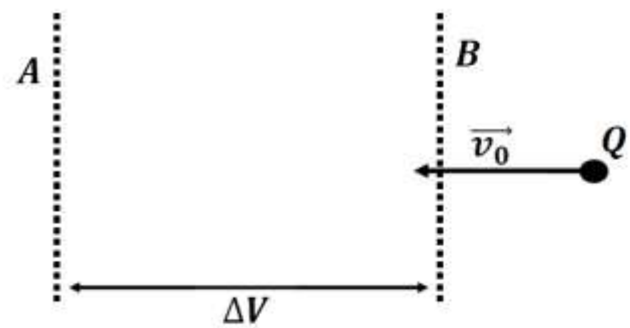
PH 221 Homework Assignment Chapter on E Potential and V Field – 34 Problems Total

1. An object has a mass $(\mathrm{m} = 7.72 \text{ x } 10^{-12} \text{ kg})$ and a charge $(\mathrm{Q} = +9.87 \text{ x } 10^{-3} \text{ C})$. The object is traveling with an initial velocity $\left(\vec{v_0} = 4.86 \text{ x } 10^{5} \text{ m}/_{\text{S}} \ (\widehat{\text{West}})\right)$, when it enters a potential difference $(\Delta\mathrm{V})$ with sides labelled A and B as shown below.



(a) Which side of the potential difference (A or B) must be positive in order to bring the object to rest by the time crosses the potential difference $(\Delta\mathrm{V})$?

(b) What is the magnitude of the potential difference $(\Delta\mathrm{V})$ needed to bring the object to rest?

Solution for Problem 1

2. How much work is done by the electric field if an object with a mass $(\mathrm{m} = 1.23 \text{ kg})$ and a charge $(\mathrm{Q} = -34.5 \text{ mC})$ is moved from a point at an electrical potential of $+749$ V to a point with an electrical potential of -347 V?

Solution for Problem 2

3. An external force provides $+3.50 \text{ x } 10^{-4}$ J of work as it moves a $+3.34$ μC charge which is at rest from Point A to Point B. Upon reaching Point B the charge now possesses a kinetic energy of $+6.75 \text{ x } 10^{-4}$ J.

(a) What is the potential difference between Point A and Point B?

(b) Which point is at the higher potential?

Solution for Problem 3

4. In order to "see" a spark, the local electric field must exceed the "Breakdown Voltage" of the medium. When that happens charges will move across the medium. For normal air, this "Breakdown Voltage" has a magnitude of $3.00 \text{ x } 10^6 \text{ V/m}$. Thunder clouds can develop voltage differences of magnitudes of $1.00 \text{ x } 10^8 \text{ V}$. How long would a spark from this voltage difference be?

Solution for Problem 4

5. If a conductor possesses too much charge, the electric field created can exceed the "Breakdown Voltage" and the charge will be able to leave the conductor by propagating through the surrounding medium. Consider a spherical conductor with radius $\text{R} = 7.23 \text{ x } 10^{-2} \text{ m}$ which is sitting in normal air. Use $\text{E}_{\text{Breakdown}} = 3.00 \text{ x } 10^6 \text{ V/m}$. What is the maximum amount of charge which can be collected on this conductor before it sparks charge off?

Solution for Problem 5

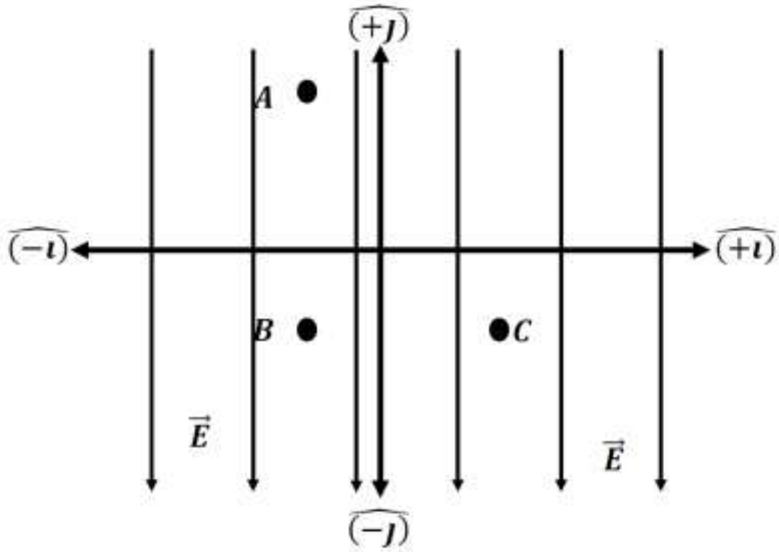
6. What is the magnitude of the electric field between two parallel plate conductors which are separated by a distance $(\text{d} = 7.76 \text{ x } 10^{-3} \text{ m})$ and which have a potential difference between them of $(\Delta\text{V} = 230.\text{V})$?

