

Uniform Electric Fields and Potential



Lesson 5

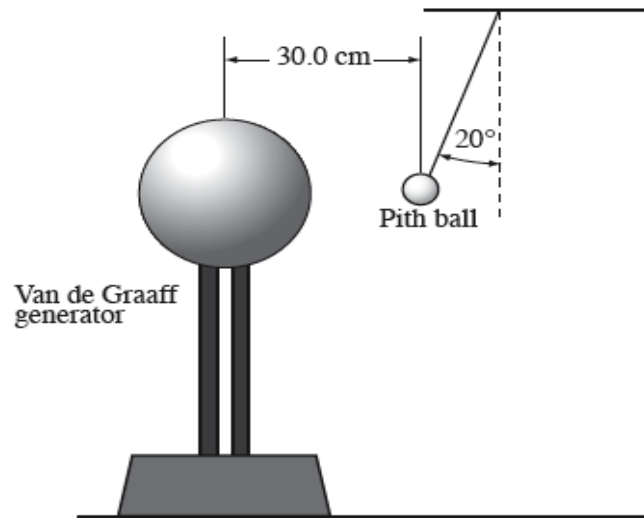
Objectives

- compare, qualitatively, gravitational potential energy and electric potential energy.
- define electric potential difference as a change in electric potential energy per unit of charge.
- calculate the electric potential difference between two points in a uniform electric field.
- explain, quantitatively, electric fields in terms of intensity (strength) and direction, relative to the source of the field and to the effect on an electric charge.

Diploma Question Alert!

Use the following information to answer the next four questions.

To determine the electric force on a 2.5×10^{-4} kg neutral pith ball, a student charges a Van de Graaff generator and suspends the pith ball by an insulating thread.



12. When the neutral pith ball is placed near the charged Van de Graaff generator, the pithball is attracted to the generator as a result of
- A. induction
 - B. grounding
 - C. conduction
 - D. induction and grounding

13. The direction of the electrical force on the pith ball is

A. \rightarrow

B. \leftarrow

C. \uparrow

D. \downarrow

14. The magnitude of the electrical force exerted on the pith ball by the charged Van de Graaff generator is

A. $2.5 \times 10^{-3} \text{ N}$

B. $2.3 \times 10^{-3} \text{ N}$

C. $8.9 \times 10^{-4} \text{ N}$

D. $8.4 \times 10^{-4} \text{ N}$

Numerical Response

6. The magnitude of the force between two charged particles that are a fixed distance apart is 3.80×10^{-4} N. If the distance between their centres is exactly doubled, then the magnitude of the force between the particles, expressed in scientific notation, is $a.bc \times 10^{-d}$ N. The values of a , b , c , and d are _____, _____, _____, and _____.

(Record all four digits of your answer in the numerical-response section on the answer sheet.)

18. The electric field strength 2.0×10^{-10} m from an alpha particle is
- A. 7.2 N/C
 - B. 14 N/C
 - C. 3.4×10^{10} N/C
 - D. 7.2×10^{10} N/C

14. The electric force between the particles is F newtons when they are 9.0 cm apart. They are moved toward each other until they are 6.0 cm apart. The force between them becomes

A. $\frac{2F}{3}$

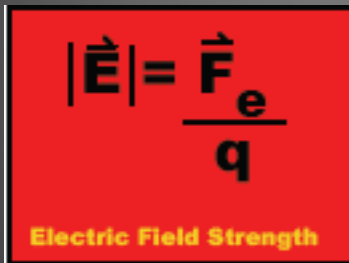
B. $\frac{3F}{2}$

C. $\frac{4F}{9}$

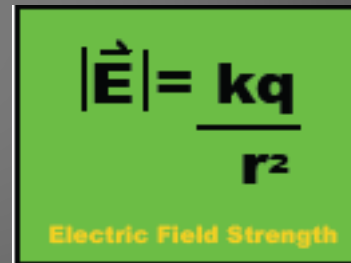
D. $\frac{9F}{4}$

Review: Electric Fields

- All charged objects produce electric fields
- The field moves in the same direction as a positive test charge would if placed in the field


