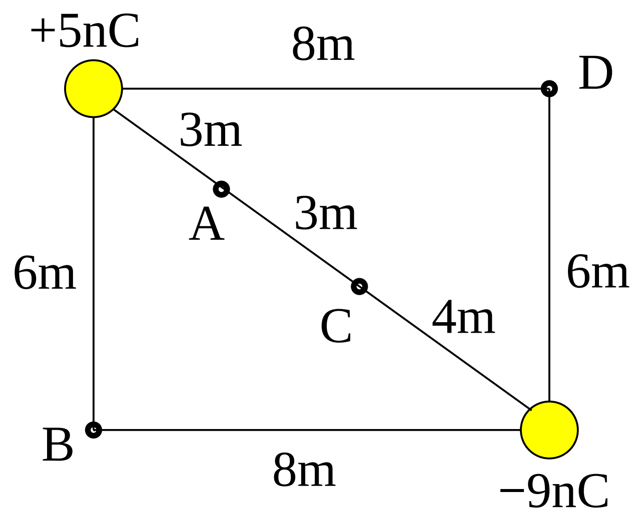
Unit Exam I: Problem #1 (Spring '14)

Consider two point charges positioned as shown.

- Find the magnitude of the electric field at point A.
- Find the electric potential at point B.
- Find the magnitude of the electric field at point C.
- Find the electric potential at point D.



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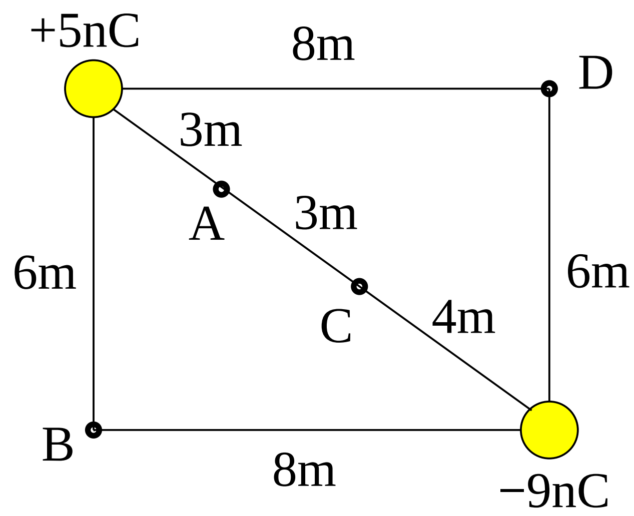

Solution:

- $E_A = k\dfrac{|5\text{nC}|}{(3\text{m})^2} + k\dfrac{|-9\text{nC}|}{(7\text{m})^2} = 5.00\text{V/m} + 1.65\text{V/m} = 6.65\text{V/m}.$

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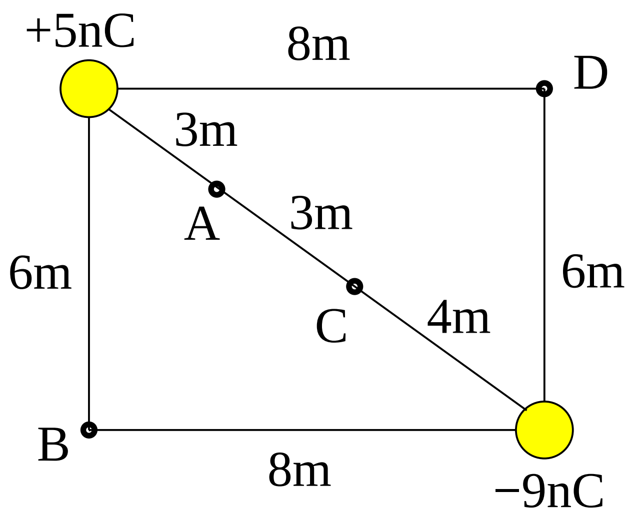

Solution:

