Chapter 22

Electric Fields

Lecture 2

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22-1 The Electric Field

Learning Objectives

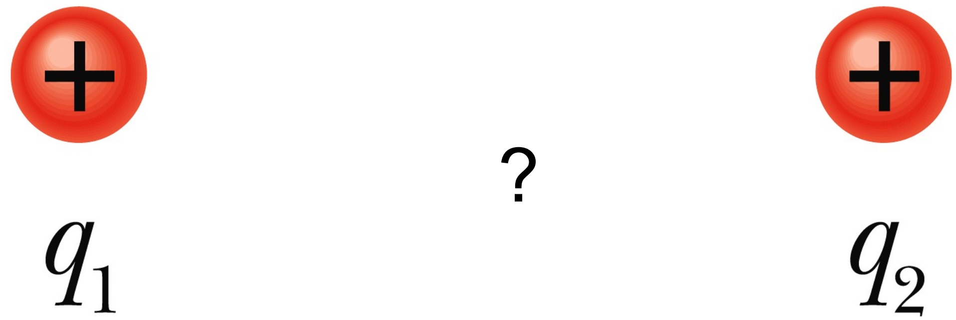
22.01 What is an electric field ***E ?***

22.02 What is a relation between electric field ***E*** and electrostatic force ***F*** ?

22.03 How to measure electric field at any given point ?

22.04 What is electric field lines?

22-1 The Electric Field



How does particle 1 “know” of the presence of particle 2? That is, since the particles do not touch, how can particle 2 push on particle 1—how can there be such an action at a distance?

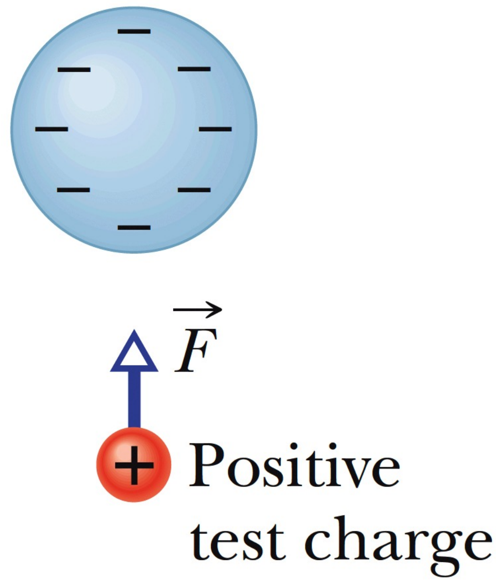
22-1 The Electric Field

Electric Field

The explanation that we shall examine here is this: Particle 2 sets up an electric field at all points in the surrounding space, even if the space is a vacuum. If we place particle 1 at any point in that space, particle 1 knows of the presence of particle 2 because it is affected by the electric field particle 2 has already set up at that point. Thus, particle 2 pushes on particle 1 not by touching it as you would push on a coffee mug by making contact. Instead, particle 2 pushes by means of the electric field it has set up.

22-1 The Electric Field

Electric Field



The electric field ***E*** at any point is defined in terms of the electrostatic force ***F*** that would be exerted on a positive test charge q_0 placed there:

$$\boxed{\vec{E} = \frac{\vec{F}}{q_0}}$$

22-1 The Electric Field

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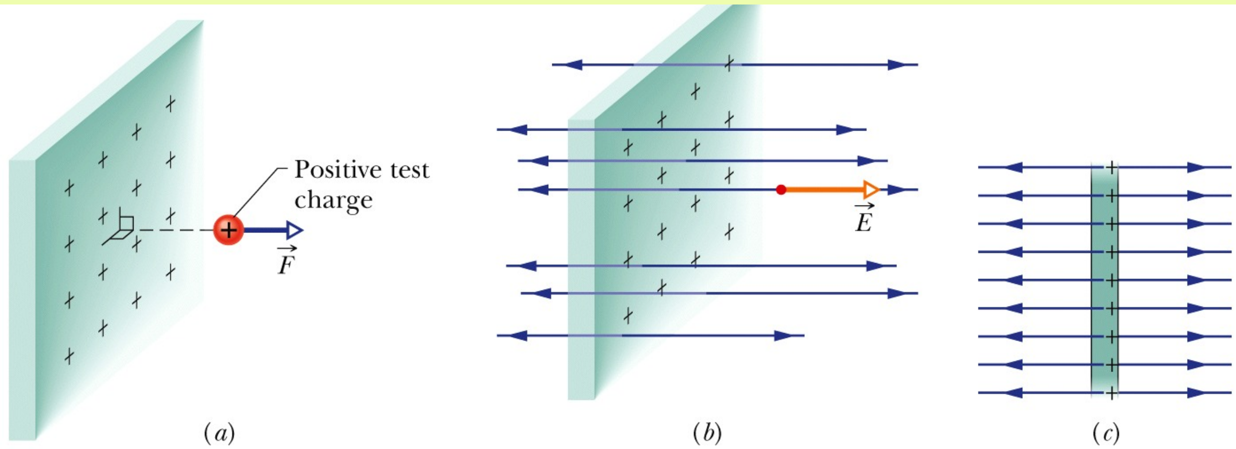
Electric Field Lines

Electric field lines help us visualize the direction and magnitude of electric fields. The electric field vector at any point is tangent to the field line through that point. The density of field lines in that region is proportional to the magnitude of the electric field there.



(a) The force on a positive test charge near a very large, non-conducting sheet with uniform positive charge on one side. (b) The electric field vector ***E*** at the test charge's location, and the nearby electric field lines, extending away from the sheet. (c) Side view.