$$|\vec{E}| = \frac{\vec{F}_e}{q}$$

Electric Field Strength


$$|\vec{E}| = \frac{kq}{r^2}$$

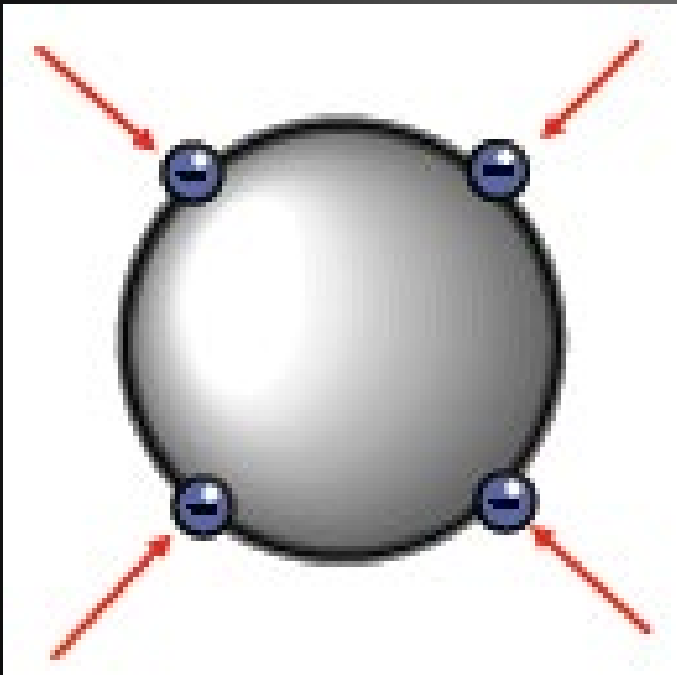
Electric Field Strength

Also:

- E-field lines due to a positive source start from the source and extend radially away from the charge to infinity.
- E-field lines due to a negative source come from infinity radially into the negative charge.
- The density of the line represents the magnitude of the field.

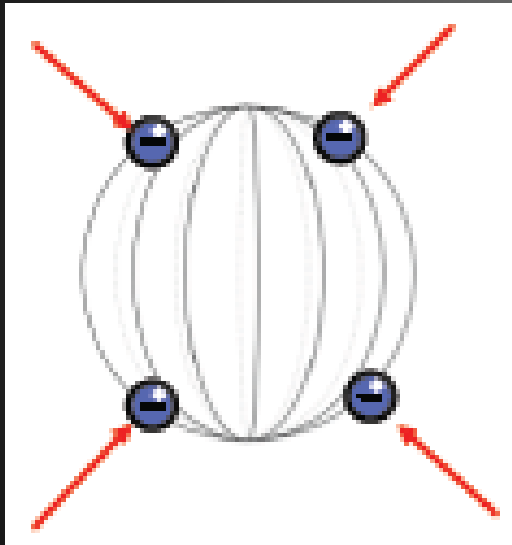
Electric Fields on Conducting Objects

Solid Conducting Spheres:



- Charge spreads out uniformly on smooth surfaces like a sphere due to repulsion. The field lines act at a perpendicular to the surface of the sphere.
- The Efield produced is like that of a point charge.

Hollow Conducting Spheres/Objects:



- Like a solid sphere, the charge (+ or -) will spread out uniformly.
- However, because of the balanced vector nature of the fields, there is no E -field inside the sphere.

- **This phenomenon led to the production of Faraday Cages: hollow objects which have a E -field of zero inside of them.**
- **No E -field means no charge acting inside the sphere/object!**



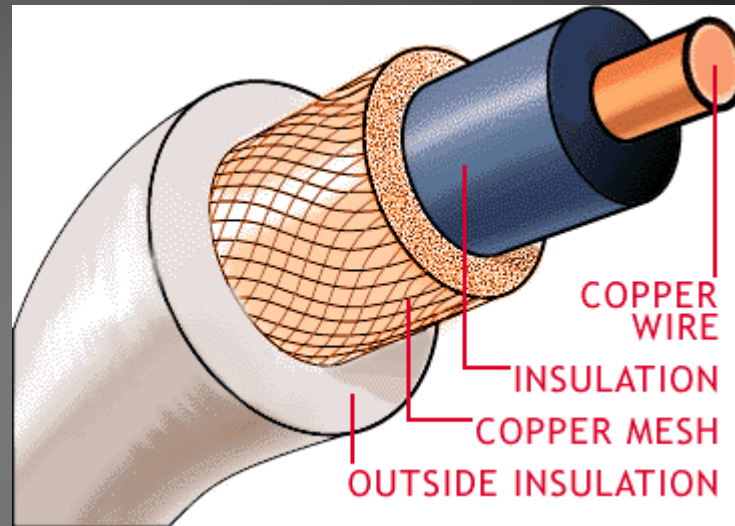
[YouTube 1](#)

