-04**

An electron enters a region of uniform electric field $\vec{E} = (60\,\hat{\imath})$ N/C with a velocity $\vec{v}_i = (50\,\hat{\imath})$ km/s. How far does the electron travel in the first 2.0×10^{-9} s time interval after entering the field?

A) 7.9×10^{-5} m
B) 1.1×10^{-5} m
C) 2.7×10^{-4} m
D) 1.3×10^{-6} m
E) 4.2×10^{-5} m



$\vec{a} = \frac{\vec{F}}{m} = \frac{q\vec{E}}{m}$ ($-e$)

$x = v_0 t + \frac{1}{2}at^2$

$x = v_0 t + \frac{1}{2}\left(\frac{-eE}{m}\right)t^2$

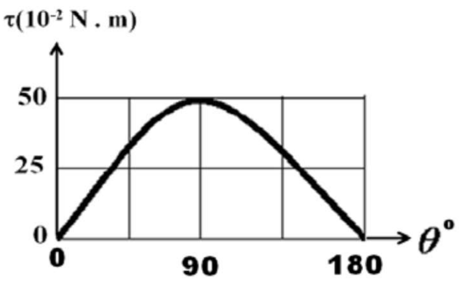
$x = (50\times10^3)(2\times10^{-9}) - \frac{1}{2}\frac{(1.60\times10^{-19})(60)}{9.11\times10^{-31}}(2\times10^{-9})^2$

$x = 7.9\times10^{-5}$ m

Q6 **M2-132-05**

A certain electric dipole is placed in a uniform electric field $\vec{E}$ of magnitude 10 N/C. The magnitude of torque on the dipole plotted as a function of the angle between $\vec{E}$ and the dipole moment $\vec{p}$ is shown in the figure. How much work is needed by an external agent to turn the electric dipole from 30^0 to 60^0 with respect to $\vec{E}$ field?

A) $+1.83\times10^{-1}$ J
B) -1.83×10^{-1} J
C) $+2.66\times10^{-1}$ J
D) -2.66×10^{-1} J
E) $+9.20\times10^{-2}$ J



$W_a = \Delta U = U_f - U_i$

$= -pE\cos\theta_f - (-pE\cos\theta_i)$

$= pE(\cos\theta_i - \cos\theta_f)$

$\tau = pE\sin\theta$

at $\theta = 90^\circ$ $\tau = pE = 50\times10^{-2}$ N.m (from the figure)

$\Rightarrow W_a = 50\times10^{-2}(\cos 30^\circ - \cos 60^\circ)$

$W_a = 0.18\text{ J} = +1.8\times10^{-1}$ J