Name: ____ Section: ____

Tuesday, September 29

Quiz 5A

A uniformly charged non-conducting sphere with radius *R* produces a potential of $V_0 > 0$ on the surface. Assume that the potential is zero at infinite distance from the sphere.

a. What is the total charge in the sphere?

$$V_0 = k\frac{q}{R} \qquad \Rightarrow \qquad \boxed{q = \frac{V_0 R}{k}}$$

(Note that we can only use this expression because of the spherical symmetry of the system)

b. "The potential is the same at any two points in the sphere." True or false? Explain.

<u>False</u>. This would be true for a conducting sphere (and in that cse the charge would be on the surface and not uniformly distributed throughout the volume).

c. A negatively charged point mass *m* is right outside the sphere and has a speed v_0. What is the minimum value of v_0 so the point charge can escape the attraction of the sphere?

Energy conservation:

$$E_i = -k\frac{qQ}{R} + \frac{1}{2}mv_0^2 \quad \text{where } Q \text{ is the charge of the point mass}$$

$$E_f = 0 + 0 \qquad \text{(minimum: } v=0 \text{ at infinity)}$$

Thus,

$$v_0 = \sqrt{\frac{2kqQ}{mR}} = \sqrt{\frac{2kQV_0R}{mRk}} = \boxed{\sqrt{\frac{2V_0Q}{m}}}$$

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Quiz 5B

A uniformly charged, non-conducting, thin spherical shell with radius R produces a potential of $V_0 > 0$ on the surface. Assume that the potential is zero at infinite distance from the shell.

a. What is the total charge in the shell?

$$V_0 = k\frac{q}{R} \qquad \Rightarrow \qquad \boxed{q = \frac{V_0 R}{k}}$$

(Note that we can only use this expression because of the spherical symmetry of the system)

b. "The potential at the center of the shell is zero." True or false? Explain.

<u>*False.*</u> *The electric field inside the shell is zero due to symmetry, so at the center the potential is the same as on the inner surface of the shell (and because this is a thin shell, this is roughly equal to* V_0*, the potential on the outer surface).*

d. A negatively charged point mass m is right outside the shell and has a speed v_0. What is the minimum value of v_0 so the point charge can escape the attraction of the shell?

Energy conservation:

$$E_i = -k\frac{qQ}{R} + \frac{1}{2}mv_0^2 \quad \text{where } Q \text{ is the charge of the point mass}$$

$$E_f = 0 + 0 \qquad \text{(minimum: } v=0 \text{ at infinity)}$$

Thus,

$$v_0 = \sqrt{\frac{2kqQ}{mR}} = \sqrt{\frac{2kQV_0R}{mRk}} = \boxed{\sqrt{\frac{2V_0Q}{m}}}$$

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Quiz 5C

A non-conducting sphere with radius R has a concentric spherical cavity with radius $R/2$. A charge $Q > 0$ is uniformly distributed throughout the object. Assume the potential is zero at infinite distance from the sphere.

a. Find the potential on the outer surface of the sphere.

$$\boxed{V_0 = k\frac{q}{R}}$$

(Note that we can only use this expression because of the spherical symmetry of the system)

b. "The potential difference between the inner and outer surfaces of this object is zero." True or false? Explain.

<u>False</u>. This would be true for a conductor. Inside the object in this quiz, E is NOT zero.

e. A point charge $-Q$ with mass m is right outside the shell and has a speed v_0. What is the minimum value of v_0 so the point charge can escape the attraction of the shell?.

Energy conservation:

$$E_i = -k\frac{Q^2}{R} + \frac{1}{2}mv_0^2$$

$$E_f = 0 + 0 \qquad \textit{(minimum: v=0 at infinity)}$$

Thus,

$$\boxed{v_0 = \sqrt{\frac{2kQ^2}{mR}}}$$

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Quiz 5D

Consider a thin, isolated, conducting spherical shell with radius R and charge Q. A non-conducting sphere of radius $R/2$ and uniformly distributed charge Q is concentric with the shell. Assume that the potential is zero at infinity.

a. Find the potential on the inner surface of the shell

$V_{inner} = V_{outer}$ because it's a conductor and $V_{outer} = k\dfrac{2Q}{R}$ because of the spherical symmetry (it's equivalent to having all the charge at the center). Thus

$$\boxed{V_{inner} = k\frac{2Q}{R}}$$

b. Find the potential difference between the shell and the surface of the non-conducting sphere.

Between the sphere and the shell, $E = k\dfrac{Q}{r^2}$. Therefore,

$$V\left(\frac{R}{2}\right) - V(R) = -\int_R^{R/2} k\frac{Q}{r^2}\,dr = kQ\left(\frac{2}{R} - \frac{1}{R}\right) = \boxed{\frac{kQ}{R}}$$

c. Now a point charge Q is brought to a point located at distance $2R$ from the center of the shell. Once the system has achieved equilibrium, is the surface of the conducting shell an equipotential surface? Explain.

Yes. The surface of a conductor in equilibrium is always an equipotential.