[YouTube 2](#)

[YouTube 3](#)

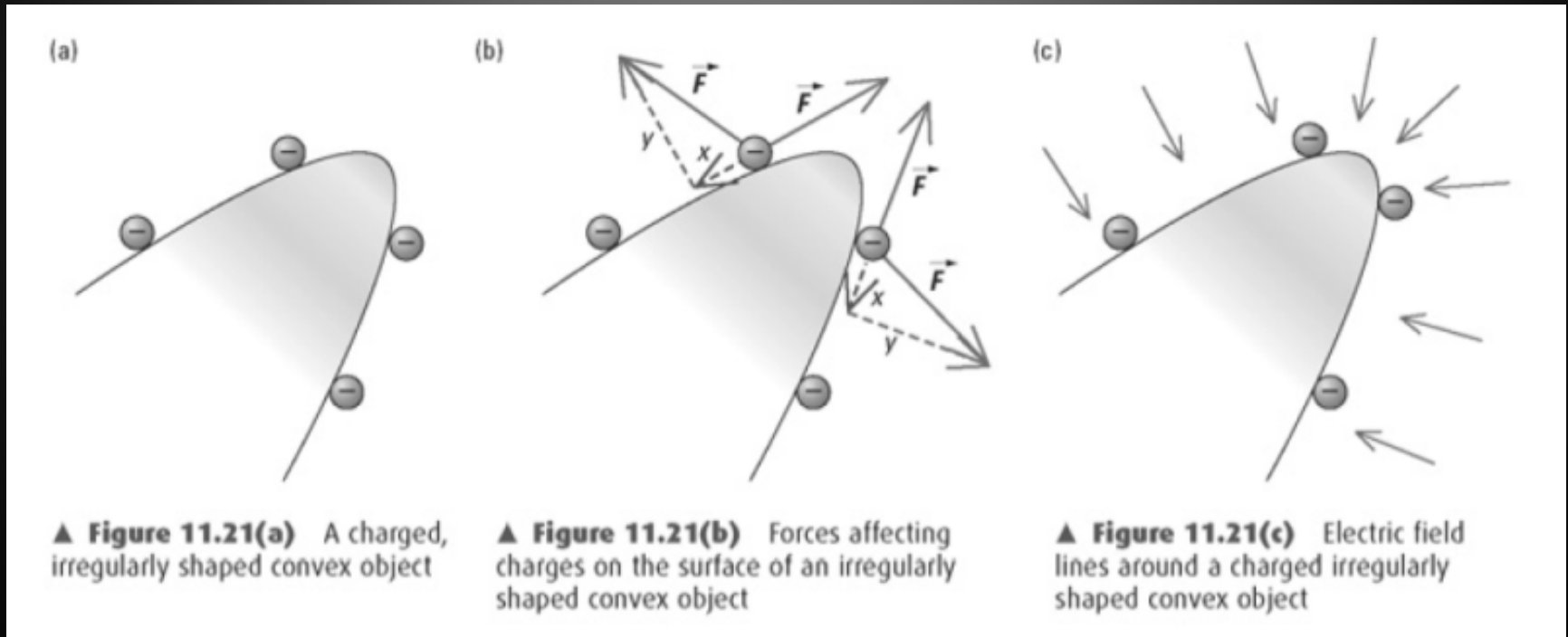
Coaxial Cable

- This electric shielding is put to use in coaxial cable which is found in many electronic devices.



Electric Fields on Pointed Objects

- Electric charge will collect on pointed objects, producing a higher density of field lines.



This can lead to some interesting effects...

