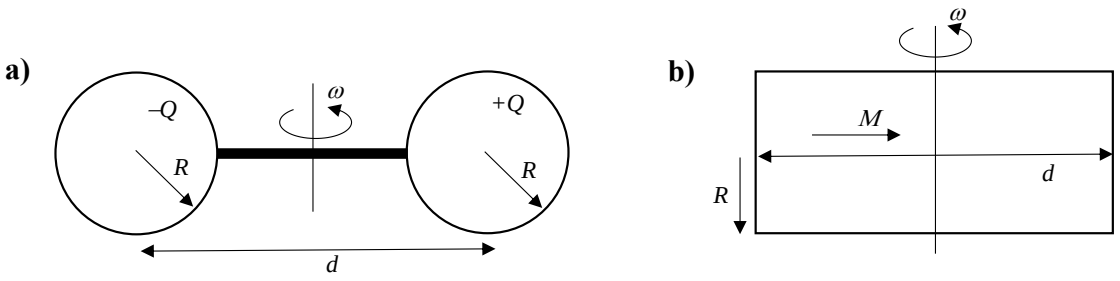
2. **Mechanical Radio Station**

It is difficult and very inefficient to broadcast radio waves at very low frequencies. One of the recent ideas is to use a mechanically rotated electric or magnetic dipole, as illustrated in the figure below.



a) Consider a dumbbell consisting of two conductive spheres of radius R separated by a distance d. They have opposite electric charges $+Q$ and $-Q$. The spheres are mechanically connected by a thin insulating rod. You can assume $d >> R$ and ignore the mutual capacitance and the image charges on the spheres. Calculate the total power radiated by the dumbbell when it is rotated around the vertical axis passing through its center at a frequency ω.

b) Consider a permanent magnet in the shape of a cylinder of radius R and length d. The cylinder is uniformly magnetized parallel to its axis with magnetization M. Calculate the total power radiated by the permanent magnet when it is rotated around the vertical axis passing through its center at a frequency ω.

c) Assume the spheres are charged so the voltages on the spheres are $V = \pm 10$ kV relative to infinity. The permanent magnet is magnetized so the magnetic field at its center is equal to 1 T (assuming $d \gg R$). The radius R is both cases is equal to 0.1 m and the distance $d = 1$ m. The frequency of rotation is 10 kHz. Roughly estimate the power radiated by each source. Which of the sources will radiate more power?