You take a flexible insulating rod of length 30 cm and put a uniform charge of 1.0 µC on it. Then you bend it into a circle. Find the magnitude and direction of the electric field at a point 20 cm directly above the center of the circle perpendicular to its plane.

**Solution.** For radius $R$ and distance from the plane of the circle $x$, define $r = \sqrt{x^2 + R^2}$. The angle from the axis to the ring subtended at the point of interest will be $\phi$. Then the differential electric field is $kdq/r^2$. The y-components cancel, so

$$E_x = \int_{\text{ring}} k \frac{dq}{r^2} \cos \phi = \int_{0}^{2\pi R} k \lambda dl \frac{x}{r^3} = k \lambda \frac{x}{r^3} \int_{0}^{2\pi R} dl = kq \frac{x}{r^3} \frac{1}{(x^2 + R^2)^{3/2}}$$

This results in the value $E_x = 9.62 \times 10^4 \text{ V/m}$.