Solution for Problem 6

7. As when walks across a carpet charge can be transferred between your shoes and the carpet creating an electrical potential difference between the carpet and the shoes. If this approaches the breakdown voltage for air, sparks can result. Assume a shoe has an area $(\text{A}_{\text{Shoe}} = 3.00 \text{ x } 10^{-2} \text{ m}^2)$ and is a distance $(\text{d} = 1.00 \text{ x } 10^{-3} \text{ m})$ above the carpet. Assume the shoe and the carpet act like two parallel plates of charge (though one is the opposite sign of the other). If an amount of charge $(\text{Q} = 5.00 \ \mu\text{C})$ is transferred between the carpet and the shoe, what is the resulting potential difference?

Solution for Problem 7

8. As shown below a uniform electric field $\left(\vec{E_0} = 6.69\ {}^{N}/_{C}\ \widehat{(-\jmath)}\right)$points in the negative y direction. The coordinates of the three points indicated are: $A(-2.00\ m, +10.0\ m), B(-2.00\ m, -4.00\ m), \text{and } C(+6.00\ m, -4.00\ m)$.



(a) Calculate the electrical potential difference going from Point A to Point B, $V_{A \to B} = V_B - V_A$.

(b) Calculate the electrical potential difference going from Point B to Point C, $V_{B \to C} = V_C - V_B$.

(c) Calculate the electrical potential difference going from Point A to Point C, $V_{A \to C} = V_C - V_A$.

Solution for Problem 8

9. A conducting hollow sphere with a radius $(R = 0.180\ m)$ is charged until it has a voltage of $V = -923.\ V$ relative to a voltage of $V = 0.00\ V$ when $r = \infty$.

(a) What is the surface charge density σ for the sphere?

(b) At what distance from the center of the sphere is the potential $V = -35.0\ V$?

Solution for Problem 9

10. Consider two solid conducting spheres. One has a radius (R_1) and a charge (Q_0) on it. The second sphere is uncharged and has a radius (R_2). The two spheres are a distance $(L \gg R_1, R_2)$. A conducting wire is then attached to both spheres which are not moved.

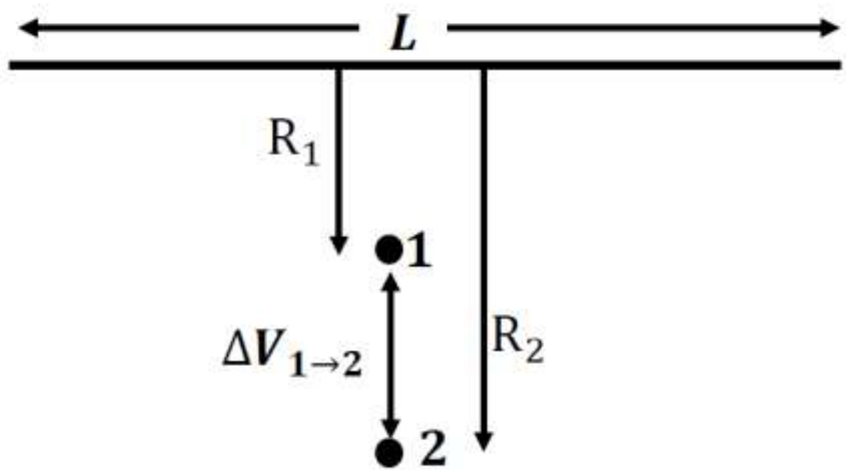
(a) Does it matter that the length of the conducting wire is much greater than either of the two radii?

(b) After the two spheres have equilibrated their electrical potentials, how much charge is on Sphere 1?

(c) After the two spheres have equilibrated their electrical potentials, how much charge is on Sphere 2?

