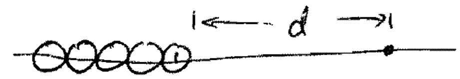
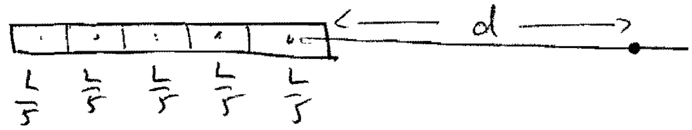
(1)



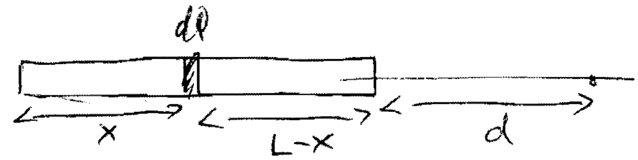
$$E = \frac{1}{4\pi\epsilon_0}\left[\frac{q}{(d+R)^2} + \frac{q}{(d+3R)^2} + \frac{q}{(d+5R)^2} + \frac{q}{(d+7R)^2} + \frac{q}{(d+9R)^2}\right]$$

(2)



$$E = \frac{1}{4\pi\epsilon_0}\left[\frac{Q/5}{(d+L/10)^2} + \frac{Q/5}{(d+3L/10)^2} + \frac{Q/5}{(d+5L/10)^2} + \frac{Q/5}{(d+7L/10)^2} + \frac{Q/5}{(d+9L/10)^2}\right]$$

(3)



(a) $dQ = \frac{Q}{L}\,dx$

(b) $E_y = E_z = 0 \qquad E_x \neq 0$

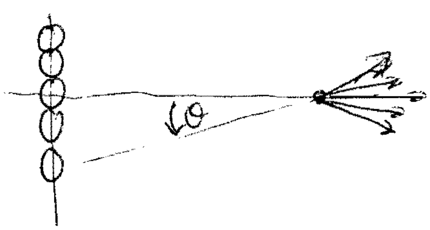
(c) $dE_x = \frac{1}{4\pi\epsilon_0}\frac{dQ}{(d+L-x)^2}$

(d) Integrate over x from $x=0$ to $x=L$

(e) $$E_x = \int_0^L \frac{1}{4\pi\epsilon_0}\frac{Q/L\,dx}{(d+L-x)^2} = \frac{1}{4\pi\epsilon_0}\frac{Q}{L}\int_0^L \frac{dx}{(d+L-x)^2}$$
$$= \frac{1}{4\pi\epsilon_0}\frac{Q}{L}\left.\frac{1}{d+L-x}\right|_0^L = \frac{1}{4\pi\epsilon_0}\frac{Q}{L}\left(\frac{1}{d} - \frac{1}{d+L}\right)$$
$$= \frac{1}{4\pi\epsilon_0}\frac{Q}{d(d+L)}$$

(f) $E_x \approx \frac{1}{4\pi\epsilon_0}\frac{Q}{d^2}$ (like point charge)

(4)



$$E = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2} \qquad E_x = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\cos\theta$$

Total: $$E_x = \frac{1}{4\pi\epsilon_0}\left[\frac{q}{d^2} + 2\frac{q}{d^2+4R^2}\frac{d}{\sqrt{d^2+4R^2}} + 2\frac{q}{d^2+16R^2}\frac{d}{\sqrt{d^2+16R^2}}\right]$$

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$$E_x = \frac{1}{4\pi\epsilon_0}\left[\frac{Q/5}{d^2} + 2\frac{Q/5}{[d^2+(L/5)^2]}\frac{d}{\sqrt{d^2+(L/5)^2}} + 2\frac{Q/5}{d^2+(2L/5)^2}\frac{d}{\sqrt{d^2+(2L/5)^2}}\right]$$

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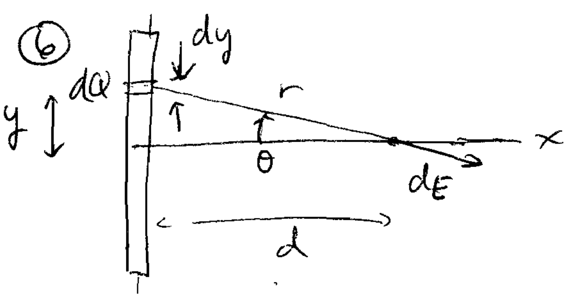

(a) $dQ = \frac{Q}{L}dy$

(b) $E_y = E_z = 0 \qquad E_x \neq 0$

(c) $$dE_x = \frac{1}{4\pi\epsilon_0}\frac{dQ}{r^2}\cos\theta = \frac{1}{4\pi\epsilon_0}\frac{Q}{L}\frac{dy}{d^2+y^2}\frac{d}{\sqrt{d^2+y^2}}$$

(d) Integrate y from $y = -L/2$ to $y = +L/2$

(e) $$E_x = \frac{1}{4\pi\epsilon_0}\frac{Q}{L}d\int_{-L/2}^{L/2}\frac{1}{(d^2+y^2)^{3/2}}dy = \frac{1}{4\pi\epsilon_0}\frac{Qd}{L}\left.\frac{y}{d^2\sqrt{d^2+y^2}}\right|_{-L/2}^{+L/2}$$

$$= \frac{1}{4\pi\epsilon_0}\frac{Q}{d\sqrt{d^2+L^2/4}}$$

(f) $E_x \approx \frac{1}{4\pi\epsilon_0}\frac{Q}{d^2}$ (like point charge)

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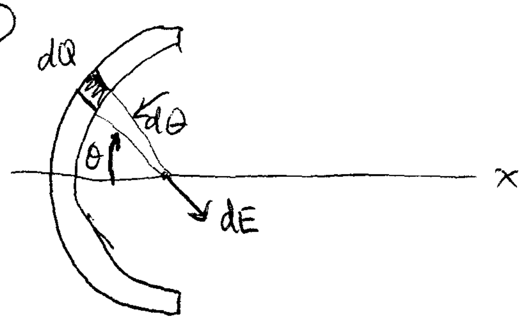

(a) θ is variable

arc length $ds = R\,d\theta$ $\qquad dQ = \frac{Q}{\pi R} R\,d\theta = \frac{Q}{\pi} d\theta$

(b) $E_y = E_z = 0 \qquad E_x \neq 0$

(c) $dE = \frac{1}{4\pi\epsilon_0} \frac{dQ}{R^2} = \frac{1}{4\pi\epsilon_0} \frac{Q}{\pi R^2} d\theta$

$dE_x = dE \cos\theta = \frac{1}{4\pi\epsilon_0} \frac{Q}{\pi R^2} \cos\theta \, d\theta$

(d) Integrate over θ from $-\pi/2$ to $+\pi/2$

(e) $E_x = \frac{1}{4\pi\epsilon_0} \frac{Q}{\pi R^2} \int_{-\pi/2}^{\pi/2} \cos\theta \, d\theta$

$= \frac{1}{4\pi\epsilon_0} \frac{Q}{\pi R^2} \sin\theta \Big|_{-\pi/2}^{\pi/2} = \frac{1}{2\pi^2\epsilon_0} \frac{Q}{R^2}$