- $E_A = k\dfrac{|5\text{nC}|}{(3\text{m})^2} + k\dfrac{|-9\text{nC}|}{(7\text{m})^2} = 5.00\text{V/m} + 1.65\text{V/m} = 6.65\text{V/m}.$
- $V_B = k\dfrac{(+5\text{nC})}{6\text{m}} + k\dfrac{(-9\text{nC})}{8\text{m}} = 7.50\text{V} - 10.13\text{V} = -2.63\text{V}.$

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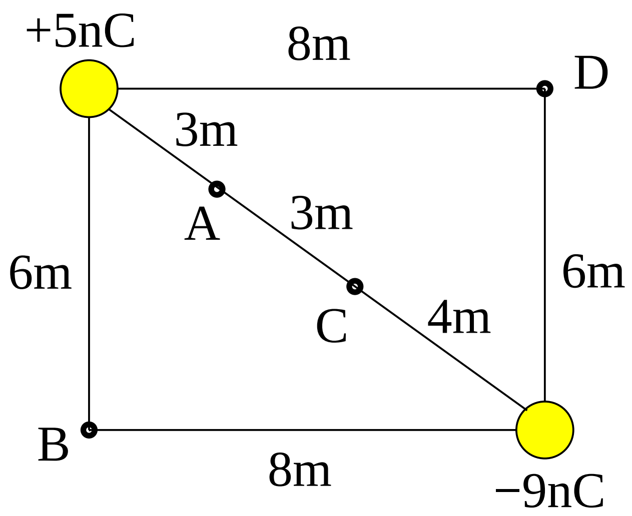

Solution:

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- $V_B = k\dfrac{(+5\text{nC})}{6\text{m}} + k\dfrac{(-9\text{nC})}{8\text{m}} = 7.50\text{V} - 10.13\text{V} = -2.63\text{V}.$
- $E_C = k\dfrac{|5\text{nC}|}{(6\text{m})^2} + k\dfrac{|-9\text{nC}|}{(4\text{m})^2} = 1.25\text{V/m} + 5.06\text{V/m} = 6.31\text{V/m}.$

Unit Exam I: Problem #1 (Spring ’14)

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- Find the magnitude of the electric field at point A.
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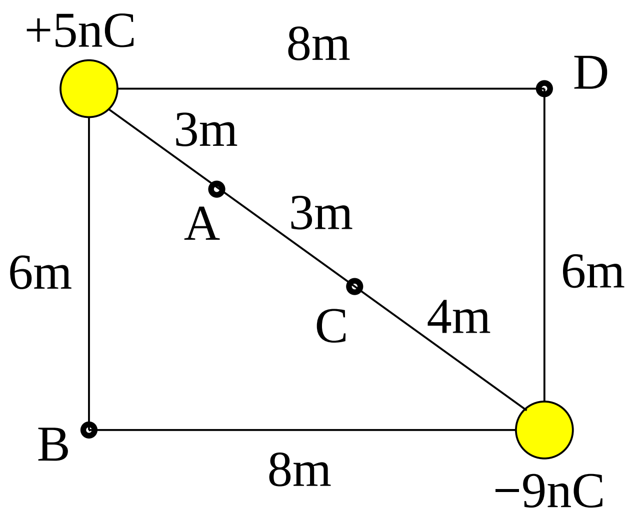


Solution:

- $E_A = k\dfrac{|5\mathrm{nC}|}{(3\mathrm{m})^2} + k\dfrac{|-9\mathrm{nC}|}{(7\mathrm{m})^2} = 5.00\mathrm{V/m} + 1.65\mathrm{V/m} = 6.65\mathrm{V/m}.$
- $V_B = k\dfrac{(+5\mathrm{nC})}{6\mathrm{m}} + k\dfrac{(-9\mathrm{nC})}{8\mathrm{m}} = 7.50\mathrm{V} - 10.13\mathrm{V} = -2.63\mathrm{V}.$
- $E_C = k\dfrac{|5\mathrm{nC}|}{(6\mathrm{m})^2} + k\dfrac{|-9\mathrm{nC}|}{(4\mathrm{m})^2} = 1.25\mathrm{V/m} + 5.06\mathrm{V/m} = 6.31\mathrm{V/m}.$
- $V_D = k\dfrac{(+5\mathrm{nC})}{8\mathrm{m}} + k\dfrac{(-9\mathrm{nC})}{6\mathrm{m}} = 5.63\mathrm{V} - 13.5\mathrm{V} = -7.87\mathrm{V}.$

