[Note: Only the first five problems will be discussed in tutorial classes. You should attempt the remaining problems and in case you get stuck, ask your tutorial instructor]

1. **[G 2.34]** Consider two concentric spherical shells, of radii a and b. Suppose the inner one carries a charge q, and the outer one a charge $-q$ (both of them uniformly distributed over the surface). Calculate the energy of this configuration, (a) using $W = \frac{\epsilon_0}{2}\int E^2 d\tau$, and (b) using $W_{tot} = W_1 + W_2 + \epsilon_0 \int \mathbf{E}_1 \cdot \mathbf{E}_2 d\tau$.

2. **[G 2.45]** A sphere of radius R carries a charge density $\rho(r) = kr$ (where k is a constant). Find the energy of the configuration. Check your answer by calculating it in at least two different ways.

3. **[G 2.36]** Two spherical cavities, of radii a and b, are hollowed out from the interior of a (neutral) conducting sphere of radius R (Fig.). At the center of each cavity a point charge is placed - call these charges q_a and q_b.

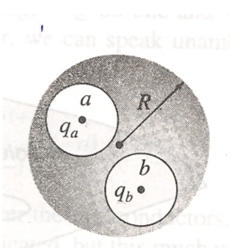
   (a) Find the surface charges σ_a, σ_b, and σ_R.
   (b) What is the field outside the conductor?
   (c) What is the field within each cavity?
   (d) What is the force on $q_a$and q_b?
   (e) Which of these answers would change if a third charge, q_c, were brought near the conductor?

4. **[G 2.43]** Find the net force that the southern hemisphere of a uniformly charged sphere exerts on the northern hemisphere. Express your answer in terms of the radius R and the total charge Q.

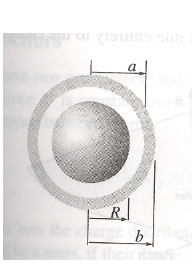
5. Let $q_1\,(>0)$ and $-q_2$, (where $q_2 > 0$) be two charges located at $(d, 0, 0)$ and $(-d, 0, 0)$ respectively. Show that the zero potential surface is spherical with center on x axis. If center of the surface is at $(c, 0, 0)$ and radius is R, find c/d and R/d in terms of q_1/q_2. Sketch surfaces for $q_1/q_2 = \frac{1}{4}, \frac{1}{3}, \frac{1}{2}, 1, 2\,3\,4$.

6. **[G 2.35]** A metal sphere of radius R, carrying charge q, is surrounded by a thick concentric metal shell (inner radius a, outer radius b, as shown in Fig.). The shell carries no net charge.

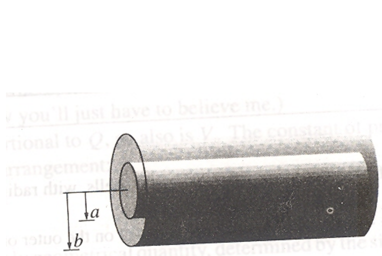
   (a) Find the surface charge density σ at R, at a, and at b.
   (b) Find the potential at the center, using infinity as the reference point.
   (c) Now the outer surface is touched to a grounding wire, which lowers its potential to zero (same as at infinity). How do your answers to (a) and (b) change?



(a) Problem 3



(b) Problem 6



(c) Problem 7

7. **[G 2.39]** Find the capacitance per unit length of two coaxial metal cylindrical tubes, of radii a and b (Fig.).

8. **[G 2.42]** If the electric field in some region is given (in spherical coordinates) by the expression
   $\mathbf{E}\,(\mathbf{r}) = \frac{A\hat{\mathbf{r}} + B\sin\theta\cos\phi\hat{\phi}}{r}$,
   where A and B are constants, what is the charge density?

9. A charge distribution on the surface of a sphere of radius R, is given by

$$\sigma(\theta, \phi) = \sigma_0 \sin\theta \sin\phi$$

Find the electric field and the potential on the z axis.

10. Use Gauss's law to find electric field at any point due to the charge distribution

    (a) $\rho = \frac{\rho_0 a}{r}$ if $r < a$ and is zero otherwise;
    (b) $\rho = \rho_0(1 - r^2/a^2)$ if $r < a$ and is zero otherwise.