22-1 The Electric Field

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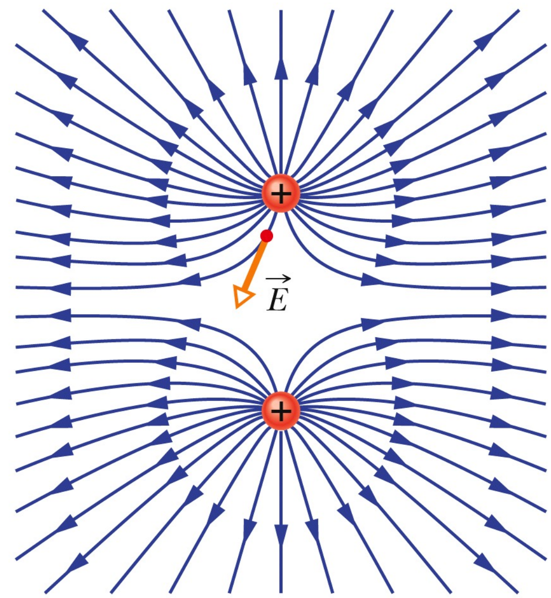
Electric field lines extend away from positive charge (where they originate) and toward negative charge (where they terminate).

(1) The electric field vector at any given point must be tangent to the field line at that point and in the same direction, as shown for one vector.

(2) A closer spacing means a larger field magnitude.

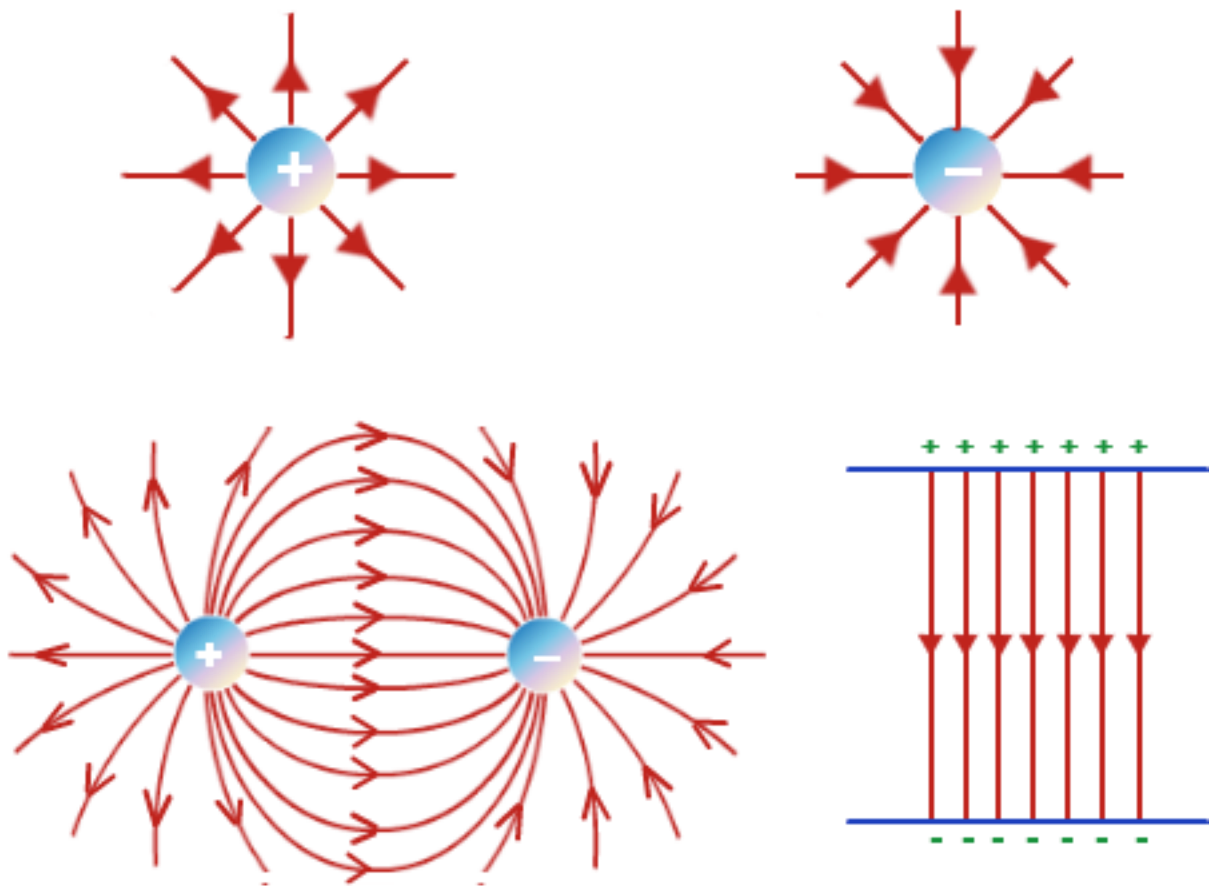


Field lines for two particles with equal positive charge. Doesn't the pattern itself suggest that the particles repel each other?

Electric Field Lines

22-1 The Electric Field

Electric Field Lines



22-2 The Electric Field Due to a Charged Particle

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Learning Objectives

22.05 What is a relation between charged particle and electric field vector ***E*** ?

22.06 For a given point what is the direction of the field vector ***E*** for a positively/negatively charged particle ?

22.07 What is the relationship between the field magnitude ***E***, the charge magnitude |*q*|, and the distance ***r*** between a point and the particle ?