Solution for Problem 10

11. A long straight wire has length (L) and has a linear charge density $\lambda = {}^{Q}/_{L}$ which is uniformly distributed along its length. Now as shown below, consider two points (1) and (2) which are radially distant from the wire (R_1) and (R_2). Note:$(L \gg R_2 > R_1)$ What is the change in electrical potential going from Point (1) to Point (2)?



Solution for Problem 11

12. A human neuron cell has a membrane that is approximately $(d = 9.00 \text{ x } 10^{-9} \text{ m})$. On average there is a potential difference of $(\Delta V = 75.0 \text{ x } 10^{-3} \text{ V})$. Estimate the electric field in the neuron cell membrane.

Solution for Problem 12

13. A nonconducting sphere has a radius (R_0) which has a charge (Q_0) which is uniformly distributed throughout its volume. Use a reference potential that $(V(r) = 0, \text{at } r = \infty)$.

(a) Determine the electric field as function of radial distance (r) for the region $R_0 \leq r < \infty$.

(b) Determine the electric field as function of radial distance (r) for the region $0 \leq r < R_0$.

(c) Determine the electric potential as function of radial distance (r) for the region $R_0 \leq r < \infty$.

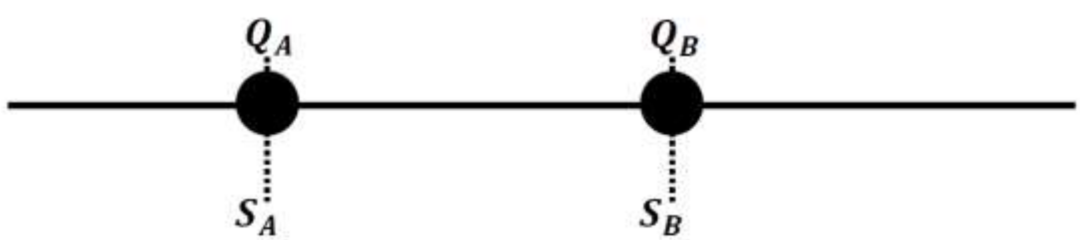
(d) Determine the electric potential as function of radial distance (r) for the region $0 \leq r < R_0$.

(e) Plot electric field vs radial distance for range $0 \leq r < \infty$.

(f) Plot electric potential vs radial distance for range $0 \leq r < \infty$.

Solution for Problem 13

14. Two point charges are shown below along an "x – axis". Their locations and charges are as follows: $Q_A = +1.34\ \mu C$, $Q_B = -4.62\ \mu C$, $S_A = -2.44$ m, and $S_B = 0.00$ m (origin of x – axis).

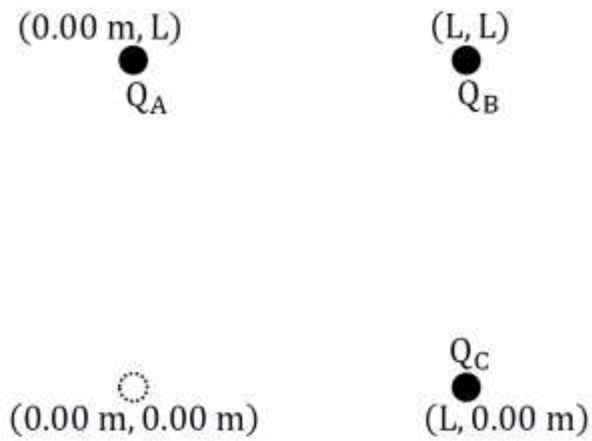


(a) Find all points along the "x – axis" where the net electric field from these two charges is equal to zero.

(b) Find all points along the "x – axis" where the net electric potential from these two charges is equal to zero.

