The major goals of this chapter are to enable you to:

1. Describe the nature of electric charges.
2. Distinguish conduction and induction.
3. Use Coulomb's law to find the force between charges.
4. Describe the characteristics of electricity.
5. Use Ohm's law to solve electric flow problems.
6. Use electrical symbols to describe circuits.
7. Find current, voltage, and resistance in simple circuits.
8. Describe the nature of cells and batteries.
9. Analyze circuits with cells in series and parallel.
10. Find electric power.

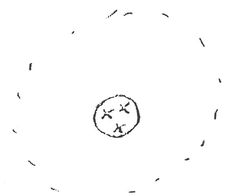
Electricity

- Electricity is the name given to a wide range of electrical phenomena, such as
  - lightning.
  - ~~spark when we strike a match~~.
  - what holds atoms together.

* الكهرباء هي اسم يطلق على مدى واسع من الظواهر الكهربائية مثل : ① الاضاءة ② ~~الشرارة~~ ③ ما يمسك الذرات مع بعض

- Electrostatics involves electric charges,
  - the forces between them,
  - ~~the aura that surrounds them, and~~
  - ~~their behavior in materials~~.

* الكهروستاتيكية تهتم وتتضمن الشحنات الكهربائية، من مثل :
① القوة بين هذه الشحنات
② ~~المجال المحيط بالشحنات~~
③ ~~تصرفه بالمواد~~.



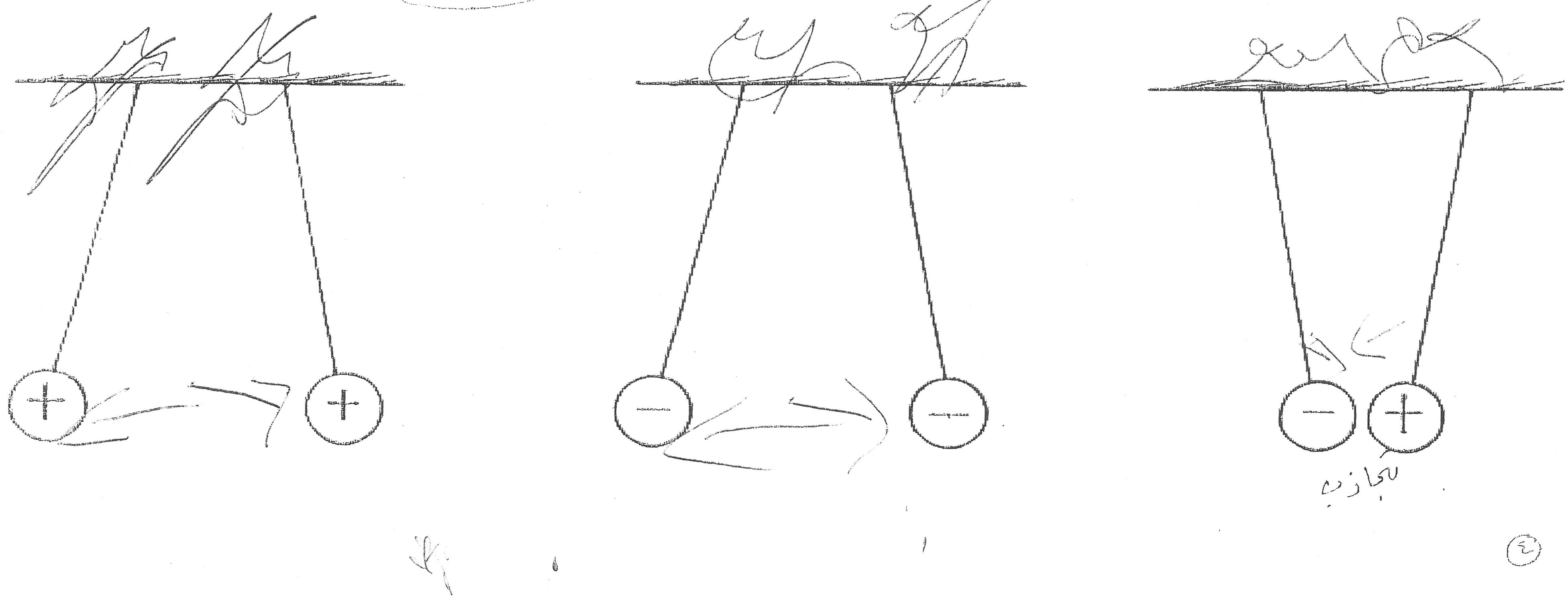
* يقصد بالكهروستاتيكية الكهرباء الساكنة.

(٣)

Electric Force and Charges

Central rule of electricity

- Opposite charges attract one another; like charges repel.



