Physics-2: Electricity & Magnetism

Electric Potential-Cont.
Potential Due to Continuous Charge Distribution
Problems and Solutions

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Problems

Section 25.2-Q.5)

A uniform electric field of magnitude 325 V/m is directed in the negative *y* direction in Figure P25.5. The coordinates of point A are (-0.2,-0.3) m and those of point B are (0.4, 0.5) m. Calculate the electric potential difference V_B-V_A using the dashed line path.

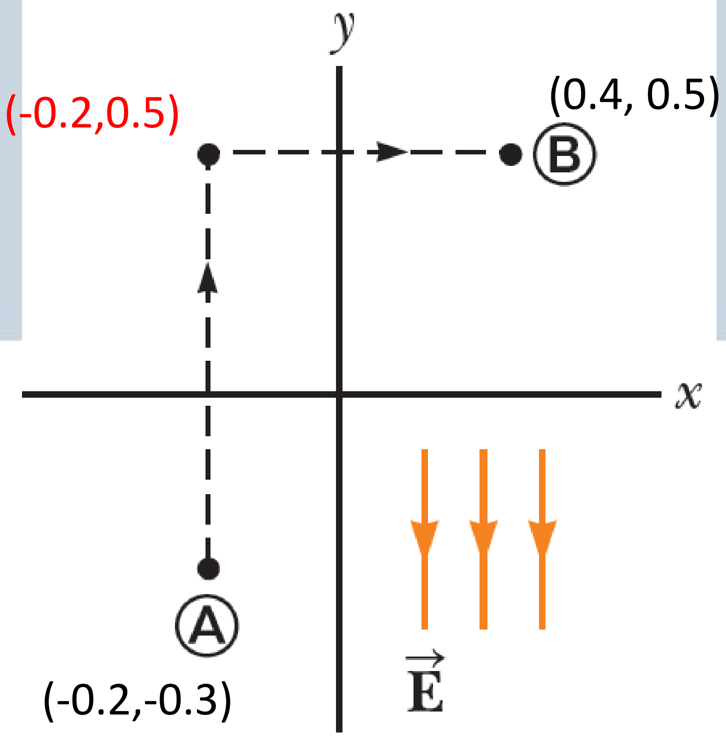
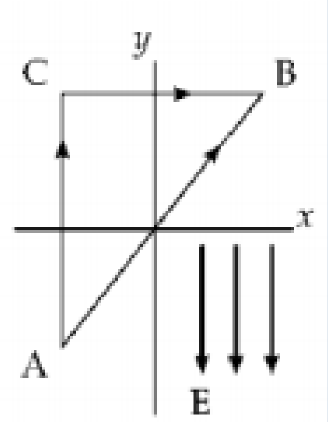


Figure P25.5

$$V_B - V_A = -\int_A^B E * ds = -\int_A^C E * ds - \int_C^B E * ds$$



$$V_B - V_A = (-E\cos 180°)\int_{-0.300}^{0.500} dy - (E\cos 90.0°)\int_{-0.200}^{0.400} dx$$

$$V_B - V_A = (325)(0.800) = +260V$$

Section 25.2-Q.13)

An insulating rod having linear charge density λ = 40.0 μC/m and linear mass density μ =0.100 kg/m is released from rest in a uniform electric field E = 100 V/m directed perpendicular to the rod (Fig. P25.13). Determine the speed of the rod after it has traveled 2.00 m.

