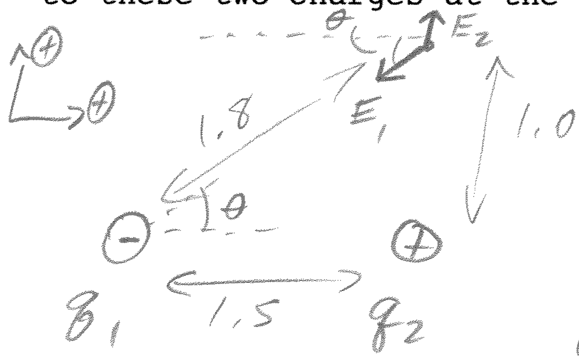
Physics 10164 - Exam 1A

Partial credit will be given provided you show all work and are solving parts of the problem correctly. Points will be deducted if you don't show your work even if you get the right answer. Clearly indicate your answer with a circle or a box and remember to include correct units and significant figures.

1. (30 pts) A -32 nC charge is located at the origin. A +22 nC charge is located at the coordinate x = 1.5 meters.

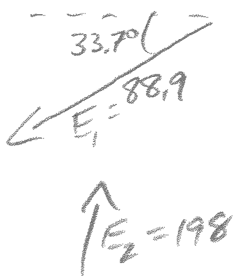
Determine the magnitude and direction of the electric field due to these two charges at the coordinate (x,y) = (1.5,1.0).



$$|\vec{E}_1| = \left|\frac{kq_1}{r_1^2}\right| \qquad \theta = \tan^{-1}\left(\frac{1}{1.5}\right) = 33.7^\circ$$

$$= \frac{(9\times10^9)(32\times10^{-9})}{1.8^2} = 88.9\ \text{V/m}$$

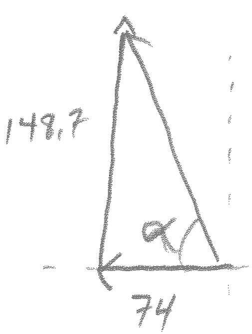
$$|\vec{E}_2| = \frac{(9\times10^9)(22\times10^{-9})}{1^2} = 198\ \text{V/m}$$



$$E_{1x} = -88.9\cos 33.7^\circ = -74.0 \qquad E_{1y} = -88.9\sin 33.7^\circ = -49.3$$

$$E_{2x} = 0 \qquad E_{2y} = 198$$

$$E_{TOT,x} = -74 \qquad E_{TOT,y} = 148.7$$



$$|E_{TOT}| = \sqrt{74^2 + 148.7^2} = \boxed{170\ \text{V/m}}$$

$$\theta = \tan^{-1}\left(\frac{148.7}{74}\right) = \boxed{64^\circ \text{ above } -x}$$

2. (40 pts) A 120 gram mass with a charge of 35 μC is fired directly upward from ground level with an initial speed of 53 m/s. This charge is affected by Earth's usual uniform gravitational field (9.8 m/s², down) as well as a uniform electric field. Assume only the electric and gravitational forces are significant in this problem.

a) If the mass reaches a maximum height of 59 meters above the ground, what is the magnitude and direction of the electric field?

b) If the voltage at ground level is zero, what is the voltage at the maximum height reached by the mass?

a) $\Delta y = 59\,m$

$V_0 = 53\,m/s$

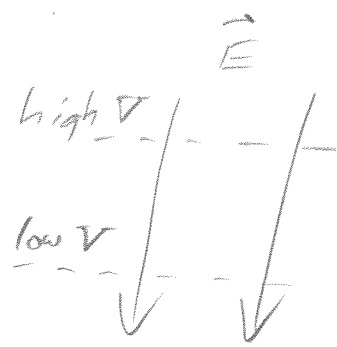
$V = 0$ (at max height)

$v^2 = V_0^2 + 2a\Delta s$

$0^2 = (53)^2 + 2a(59)$

$a = -23.8\,m/s^2$

Since $a > 9.8\,m/s^2$ down, F_E must point down.
Since q is positive, $\vec{E}$ points down.



$\Sigma \vec{F} = -mg - qE = ma$

$-(.120)(9.8) - (35\times10^{-6})E = (.120)(-23.8)$

$-1.176 - (35\times10^{-6})E = -2.856$

$E = \dfrac{-1.68}{-35\times10^{-6}} = \boxed{48{,}000\ V/m,\ down}$

Alt $\Sigma W_F = W_g + W_E = \Delta K$

$W_g = -mg\Delta s = -(.120)(9.8)(59)$
$= -69.384$

$W_E = -qE\Delta s = -(35\times10^{-6})E(59)$
$= -.002065E$

$\Delta K = \frac{1}{2}mv^2 - \frac{1}{2}mv_0^2 = 0 - \frac{1}{2}(.12)(53)^2$
$= -168.54$

$\Rightarrow -69.384 - .002065E = -168.54$

$E = \dfrac{-99.156}{-.002065} = \boxed{48{,}000\ \frac{V}{m},\ down}$

b) Since E points down, V_F is higher than V_i

$V_F - V_i = E \cdot \Delta s$

$V_F = (48{,}000)(59)$

$= \boxed{2.8\times10^6\ Volts}$

#3. (30 pts) A copper wire has a resistivity of 1.7 x 10^{-8} Ohm-meters and a power loss of 3.5 Watts/meter when it carries a 250 Amp current.

a) Assuming the wire operates at a standard temperature of 20°C, what is the diameter of the wire?

b) If energy costs 12 cents per kilowatt-hour, how much does this power loss cost per day for a 5.0 km cable?

a) $P = I^2 R$ Assume $\ell = 1$ meter, so P lost is 3.5 Watts

$3.5 = (250)^2 R$

$R = 5.6 \times 10^{-5}\,\Omega = \rho \frac{\ell}{A}$

$5.6 \times 10^{-5} = \frac{(1.7 \times 10^{-8})(1)}{\text{Area}}$

$\text{Area} = 3.036 \times 10^{-4}\,m^2 = \pi r^2$

$r^2 = 9.66 \times 10^{-5}$

$r = 9.83\,mm \quad d = 2r \approx 20\,mm$

b) $P = \frac{3.5\ \text{Watts}}{\text{meter}} * 5000\,m = 17500\ \text{Watts}$

$E = \left(\frac{17500\ J}{sec}\right)\left(\frac{1\ day}{1}\right)\left(\frac{86400\ sec}{day}\right) = 1.51 \times 10^9\ J$

$\text{Cost} = 1.51 \times 10^9\ J \cdot \frac{1\ kWhr}{3.6 \times 10^6\ J} \cdot \frac{12\ cents}{kW \cdot hr} = 5040\ cents$

$\approx \$50$