Electric Force and Charges

Protons

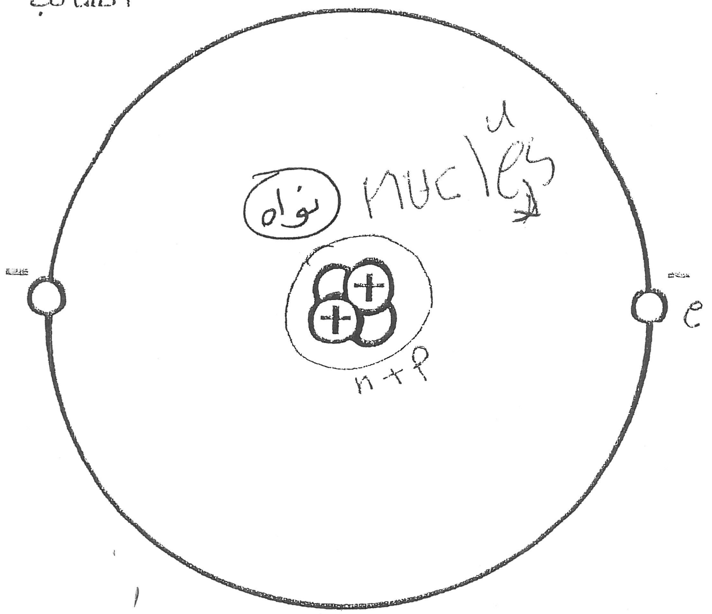
- Positive electric charges
- Repel positives, but attract negatives

Electrons

- Negative electric charges
- Repel negatives, but attract positives

Neutrons

- Neutral electric charge



Electric Force and Charges

الكهربائية القوة و الشحنة

* حقائق اساسية حول الذرات

Fundamental facts about atoms

1. Every atom is composed of a positively charged nucleus surrounded by negatively charged electrons.
2. Each of the electrons in any atom has the same quantity of negative charge and the same mass.

① كل ذرة تتألف من نواة موجبة الشحنة محاطة بـ الكترونات سالبة الشحنة

② كل من الالكترونات في أي ذرة لها نفس المقدار من الشحنة ونفس الكتلة

③ البروتونات والنيترونات تؤلف النواة. حيث أن كتلة البروتون تعادل (1800) مرة ضعف كتلة الالكترون. لكنه مقدار شحنة البروتون تساوي مقدار شحنة الالكترون.

ملاحظة: كتلة النيترون اكبر قليلاً من كتلة البروتون، وليس لها شحنة

④ الذرة عادة تحتوي على عدد بروتونات مساوي لعدد الالكترونات. لذلك محايدة الشحنة

$m_n > m_p > m_e$

Electric Force and Charges

Fundamental facts about atoms (continued)

3. Protons and neutrons compose the nucleus. Protons are about 1800 times more massive than electrons, but each one carries an amount of positive charge equal to the negative charge of electrons. Neutrons have slightly more mass than protons and have no net charge.

4. Atoms usually have as many electrons as protons, so the atom has zero net charge.

البروتونات لديها (1800) ضعف اكثر كتله من كتلة الالكترونات .

ولكن مقدار شحنه البروتونات يساوي مقدار شحنه الالكترونات .

مختلفين بالكتله

ومتساوين في عدد الشحنات ،

Electric Force and Charges

الشحنات و القوة الكهربائية

Ion

- Positive ion—atom losing one or more electrons has positive net charge.
- Negative ion—atom gaining one or more electrons has negative net charge.

* الايون الموجب : ذرة فقدت واحد أو أكثر من الالكترونات لذا لها محصلة شحنة موجبة.

* الايون السالب : ذرة كسبت الكترون واحد أو أكثر لذلك لها محصلة شحنة سالبة.

Electric Force and Charges

Electrons in an atom

- Innermost—attracted very strongly to oppositely charged atomic nucleus
- Outermost—attracted loosely and can be easily dislodged

* الالكترونات الداخلية (القريبة من النواة) ترتبط بقوة الى النواة موجبة الشحنة

* الالكترونات الخارجية (البعيدة) ترتبط بقوة أقل لذلك يسهل على الذرة فقدها

Electric Force and Charges

Electrons in an atom

Examples:

- When rubbing a comb through your hair, electrons transfer from your hair to the comb. Your hair has a deficiency of electrons (positively charged).
- When rubbing a glass rod with silk, electrons transfer from the rod onto the silk and the rod becomes positively charged.

* وكمثال: عندما تقوم بدلك مشط خلال شعرك . فإن الالكترونات تنتقل من شعرك الى المشط . لذلك شعرك تنقص عليه الالكترونات لذلك تصبح شحنته موجبة

* وكمثال: عندما تدلك قضيب من الزجاج مع الحرير . فإن الالكترونات تنتقل من القضيب الى الحرير . لذلك تصبح للقضيب شحنة موجبة

Coulomb's Law

Coulomb's law

- Relationship among electrical force, charge, and distance discovered by Charles Coulomb in the 18th century
- States that for a pair of charged objects (q_1 and q_2) that are much smaller than the distance (d) between them, the force between them varies directly, as the product of their charges, and inversely, as the square of the separation distance

Coulomb's Law

Coulomb's law (continued)

