# Week 6, Session 2 Solutions

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## 1 Coulomb's Law

### 1.1 Charges in a Bowl

(a) If the charges are separated by some angle $\theta$, then the physical distance separating them is

$$d = 2Rsin\left(\frac{\theta}{2}\right) \tag{1}$$

From Newton's second law, we garner

$$\begin{aligned} Ncos\frac{\theta}{2} &= mg \\ Nsin\frac{\theta}{2} &= \frac{1}{4\pi\epsilon_0}\frac{Q^2}{d^2} \\ &= \frac{1}{4\pi\epsilon_0}\frac{Q^2}{4R^2sin^2\frac{\theta}{2}} \end{aligned}$$

From the first equation, $N = \frac{mg}{cos\frac{\theta}{2}}$. From the second,

### 1.2 Oh Charge, Where Art Thou?

Two point charges are located on the $x$ axis. They are both positive, bu the one located at $x = 0$ has a charge of $q$ while the one located at $x = L$ has a charge of $4q$. If a third charge is placed on the $x$ axis in between the two charges so that the net force on ANY of the charges is zero, determine the magnitude of the third charge and its location.

(*Source: physics-prep.com*)

### 1.3 Return of the Spring

A spring with spring constant $k_s$ and rest length $L$ has positive charges $Q$ attached to either end.

(a) Find an equation that will determine the length $D$ of the spring, once the charges have come to rest.

(b) Repeat part (a), this time assuming that the charges on either end are both *negative*.

(c) Repeat again, this time assuming that the charges on either end have *opposite* signs.

(*Source: workbook* )

## 1.4 A Balancing Act

A charge $q$ hangs on the end of a string while another charge $-Q$ of mass $m$ is brought beneath it.

(a) At what distance $d$ below the hanging mass is the charge $-Q$ in equilibrium?

(b) Is this equilibrium stable? If so, find the frequency of small oscillations about it.

## 1.5 Dipoles

(Challenge) Find the electric field due to a dipole located at the origin both along its axis and in the plane perpendicular to its axis. (Hint: find the field from two point charges with charge $q$ located at $y = d/2$ and charge $-q$ located at $y = -d/2$ and then take the limit as $d$ goes to zero.)