22.09 If more than one electric field is set up at a point, draw each electric field vector and then find the net electric field by adding the individual electric fields as vectors (not as scalars).

22-2 The Electric Field Due to a Charged Particle

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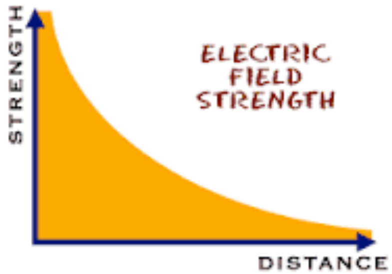
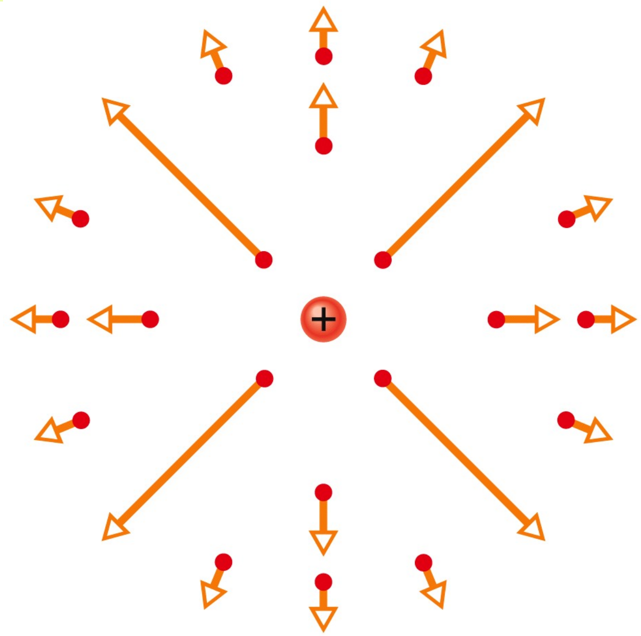
The magnitude of the electric field ***E*** set up by a particle with charge *q* at distance *r* from the particle is

$$\boxed{E = \frac{1}{4\pi\varepsilon_0}\frac{|q|}{r^2}}$$



The **electric field vectors** set up by a positively charged particle all point directly away from the particle. Those set up by a negatively charged particle all point directly toward the particle.

If more than one charged particle sets up an electric field at a point, the net electric field is the vector **sum** of the individual electric fields—**electric fields obey the superposition principle**.



The electric field vectors at various points around a positive point charge.

22-3 The Electric Field Due to a Dipole

Learning Objectives

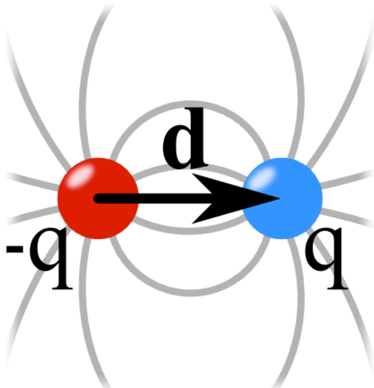
22.10 What is electric dipole, dipole axis, and electric dipole moment ?

22.11 What is electric field due to an electric dipole ?

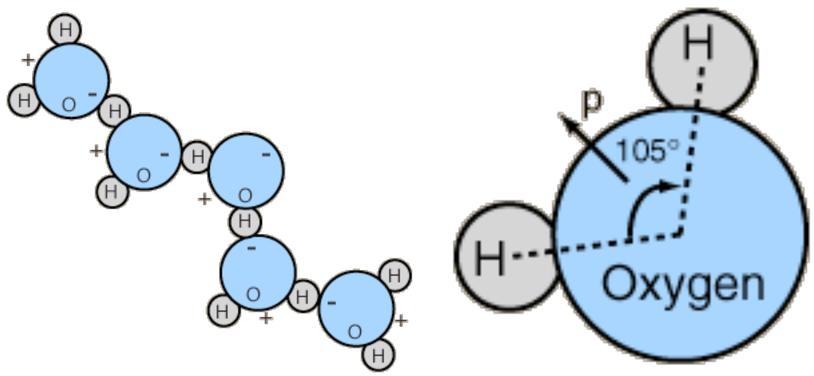
And how to derive it ?

2.13 For a single charged particle and an electric dipole, compare the rate at which the electric field magnitude decreases with increase in distance. That is, identify which drops off faster.

Electric Dipoles

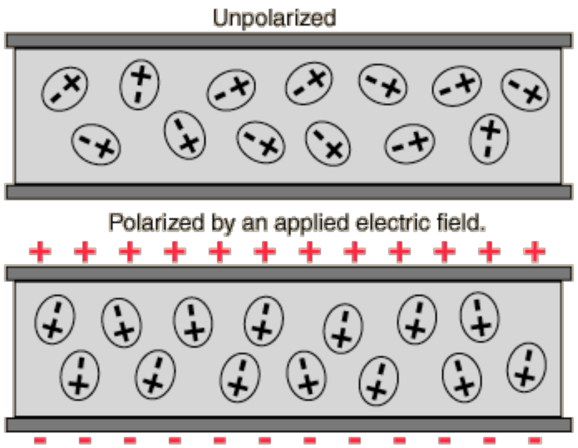


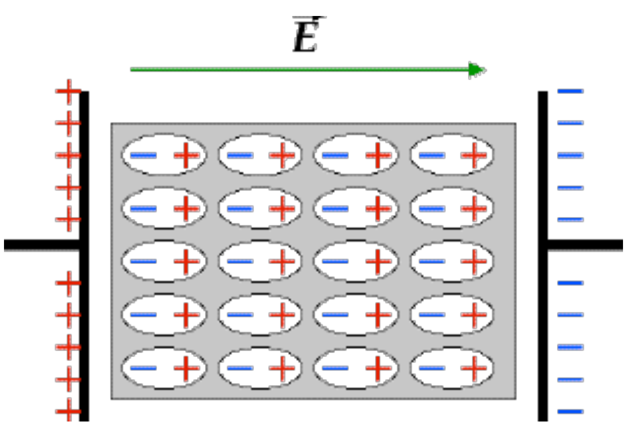
(d: small distance)