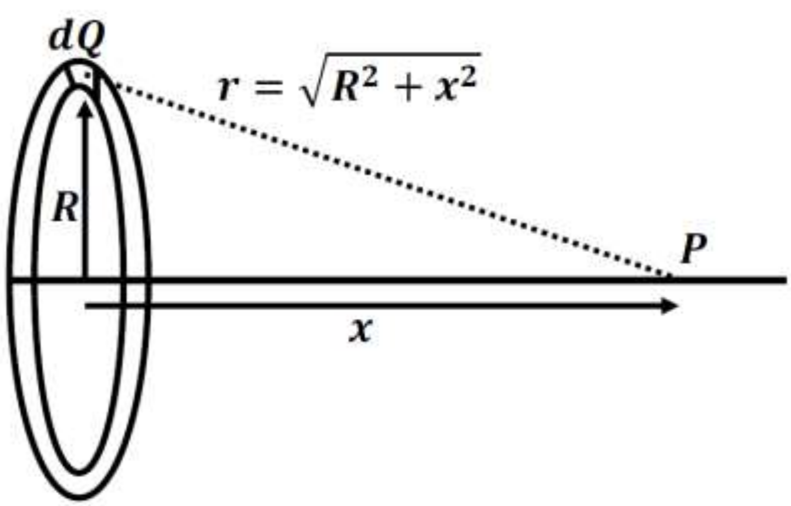
Solution for Problem 14

15. As shown below, three corners of a "Square" which has sides (L). The three charges are $Q_A = -3Q, Q_B = +4Q$, and $Q_C = +Q$. Assume the zero of electrical potential is far away $(r \rightarrow \infty)$. What is the electrical potential at the origin?



<u>Solution for Problem 15</u>

16. A Thin nonconducting ring of radius R has a charge of Q uniformly distributed throughout the ring as shown below.

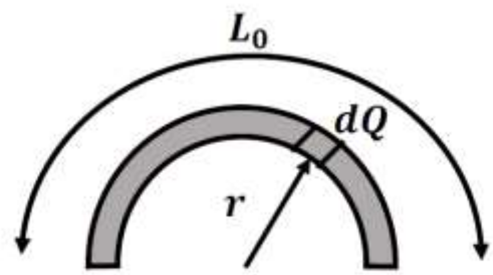


(a) Determine the electric potential at points along the x – axis.

(b) Determine the electric field at points along the x – axis.

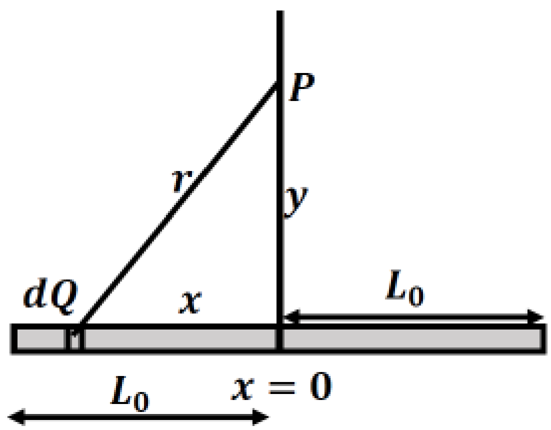
<u>Solution for Problem 16</u>

17. A nonconducting material has a length (L_0) is shaped as a semi-circle It has a charge of (Q_0) uniformly distributed through it. What is the electrical potential at the center of the semi-circle as shown below.



Solution for Problem 17

18. A thin rod of nonconducting material is centered at the origin of an x-y coordinate system as shown below. The rod has a length of $2L_0$ and a total charge Q_0 uniformly distributed over the rod. Assume the electric potential $V = 0$ when $r \to \infty$.

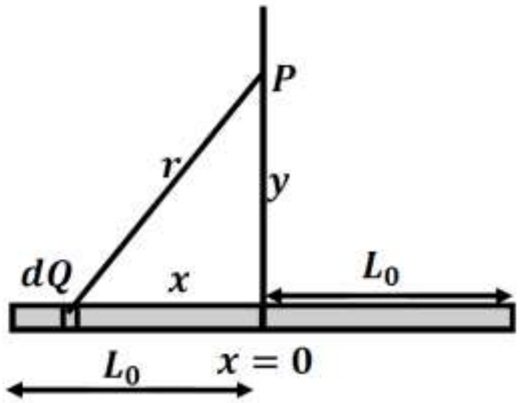


(a) Determine the electric potential at points along the y – axis.

(b) Determine the electric field at points along the y – axis.

Solution for Problem 18

19. Consider a nonconducting rod of length $(2\ L_0)$ along the x – axis. The charge is nonuniformly distributed with a linear charge density given by $\lambda = ax$.
Note: for $x < 0, \lambda < 0$.



(a) Determine the electric potential for points P along the y axis, perpendicular to the length of the rod.

(b) Determine the electric potential for points P along the x axis, parallel to the length of the rod and outside of the rod $|x| > L_0$.

<u>**Solution for Problem 19**</u>

20. In a region of space the electric potential is found to be described by the relationship:

$$V = 4y^3 - 1.74xyz + 5.67x^2z$$

Where V is in Volts when x, y, and z are in meters. Determine the electric field $\vec{E}$ in this region of space.