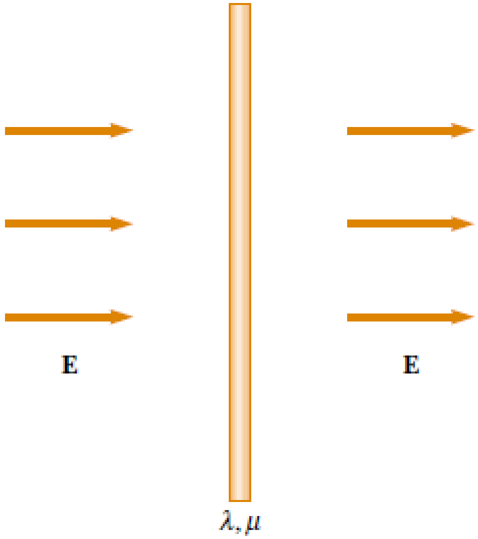


Figure P25.13

$$V = -Ed$$

$$U_e = QV = -\lambda l E d$$

$$(K+U)_i = (K+U)_f$$

$m=\mu L$ $\quad$ d=2.00 m

$$0+0 = \frac{1}{2}\mu L v^2 - \lambda L E d$$

$$v = \sqrt{\frac{2\lambda E d}{\mu}} = \sqrt{\frac{2(40.0\times10^{-6}\ \text{C/m})(100\ \text{N/C})(2.00\ \text{m})}{(0.100\ \text{kg/m})}} = \boxed{0.400\ \text{m/s}}$$

19. Given two particles with 2.00 μC charges, as shown in Figure P25.16, and a positive test charge $q = 1.28 \times 10^{-18}$ C at the origin, **(a)** what is the net force exerted by the two 2.00 μC charges on the test charge *q*? **(b)** What is the electric field at the origin due to the two 2.00 μC charges? **(c)** What is the electric potential at the origin due to the two 2.00 μC.

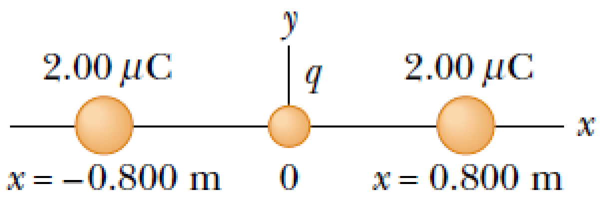


Figure P25.16

(a) Since the charges are equal and placed symmetrically, $\boxed{F = 0}$.

(b) Since $F = qE = 0$, $\boxed{E = 0}$.

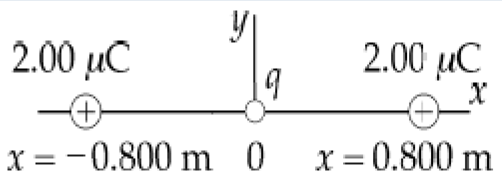


FIG. P25.16

(c) $$V = 2k_e \frac{q}{r} = 2\left(8.99 \times 10^9 \ \text{N} \cdot \text{m}^2/\text{C}^2\right)\left(\frac{2.00 \times 10^{-6} \ \text{C}}{0.800 \ \text{m}}\right)$$

$$V = 4.50 \times 10^4 \ \text{V} = \boxed{45.0 \ \text{kV}}$$

electric potential at the origin

Section 25.4-Q.37)

The potential in a region between $x = 0$ and $x = 6.00$ m is $V = a + bx$, where $a = 10.0$ V and $b = -7.00$ V/m. Determine (a) the potential at $x = 0$, 3.00 m, and 6.00 m, and (b) the magnitude and direction of the electric field at $x = 0$, 3.00 m, and 6.00 m.

$$V = a + bx = 10.0\text{ V} + (-7.00\text{ V/m})x$$

(a) At $x = 0$, $V = \boxed{10.0\text{ V}}$

At $x = 3.00$ m, $V = \boxed{-11.0\text{ V}}$

At $x = 6.00$ m, $V = \boxed{-32.0\text{ V}}$

(b) $$E = -\frac{dV}{dx} = -b = -(-7.00\text{ V/m}) = \boxed{7.00\text{ N/C in the } +x \text{ direction}}$$

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Section 25.5-Q.47)

A wire having a uniform linear charge density λ is bent into the shape shown in Figure P25.47. Find the electric potential at point *O.*