Water: H_2O

Dielectric material





22-3 The Electric Field Due to a Dipole

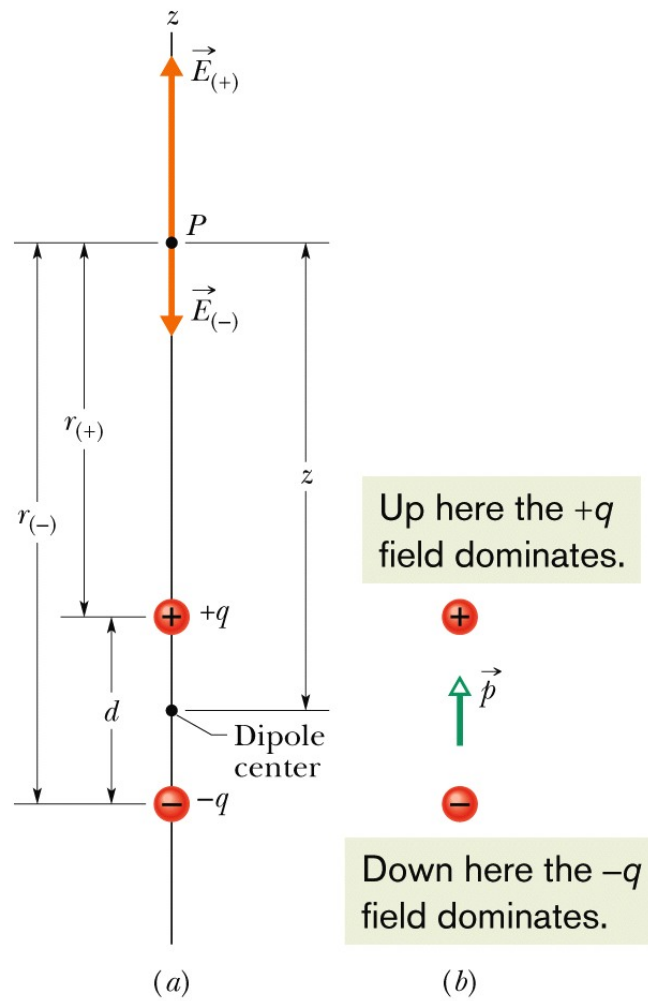
Electric Dipole

- An electric dipole consists of two particles with charges of equal magnitude q but opposite signs, separated by a small distance d.

- The magnitude of the electric field set up by an electric dipole at a distant point on the dipole axis (which runs through both particles) can be written in terms of either the product qd or the magnitude p of the dipole moment:

$$\boxed{E = \frac{1}{2\pi\varepsilon_0}\frac{qd}{z^3} = \frac{1}{2\pi\varepsilon_0}\frac{p}{z^3},}$$

where z is the distance between the point and the center of the dipole.