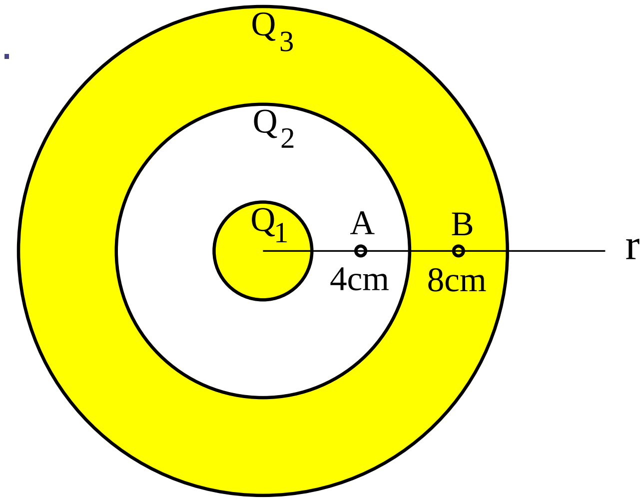
Unit Exam I: Problem #2 (Spring ’14)

Consider a conducting sphere of radius $r_1 = 2$cm and a conducting spherical shell of inner radius $r_2 = 6$cm and outer radius $r_3 = 10$cm. The charges on the two surfaces of the shell are $Q_2 = Q_3 = 1.3$nC [3.1nC].

(a) Find the charge Q_1 on the surface of the conducting sphere.

(b) Find the magnitude of the electric field at points A and B.

(c) Find the surface charge density σ_3 on the outermost surface.



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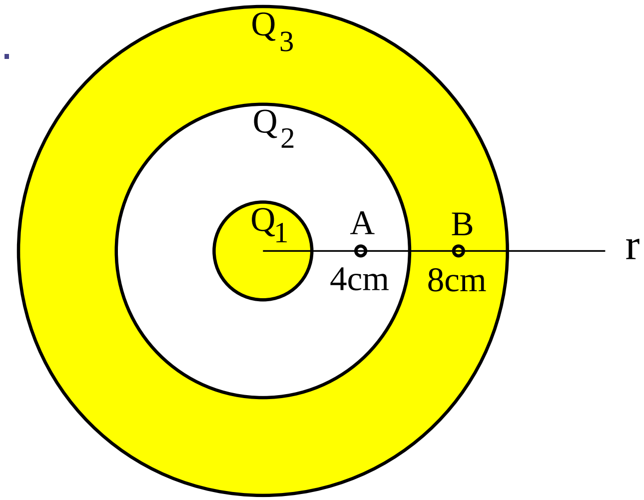

Solution:

(a) Gauss' law implies that
$Q_1 = -Q_2 = -1.3$nC [-3.1nC].

Consider a conducting sphere of radius $r_1 = 2$cm and a conducting spherical shell of inner radius $r_2 = 6$cm and outer radius $r_3 = 10$cm. The charges on the two surfaces of the shell are $Q_2 = Q_3 = 1.3$nC [3.1nC].
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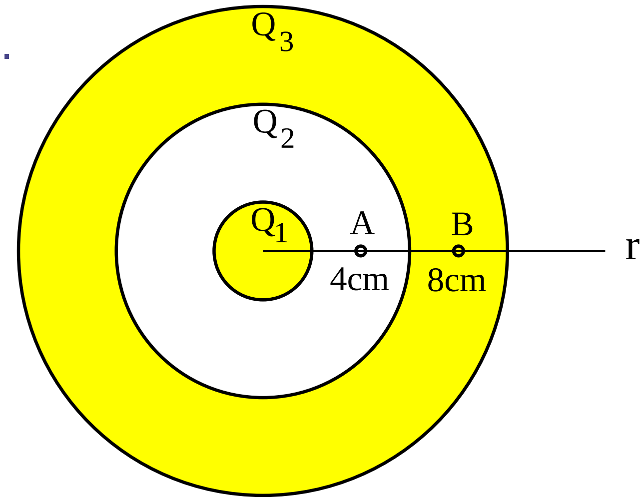

Solution:

(a) Gauss' law implies that
$Q_1 = -Q_2 = -1.3$nC [-3.1nC].