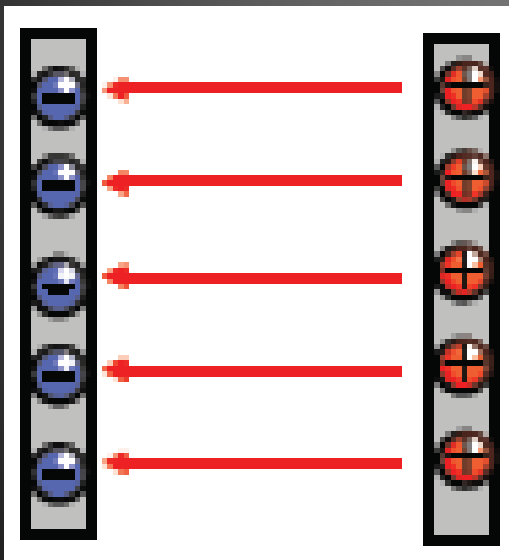
St. Elmo's Fire



- If the buildup of charge is great enough, it can discharge into the air, causing it to ionize. This hot ionized air is called plasma and ranges from white to bluish in colour.
- It is often observed on sailing ships or airplanes during thunderstorms.

Electric Fields on Parallel Plates

If two conducting plates are charged, a uniform E-field is produced between them.



- The field will be of uniform strength and spacing.
- Also, the field only exists between the plates (and to a small extent around the edges).

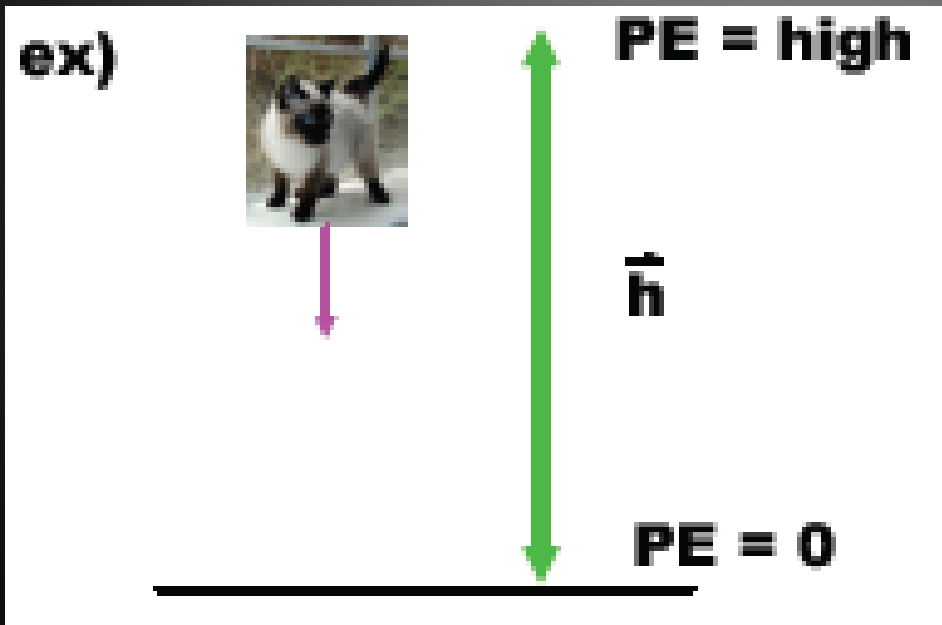
This is the basic principle behind a capacitor.

- Let's describe what is happening between these parallel plates.
- To do this, we need to take an aside and go back in time to Physics 20.
- Ahh, P20! Feel's Nice!
- We will look at the idea of Potential Energy Differences.



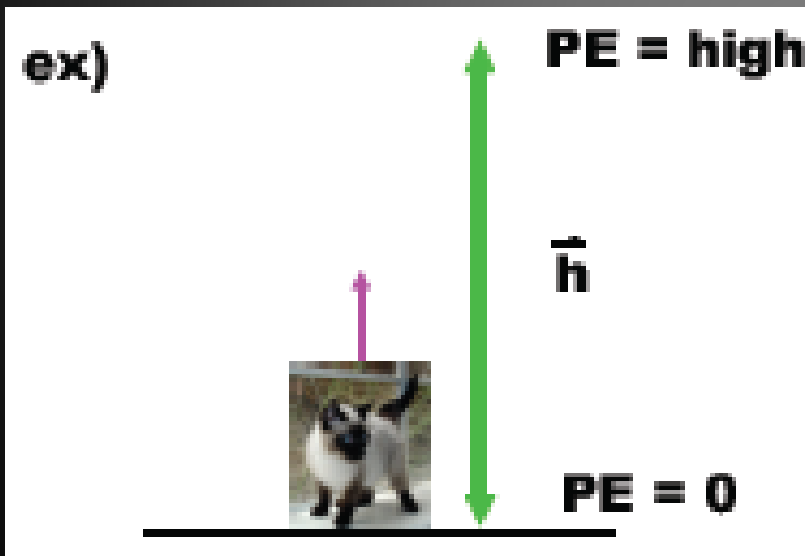
P20 Review:

- When I drop an object, it moves from an area of high E_p to low E_p .



This is due to the effect of the gravitational field.

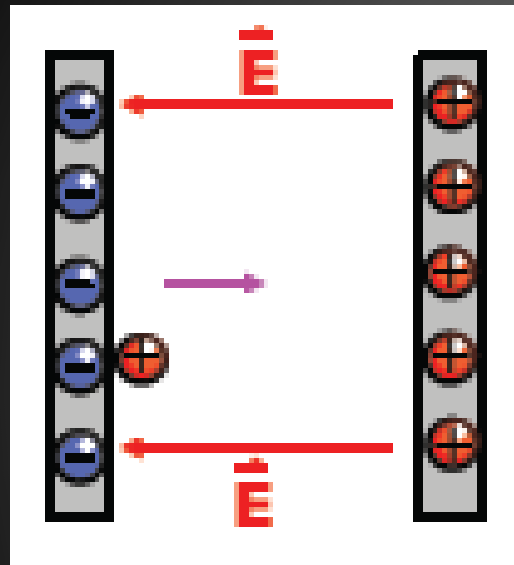
- In order to lift an object up from one area of low E_p to high E_p , we must expend energy in the form of work.



Work is a change in energy. It can also be represented by the eqn:

$$W = \vec{F} \cdot \vec{d}$$

Now, back to P30...



- If we move a charge against an E-field, we move it from an area of low E_p to high E_p .
- This must mean we are expending work.

$$W = \vec{F}\vec{d} \quad \text{and as } \vec{F} = q|\vec{E}|$$

$$W = q|\vec{E}|\vec{d}$$

This is the work needed to overcome the repulsive force between two charges.

where: W = work (J)

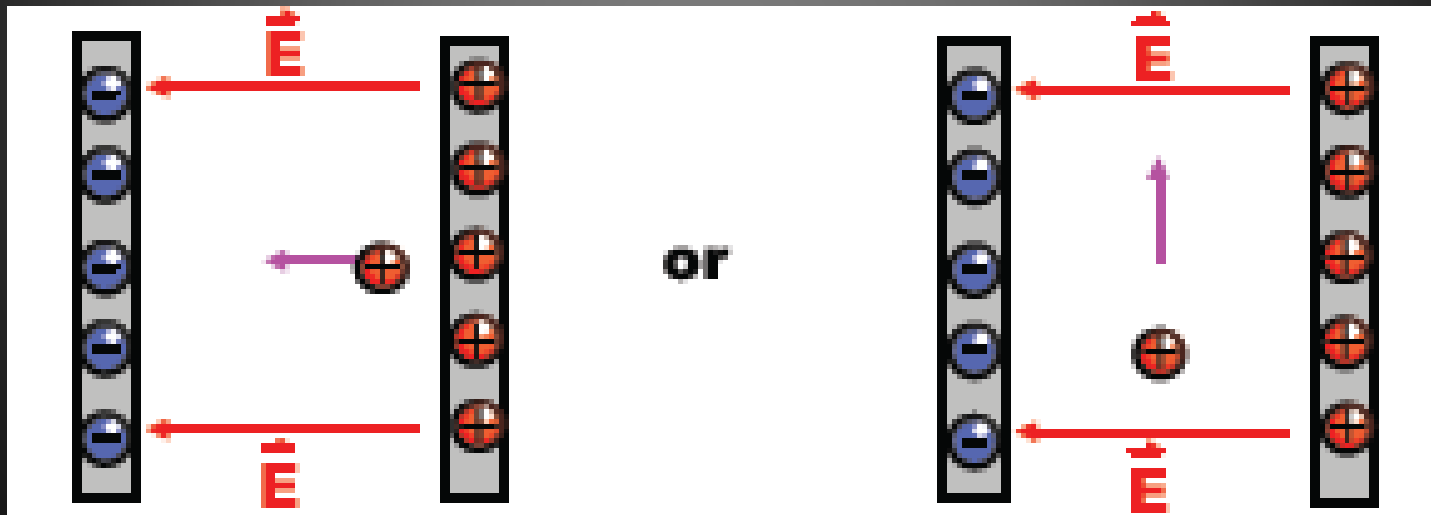
q = charge (C)