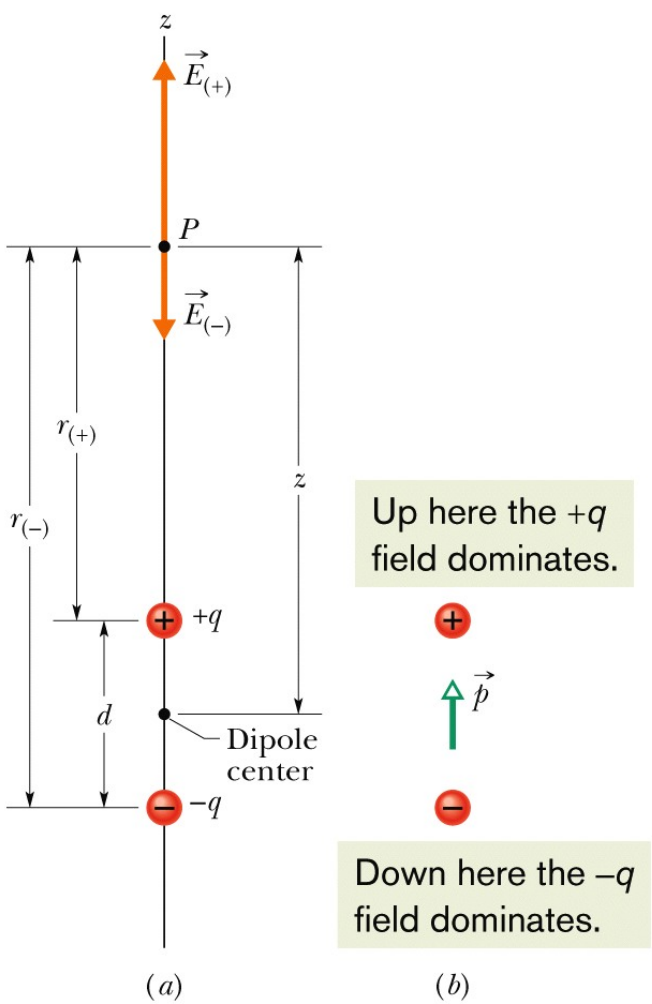


Dipole Field

$$E = E_{(+)} - E_{(-)}$$
$$= \frac{1}{4\pi\varepsilon_0} * \frac{q}{r_{(+)}^2} - \frac{1}{4\pi\varepsilon_0} * \frac{q}{r_{(-)}^2}$$
$$= \frac{q}{4\pi\varepsilon_0\left(z - \frac{1}{2}d\right)^2} - \frac{q}{4\pi\varepsilon_0\left(z + \frac{1}{2}d\right)^2}$$
$$= \frac{q}{4\pi\varepsilon_0 z^2}\left(\frac{1}{\left(1 - \frac{d}{2z}\right)^2} - \frac{1}{\left(1 + \frac{d}{2z}\right)^2}\right)$$
$$= \frac{q}{4\pi\varepsilon_0 z^2} * \frac{\frac{2d}{z}}{\left(1 - \left(\frac{d}{2z}\right)^2\right)^2}$$
$$= \frac{q}{2\pi\varepsilon_0 z^3} * \frac{d}{\left(1 - \left(\frac{d}{2z}\right)^2\right)^2}$$

(d << z)

$$\boxed{E = \frac{1}{2\pi\varepsilon_0}\frac{p}{z^3}}$$



22.8.4. A positively charged object is located to the left of a negatively charged object as shown. Electric field lines are shown connecting the two objects. The five points on the electric field lines are labeled A, B, C, D, and E. At which one of these points would a test charge experience the largest force?

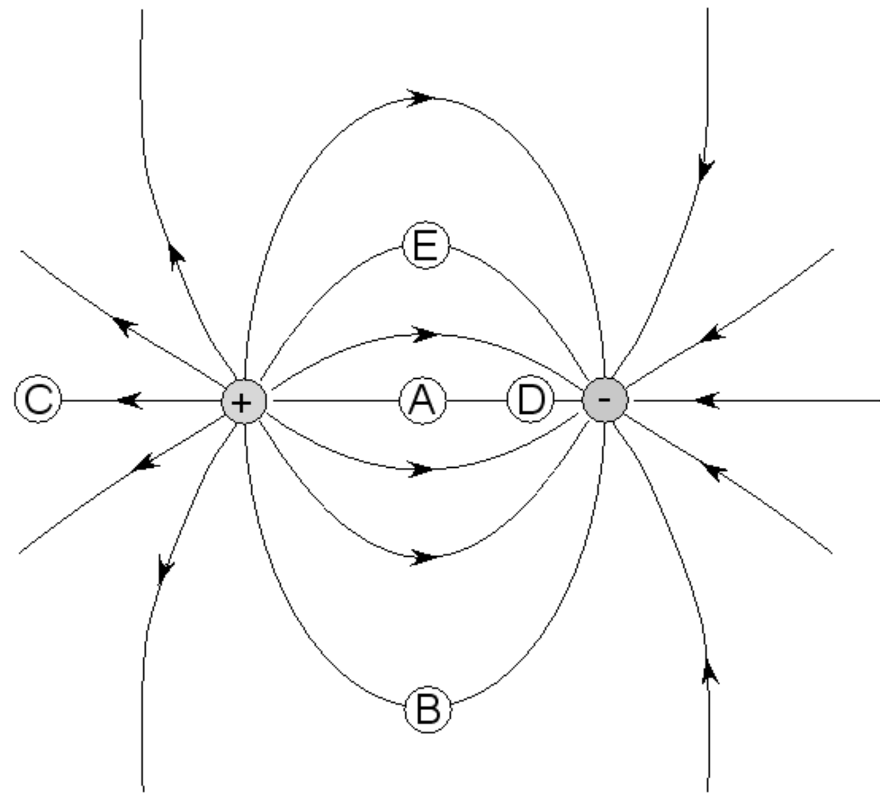
a) A

b) B

c) C

d) D

e) E



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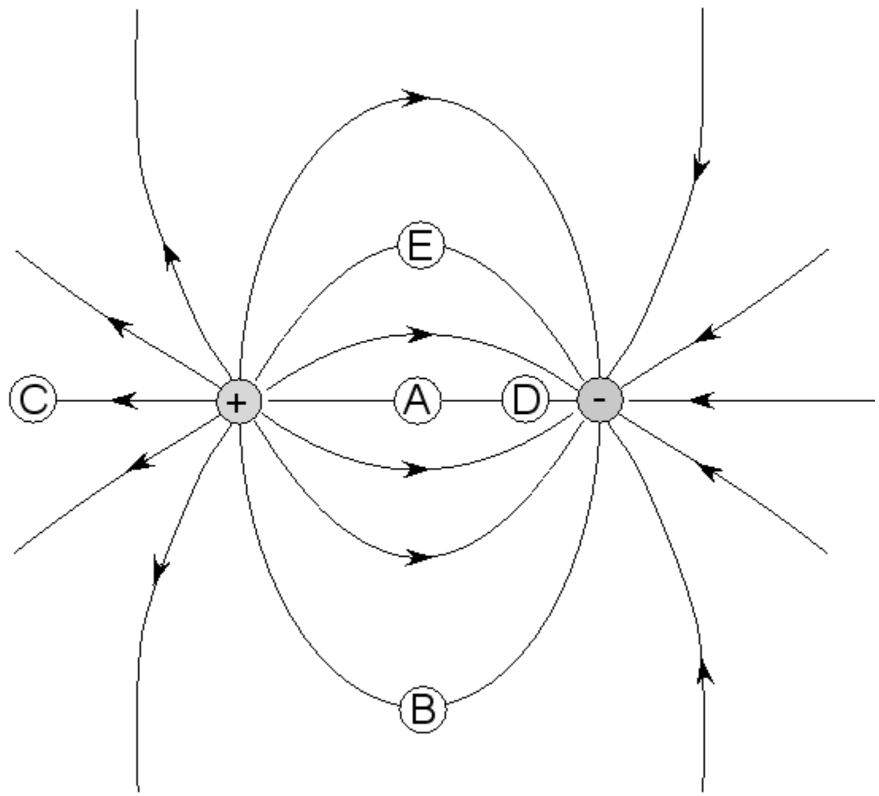


