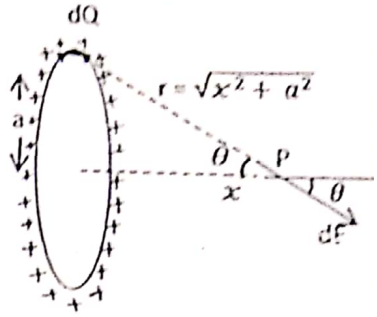
Q3. a) Derive an expression for electric field intensity at any point on axis of uniformly charged ring.
b) When does charged circular ring behave as point charge?

Ans. a) Consider a circular ring of radius a. charge on ring is Q.
Let there be a point P at distance x from centre of ring.



Step1: Field at P due to small charge dQ. (Shown at top of ring).

$$dE = \frac{dQ}{4\pi\epsilon_0 r^2}$$

Step2: Horizontal component of dE will add up.

i.e $E_x = \int dE.\cos\theta.$

$$= \int \frac{dQ}{4\pi\epsilon_0 r^2} \cdot \frac{x}{r}$$

$$= \frac{1}{4\pi\epsilon_0} \cdot \frac{x}{r^3} \int dQ$$

$$\boxed{E_x = \frac{1}{4\pi\epsilon_0} \cdot \frac{x}{r^3} \cdot Q}$$

$$E_x = \frac{Q}{4\pi\epsilon_0} \cdot \frac{x}{r^3}$$

$$\boxed{E_x = \frac{Q}{4\pi\epsilon_0} \cdot \frac{x}{(x^2+a^2)^{3/2}}}$$

Discussion.

1. If P is at centre, x =0

$$E_x = \frac{Q}{4\pi\epsilon_0} \cdot \frac{0}{r^3} = 0 \qquad \boxed{E_x = 0} \text{ at centre.}$$

b) When point P is far away from origin (x>>a).

$$E_x \simeq \frac{Q}{4\pi\epsilon_0} \cdot \frac{x}{(x^2)^{3/2}}$$

$$= \frac{Q}{4\pi\epsilon_0} \cdot \frac{x}{x^3}.$$

$$\boxed{E_x = \frac{Q}{4\pi\epsilon_0} \cdot \frac{1}{x^2}}$$

t is same as that of Electric field due to "point charge."
so, When point P is far away from origin, ring behaves as a point charge.

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