$|\vec{E}|$ = absolute value of electric field (N/C)

\vec{d} = displacement (m)



- Question: Does it require any work to move the charge with the field or perpendicularly to it?



- All this talk about work makes me think about energy...how do we describe energy when talking about electricity?
- In electricity, we talk about energy per unit of charge. Just as we described E-fields as the amount of force per unit of charge, we can describe the Potential Difference as the energy per unit of charge.

$$V = \frac{\Delta E}{q}$$

where: V = potential difference (J/C)

ΔE = change in energy potential (J)

q = charge (C)

Another name for potential difference is

Voltage

- The units of potential difference (voltage) can be expressed as J/C or volts (V). Yes, the unit is the same as the symbol...weird.
- *Note: like all energy, potential difference is a scalar!

$$V = \frac{\Delta E}{q}$$

Examples

- **Moving a small charge of $1.6 \times 10^{-19} \text{ C}$ against an electric field produced by parallel plates increases its electric potential energy by $3.2 \times 10^{-16} \text{ J}$. What is the potential difference between the plates?**

Examples

- **In moving a charge of 5.0 C from one charged parallel plate to another, a battery raises the electric potential energy of the charge by 60 J. Determine the potential difference between the battery terminals.**

- If we combine the two new equations for today, we can develop a relationship between the separation of the parallel plates and the electric field:

$$W = q|\vec{E}|d$$

$$V = \frac{\Delta E}{q}$$

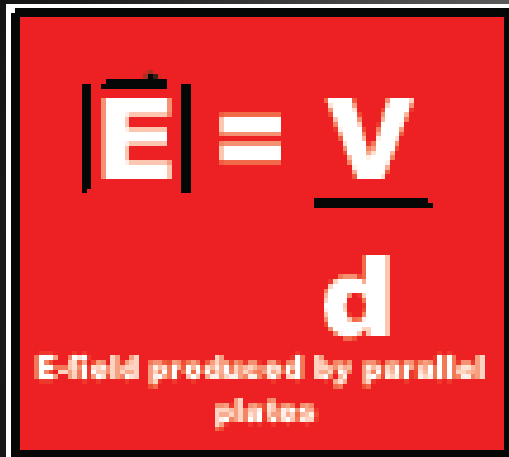
As work is a change in energy...

$$V = \frac{q|\vec{E}|d}{q}$$

$$|\vec{E}| = \frac{V}{d}$$

E-field produced by parallel plates

**This is only for parallel plates!

A red rectangular box with a black border. Inside, on the left, is a simple black and white diagram of a battery with a '+' sign on top. To the right of the battery is the equation $E = \frac{V}{d}$ in white text. Below the equation, the text 'E-field produced by parallel plates' is written in a smaller white font.

$E = \frac{V}{d}$
E-field produced by parallel plates

- This equation gives the magnitude of the **UNIFORM E-field** between charged parallel plates.
- If a charge is placed anywhere in between the plates, it will experience the same field.
- ****However, the voltage it experiences – and thus its energy – changes depending on its position!****

- **Two charged parallel plates are 4.0 cm apart. The magnitude of the E -field between them is 625 N/C.**
 - a) What is the potential difference between the plates?**
 - b) What work is done moving a single electron from one plate to the other?**
 - c) What work would it take to move a proton from one plate to another?**

- **A voltmeter measures the potential difference between two parallel plates to be 60.0 V. The plates are 3.00 cm apart. What is the magnitude of the E-field between them?**

The Electron Volt

- An electron volt (eV) is a very small unit of energy that is often used when dealing with individual particles. It is the amount of energy an electron gains or loses when moving through a potential difference of exactly 1.0 V.

$$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$$

- You will often encounter this unit in your journeys. The conversion is listed on your data sheet.