22.8.5. A positively charged object is located to the left of a negatively charged object as shown. Electric field lines are shown connecting the two objects. The five points on the electric field lines are labeled A, B, C, D, and E. At which one of these points would a test charge experience the smallest force?

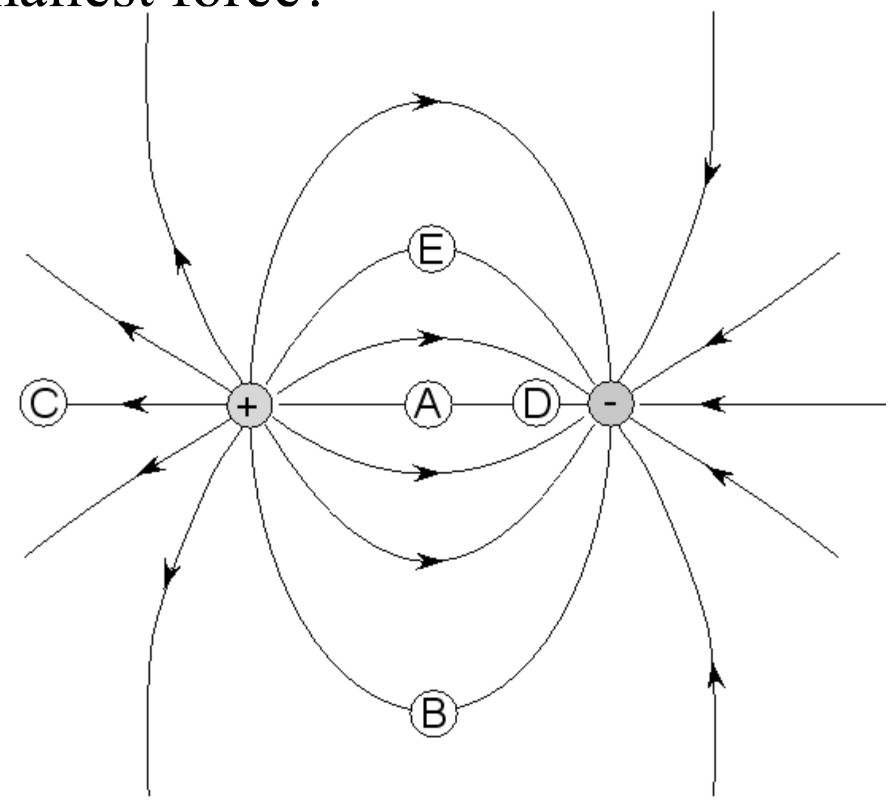
a) A

b) B

c) C

d) D

e) E



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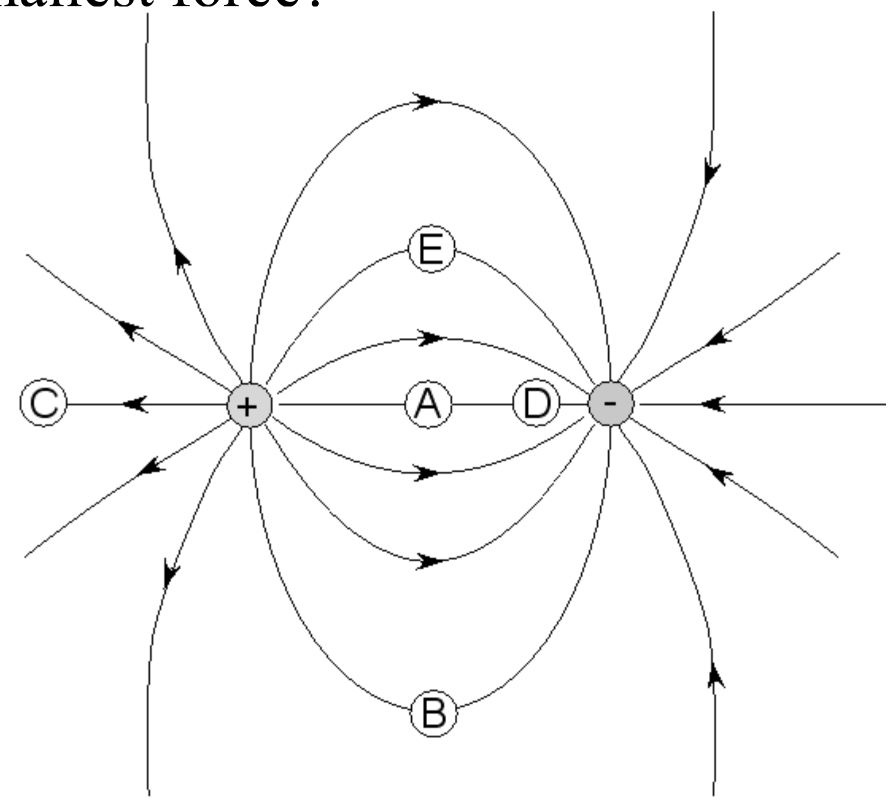
d) D

e) E



22.8.6. A positively charged object is located to the left of a negatively charged object as shown. Electric field lines are shown connecting the two objects. The five points on the electric field lines are labeled A, B, C, D, and E. At which one of these points would a test charge experience the largest force?