(b) $$E_A = k\frac{1.3\text{nC}}{(4\text{cm})^2} = 7.31 \times 10^3\text{N/C}$$
$$\left[k\frac{3.1\text{nC}}{(4\text{cm})^2} = 1.74 \times 10^4\text{N/C}\right].$$

$E_B = 0$ inside conductor.

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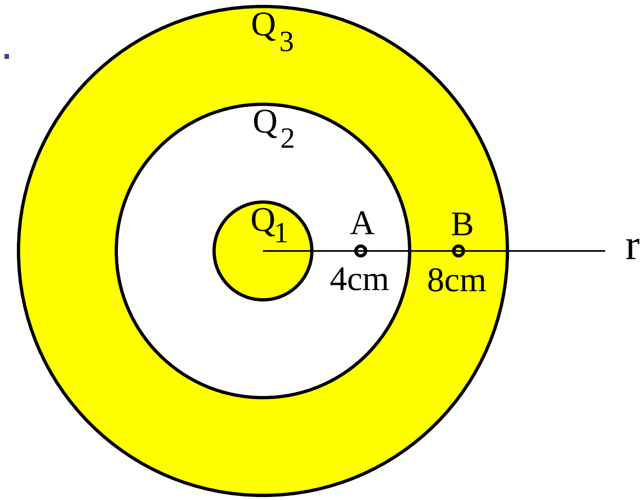

Solution:

(a) Gauss’ law implies that
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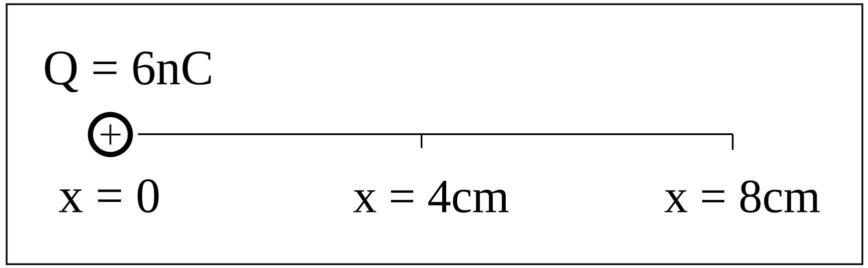
$$\left[k\frac{3.1\text{nC}}{(4\text{cm})^2} = 1.74 \times 10^4\text{N/C}\right].$$

$E_B = 0$ inside conductor.

(c) $$\sigma_3 = \frac{Q_3}{4\pi r_3^2} = \frac{1.3\text{nC}}{1257\text{cm}^2} = 1.03 \times 10^{-8}\text{C/m}^2 \quad \left[\frac{3.1\text{nC}}{1257\text{cm}^2} = 2.47 \times 10^{-8}\text{C/m}^2\right]$$

Unit Exam I: Problem #3 (Spring '14)

Consider a point charge $Q = 6$nC fixed at position $x = 0$.
(a) Find the electric potential energy U_4 of a charged particle with mass $m = 1$mg and charge $q = 2\mu$C placed at position $x = 4$cm.
(b) Find the electric potential energy U_8 of a charged particle with mass $m = 2$mg and charge $q = -1\mu$C placed at position $x = 8$cm.
(c) Find the kinetic energy K_8 of that particle, released from rest at $x = 4$cm, when it has reached position $x = 8$cm.
(d) Find the kinetic energy K_4 of that particle, released from rest at $x = 8$cm, when it has reached position $x = 4$cm.
(e) Find the velocity v_8 of that particle at $x = 8$cm.
(f) Find the velocity v_4 of that particle at $x = 4$cm.