<u>**Solution for Problem 20**</u>

21. The electric potential in some region of space is found to be:

$$V = \frac{Az^2}{B^3 - z}$$

Where constants A and B have the units appropriate in order that V has units of Volts when z has units of meters. Determine the electric field $\vec{E}$ related to this potential.

<u>**Solution for Problem 21**</u>

22. In a certain region of space the electrical potential is expressed by the relationship:

$$V = \frac{A}{(y^2 + B^2)^2}$$

Where $A = 25.0\ Vm^4, B = 0.35\ m$, and V has units of Volts when y is in units of meters.

(a) Determine V at $y = 0.15\ m.$

(b) Find an expression for electric field $\vec{E}$ as a function of y.

(c) Determine $\vec{E}$ at $y = 0.15\ m.$

<u>**Solution for Problem 22**</u>

23. A solid metal (conducting) sphere has a radius $(R_0 = 0.220\ m)$ has a charge $(Q_0 = 265.\ \mu C)$ on it.

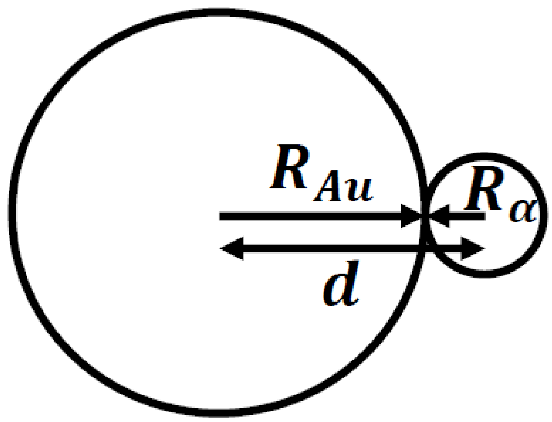
(a) Calculate the radius where the equipotential surface for $V = 100.\,V$ would exist.

(b) Calculate the radius where the equipotential surface for $V = 1{,}000.\,V$ would exist.

(c) Calculate the radius where the equipotential surface for $V = 10{,}000.\,V$ would exist.

<u>**Solution for Problem 23**</u>

24. The radius of a gold nucleus is approximately $(\mathrm{R_{Au}} = 7.00 \times 10^{-15}\ \mathrm{m})$ and it possesses a net charge $(\mathrm{Q_{Au}} = +1.26 \times 10^{-17}\ \mathrm{C})$. The radius of an alpha particle is approximately $(\mathrm{R_\alpha} = 1.68 \times 10^{-15}\ \mathrm{m})$ and it possesses a net charge $(\mathrm{Q_\alpha} = +3.20 \times 10^{-19}\ \mathrm{C})$. In the Rutherford Scattering Experiment of 1911, alpha particles were sent to collide with gold atoms in a thin foil. What accelerating voltage would be required for an alpha particle to "just touch" a gold nucleus momentarily before being electrostatically repulsed away? Assume we can treat the gold nucleus and alpha particles as point charge particles.



Solution for Problem 24

25. Two identical charges have masses $(\mathrm{m} = 2.00 \times 10^{-2}\ \mathrm{kg})$ and charges $(\mathrm{Q} = -13.3 \times 10^{-6}\ \mathrm{C})$. They are initially separated by distance $(\mathrm{d} = 0.127\ \mathrm{m})$. They are initially at rest when the two particles are released and are free to move. Since are both negatively charged they repulse each other and begin to move apart along a straight line. When they are very far from each other what is their speed?

Solution for Problem 25

26. A proton starts from rest a distance $(\mathrm{d} = 0.693\ \mathrm{m})$ from a fixed-point charge with a charge $(\mathrm{Q_{Fix}} = +2.98 \times 10^{-9}\ \mathrm{C})$. When the proton is very far from the fixed charge, what is its speed?

Solution for Problem 26

27. A particle of dust has a mass $(m = 0.045 \text{ g})$ and a charge $(Q = 3.54 \ \mu\text{C})$. It is found at rest at a location $(x = 3.00 \text{ m})$. An apparatus is activated which creates an electric potential in this location described by

$$V(x) = -\left(4.00 \ {}^{V}/_{m^2}\right) x^2 + \left(3.00 \ {}^{V}/_{m^3}\right) x^3$$

Note: $V(x)$ should have units of Volts when x has units of meters.
What is the initial acceleration that acts on this dust particle?