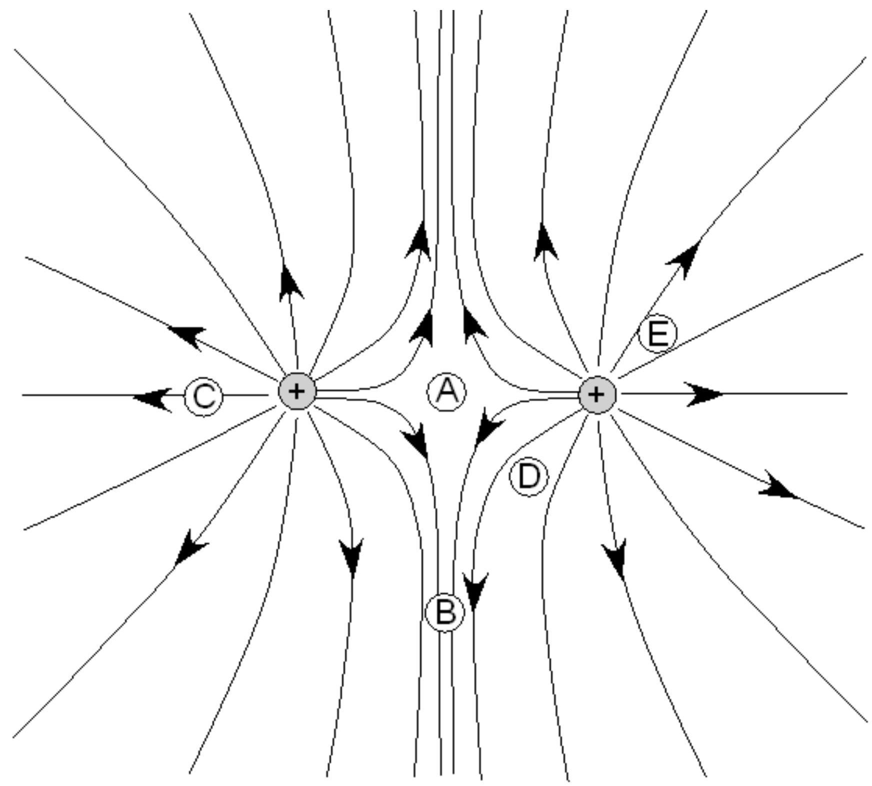
a) A

b) B

c) C

d) D

e) E



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a) A

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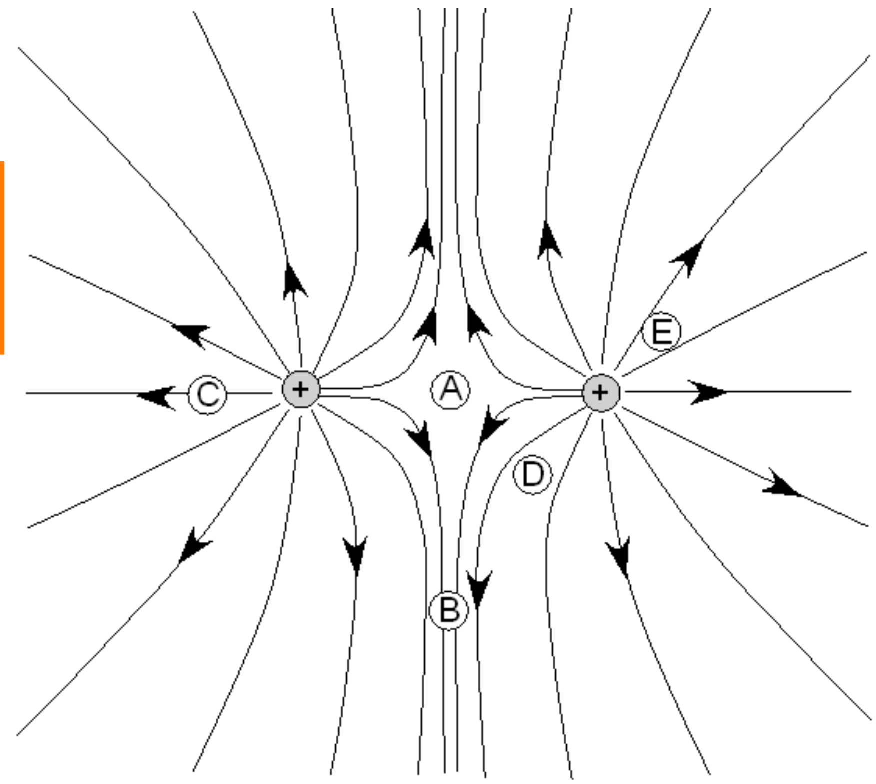
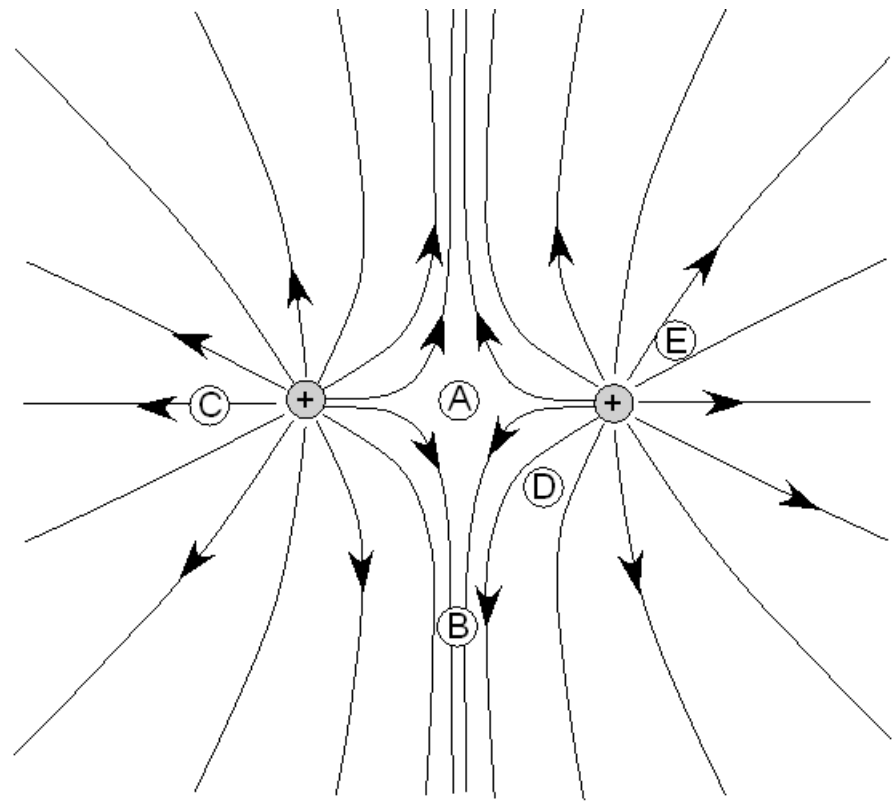
c) C