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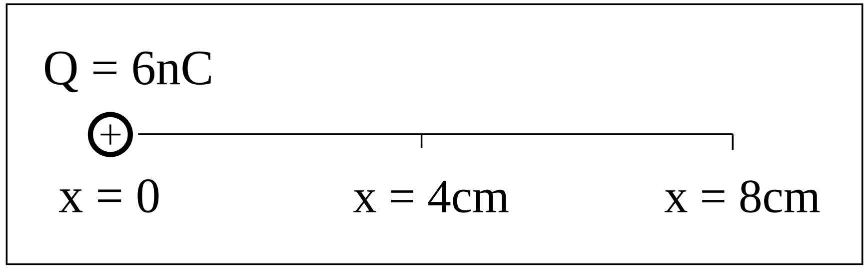
(b) Find the electric potential energy U_8 of a charged particle with mass $m = 2\text{mg}$ and charge $q = -1\mu\text{C}$ placed at position $x = 8\text{cm}$.
(c) Find the kinetic energy K_8 of that particle, released from rest at $x = 4\text{cm}$, when it has reached position $x = 8\text{cm}$.
(d) Find the kinetic energy K_4 of that particle, released from rest at $x = 8\text{cm}$, when it has reached position $x = 4\text{cm}$.
(e) Find the velocity v_8 of that particle at $x = 8\text{cm}$.
(f) Find the velocity v_4 of that particle at $x = 4\text{cm}$.



Solution:

(a) $U_4 = k\dfrac{qQ}{4\text{cm}} = 2.7\text{mJ}.$

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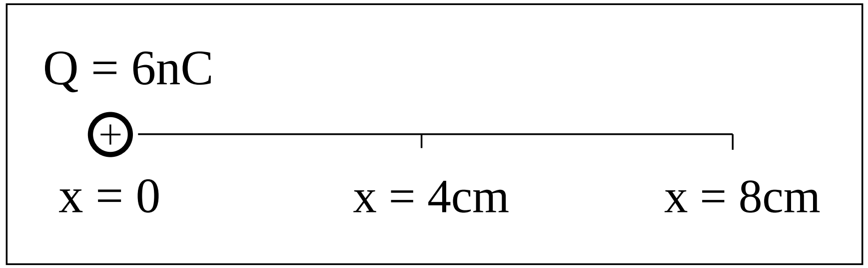

Solution:

(a) $U_4 = k\dfrac{qQ}{4\text{cm}} = 2.7\text{mJ}.$

(c) $K_8 = (2.7 - 1.35)\text{mJ} = 1.35\text{mJ}.$

Consider a point charge $Q = 6\text{nC}$ fixed at position $x = 0$.
(a) Find the electric potential energy U_4 of a charged particle with mass $m = 1\text{mg}$ and charge $q = 2\mu\text{C}$ placed at position $x = 4\text{cm}$.
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(e) Find the velocity v_8 of that particle at $x = 8\text{cm}$.
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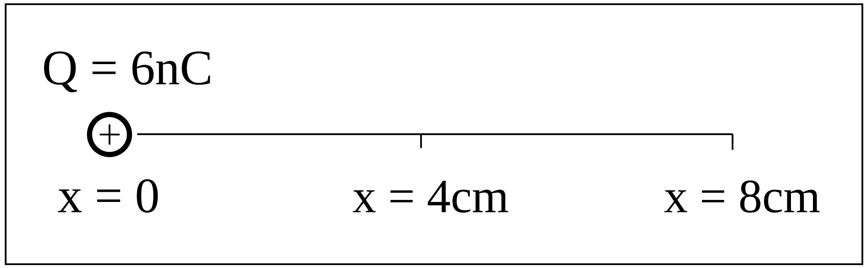

Solution:

(a) $U_4 = k\dfrac{qQ}{4\text{cm}} = 2.7\text{mJ}.$

(c) $K_8 = (2.7 - 1.35)\text{mJ} = 1.35\text{mJ}.$

(e) $v_8 = \sqrt{\dfrac{2K_8}{m}} = 52.0\text{m/s}.$

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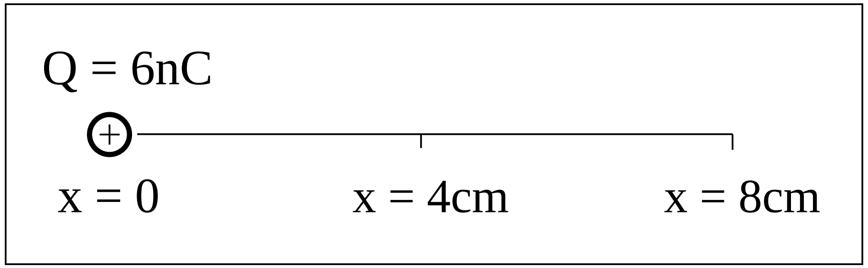

Solution:

(a) $U_4 = k\dfrac{qQ}{4\text{cm}} = 2.7\text{mJ}.$

(b) $U_8 = k\dfrac{qQ}{8\text{cm}} = -0.675\text{mJ}.$

(c) $K_8 = (2.7 - 1.35)\text{mJ} = 1.35\text{mJ}.$

(e) $v_8 = \sqrt{\dfrac{2K_8}{m}} = 52.0\text{m/s}.$

Unit Exam I: Problem #3 (Spring '14)

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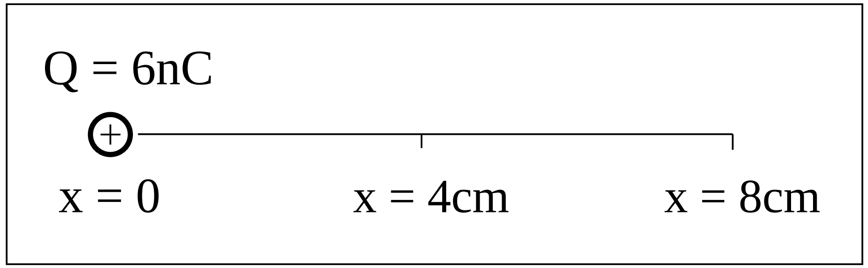

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(b) $U_8 = k\dfrac{qQ}{8\text{cm}} = -0.675\text{mJ}.$

(c) $K_8 = (2.7 - 1.35)\text{mJ} = 1.35\text{mJ}.$

(d) $K_4 = (1.35 - 0.675)\text{mJ} = 0.675\text{mJ}.$

(e) $v_8 = \sqrt{\dfrac{2K_8}{m}} = 52.0\text{m/s}.$

Unit Exam I: Problem #3 (Spring '14)

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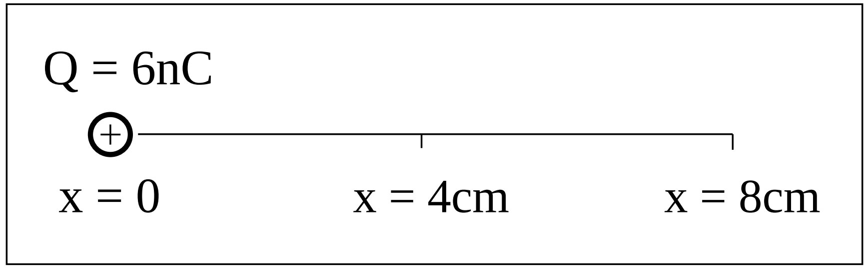
(e) Find the velocity v_8 of that particle at $x = 8\text{cm}$.
(f) Find the velocity v_4 of that particle at $x = 4\text{cm}$.



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(d) $K_4 = (1.35 - 0.675)\text{mJ} = 0.675\text{mJ}.$

(e) $v_8 = \sqrt{\dfrac{2K_8}{m}} = 52.0\text{m/s}.$

(f) $v_4 = \sqrt{\dfrac{2K_4}{m}} = 26.0\text{m/s}.$