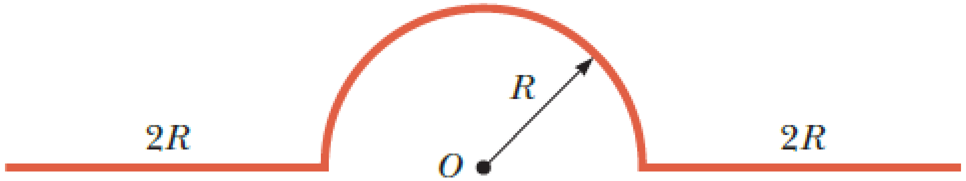

Figure P25.47

P25.47

$$V = k_e \int_{\text{all charge}} \frac{dq}{r} = k_e \int_{-3R}^{-R} \frac{\lambda dx}{-x} + k_e \int_{\text{semicircle}} \frac{\lambda ds}{R} + k_e \int_{R}^{3R} \frac{\lambda dx}{x}$$

$$V = -k_e \lambda \ln(-x)\Big|_{-3R}^{-R} + \frac{k_e \lambda}{R} \pi R + k_e \lambda \ln x \Big|_{R}^{3R}$$

$$V = k_e \lambda \ln \frac{3R}{R} + k_e \lambda \pi + k_e \lambda \ln \frac{3R}{R} = \boxed{k_e \lambda (\pi + 2 \ln 3)}$$

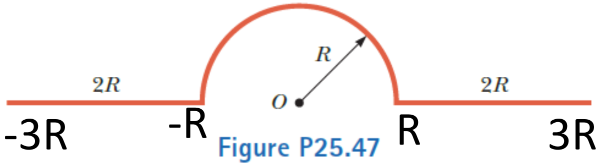

Figure P25.47

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Section 25.6-Q.50)

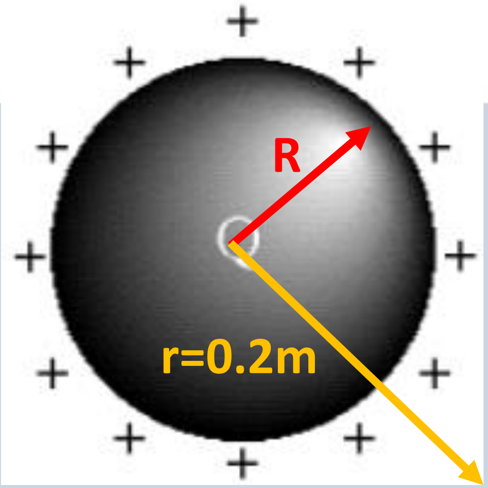
A spherical conductor has a radius of 14.0 cm and charge of 26.0 μC. Calculate the electric field and the electric potential (a) r = 10.0 cm, (b) r = 20.0 cm, and (c) r = 14.0 cm from the center.

(a) $E = \boxed{0}\ ;$

$$V = \frac{k_e q}{R} = \frac{(8.99\times10^{9})(26.0\times10^{-6})}{0.140} = \boxed{1.67\text{ MV}}$$

(b) $$E = \frac{k_e q}{r^2} = \frac{(8.99\times10^{9})(26.0\times10^{-6})}{(0.200)^2} = \boxed{5.84\text{ MN/C}}\ \text{away}$$

$$V = \frac{k_e q}{R} = \frac{(8.99\times10^{9})(26.0\times10^{-6})}{0.200} = \boxed{1.17\text{ MV}}$$



(c) $$E = \frac{k_e q}{R^2} = \frac{(8.99\times10^{9})(26.0\times10^{-6})}{(0.140)^2} = \boxed{11.9\text{ MN/C}}\ \text{away}$$

$$V = \frac{k_e q}{R} = \boxed{1.67\text{ MV}}$$

Section 25.8-Q.75)

(a) A uniformly charged cylindrical shell has total charge *Q*, radius *R*, and height *h*. Determine the electric potential at a point a distance *d* from the right end of the cylinder, as shown in Figure P25.75. (*Suggestion:* use the result of Example 25.5 by treating the cylinder as a collection of ring charges.) **(b) What If?** Use the result of Example 25.6 to solve the same problem for a solid cylinder.