d) D

e) E



22.8.7. A positively charged object is located to the left of a negatively charged object as shown. Electric field lines are shown connecting the two objects. The five points on the electric field lines are labeled A, B, C, D, and E. At which one of these points would a test charge experience the smallest force?



a) A

b) B

c) C

d) D

e) E

22.8.7. A positively charged object is located to the left of a negatively charged object as shown. Electric field lines are shown connecting the two objects. The five points on the electric field lines are labeled A, B, C, D, and E. At which one of these points would a test charge experience the smallest force?

a) A

b) B

c) C

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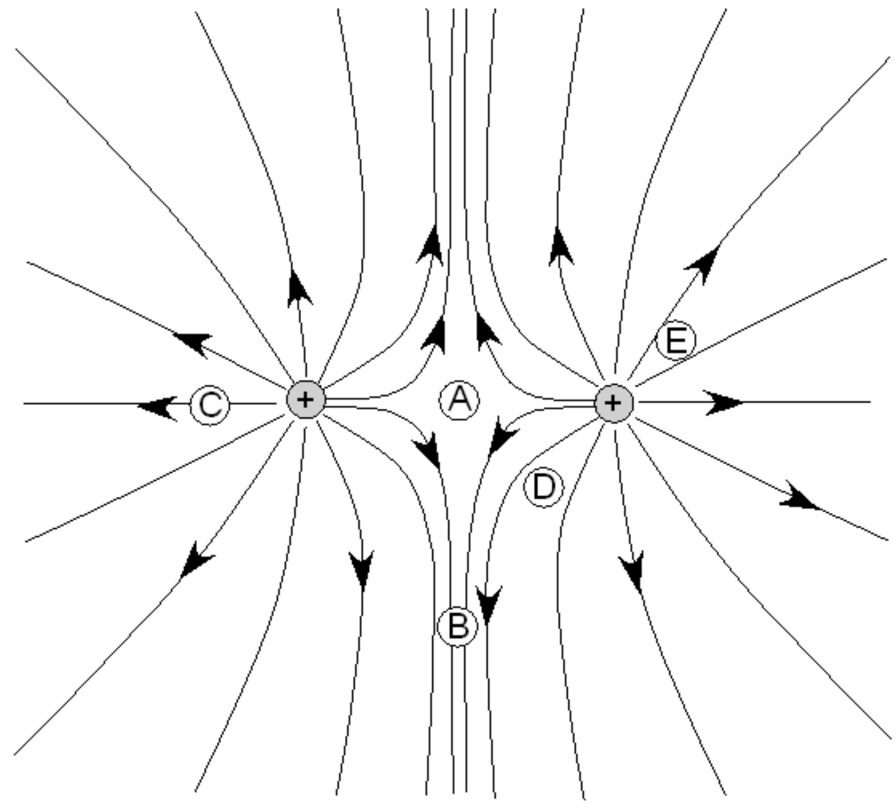
e) E



22.9.1. A single, positive test charge is brought near a dipole. Under what circumstances will the force exerted on the test charge by the dipole be given by $F = \dfrac{de^2}{2\pi\varepsilon_0 z^3}$?

a) the test charge is a much greater charge than that of the dipole

b) the test charge is a much smaller charge than that of the dipole

c) the test charge is very far from the dipole compared to the distance between the dipole charges

d) the test charge on a line that passes through the dipole axis

e) the test charge on a line is perpendicular to the dipole axis

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What Causes Lightening ?

Homework Problem Set #1 is available.

Due date: 2016.09.19