Solution for Problem 27

28. An object has a kinetic energy of $(K = 0.750 \text{ keV})$. What is its speed if the object is:

(a) An electron?

(b) A proton?

Solution for Problem 28

29. Chemical reactions can be either endothermic (Energy is absorbed during the reaction) or Exothermic (Energy is released during the reaction). Consider a reaction where two singly positively charged ions are initially separated by a distance $(d_0 = 0.230 \text{ nm})$. After the reaction the two ions are now separated by a distance $(d_f = 0.307 \text{ nm})$.

(a) What is the change in the electrical potential energy?

(b) Is this change energy gained or lost?

Solution for Problem 29

30. A proton starting at rest and moving from Point A to Point B gains 2.56 keV of kinetic energy.

(a) How much kinetic energy would an electron gain going from Point B to Point A, again assuming it began at rest?

(b) Determine the ratio of the speeds $\frac{v_{e^-}}{v_{e^+}}$ after each object moved between their respective points above.

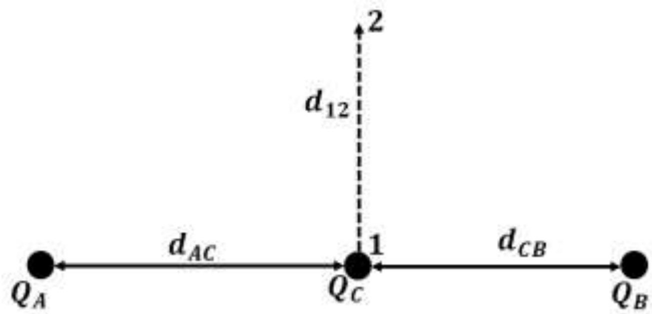
Solution for Problem 30

31. Calculate the total electrostatic potential energy of a conducting sphere $(R = R_0)$ that has a total charge $(Q = Q_0)$ on it.

Solution for Problem 31

32. As shown below there are three charges: $Q_A = -87.3\ \mu C, Q_B = +23.6\ \mu C$, and $Q_C = -17.8\ \mu C$. The distances shown below are: $d_{AC} = 0.643\ m, d_{CB} = 0.492\ m,$

and $d_{12} = 0.844\ m$. What is the change in electrical potential energy possessed by charge Q_C moving from Point 1 to Point 2?



Solution for Problem 32

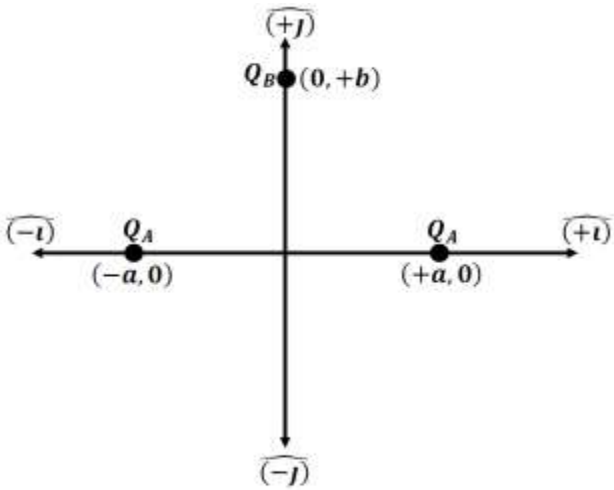
33. The electric field near the surface of the Earth is approximately $\left(\overrightarrow{E_{Earth}} = 150.\ {}^{V}/_{m}\ (\widehat{Down})\right)$. Two objects have the same mass $(m = 0.570\ kg)$. One object is positively charged $(Q_1 = +750.\ \mu C)$, while the second object is negatively charged $(Q_2 = -750.\ \mu C)$. Assume the two objects are dropped from rest and we will ignore air resistance.

(a) What is the difference in the speed between the two masses after they have fallen a distance $(h = 3.50\ m)$?

(b) Which mass is faster?

Solution for Problem 33

34. As shown below, there are two charges (Q_A) that are positive and sit equally distant from the origin on the x – axis a distance (a) from the origin. A third charge (Q_B) is negative and sits on the y – axis a distance (b) from the origin. All three charges have identical masses (m). What is the smallest value of a velocity directed along the positive y – axis that must be applied to the charge (Q_B) so that the charge will escape the attraction of the two positive charges and ultimately arrive at an infinite distance away?



Solution for Problem 34