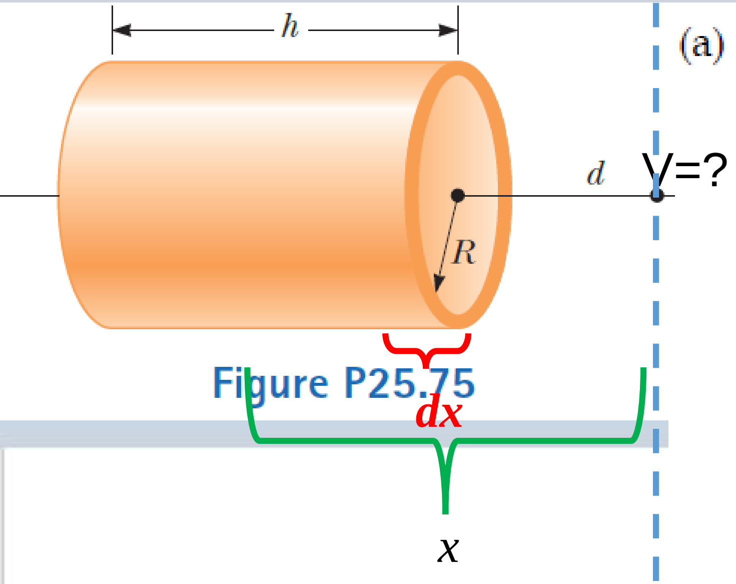


Figure P25.75

(a) Take the origin at the point where we will find the potential. One ring, of width dx, has charge $\frac{Q}{h}dx$ and, according to Example 25.5, creates potential

$$dV = \frac{k_e Q dx}{h\sqrt{x^2+R^2}}.$$

The whole stack of rings creates potential

$$V = \int_{\text{all charge}} dV = \int_d^{d+h} \frac{k_e Q dx}{h\sqrt{x^2+R^2}} = \frac{k_e Q}{h}\ln\left(x+\sqrt{x^2+R^2}\right)\Big|_d^{d+h} = \boxed{\frac{k_e Q}{h}\ln\left(\frac{d+h+\sqrt{(d+h)^2+R^2}}{d+\sqrt{d^2+R^2}}\right)}.$$

$$\int \frac{dx}{\sqrt{x^2+a^2}} = \ln\left(x+\sqrt{x^2+a^2}\right) + C$$

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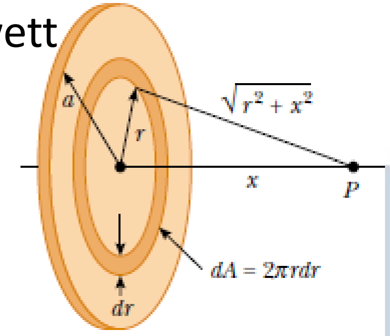

(b) A disk of thickness dx has charge $\frac{Q dx}{h}$ and charge-per-area $\frac{Q dx}{\pi R^2 h}$. According to Example 25.6, it creates potential

$$dV = 2\pi k_e \frac{Q dx}{\pi R^2 h}\left(\sqrt{x^2+R^2}-x\right).$$

Integrating,

$$V = 2\pi k_e \sigma\left[(x^2+a^2)^{1/2}-x\right] \qquad (25.23)$$

$$V=\int_d^{d+h}\frac{2k_eQ}{R^2h}\left(\sqrt{x^2+R^2}\,dx - x\,dx\right)=\frac{2k_eQ}{R^2h}\left[\frac{1}{2}x\sqrt{x^2+R^2}+\frac{R^2}{2}\ln\left(x+\sqrt{x^2+R^2}\right)-\frac{x^2}{2}\right]_d^{d+h}$$

$$V=\boxed{\frac{k_eQ}{R^2h}\left[(d+h)\sqrt{(d+h)^2+R^2}-d\sqrt{d^2+R^2}-2dh-h^2+R^2\ln\left(\frac{d+h+\sqrt{(d+h)^2+R^2}}{d+\sqrt{d^2+R^2}}\right)\right]}$$