- If the charges are alike in sign, the force is repelling; if the charges are not alike, the force is attractive.
- In equation form:

$$F = k\frac{q_1 q_2}{d^2} \qquad k = 9{,}000{,}000{,}000\ Nm^2/C^2$$

- Unit of charge is coulomb, C
- ~~Similar to Newton's law of gravitation for masses~~
- Underlies the bonding forces between molecules

Electric Field

Electric field

- Space surrounding an electric charge (an energetic aura)
- ~~Describes electric force~~
- ~~Around a charged particle obeys inverse-square law~~
- Force per unit charge (unit: N/C)

If a body with charge q experiences a force F at some point in space, then the electric field E at that point is

$$E = \frac{F}{q}$$

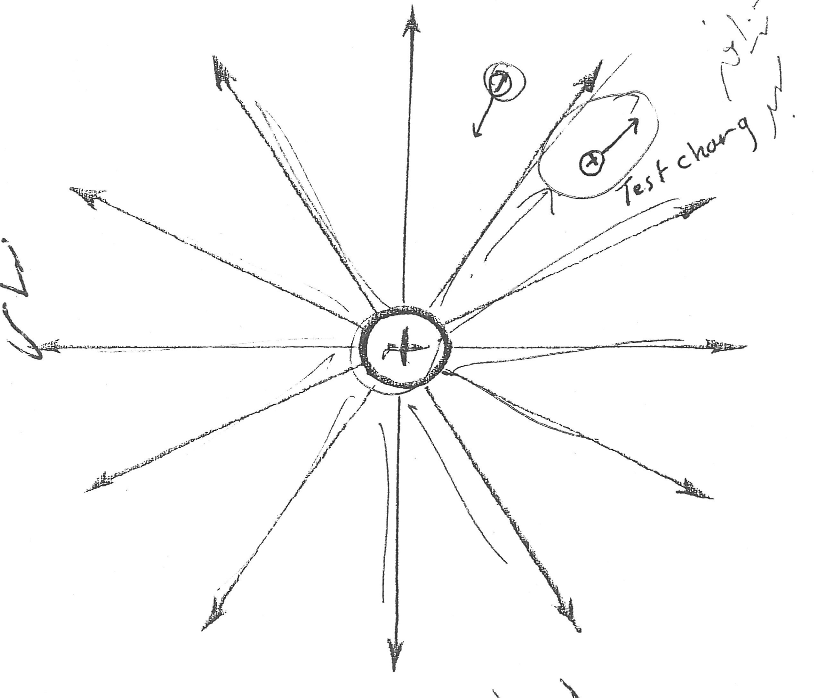
Electric Field

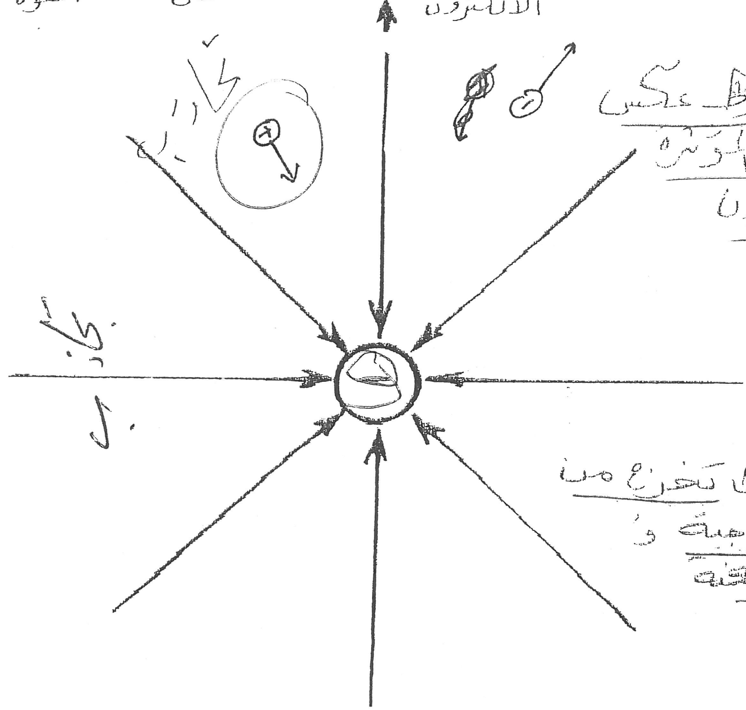
المجال الكهربائي

* يكون اتجاه المجال الكهربائي حسب القوة المؤثرة على شحنة الاختبار (Test charge)
* شحنة الاختبار هي شحنة صغيرة موجبة

Electric field direction

- Same direction as the force on a small positive test charge
- Opposite direction to the force on an electron





* خطوط المجال عكس اتجاه القوة المؤثرة على الالكترون
* خطوط المجال تخرج من الشحنة الموجبة و تدخل في الشحنة السالبة

EXAMPLE 4.1

Two charges, each with magnitude $+6.50\ \mu C$, are separated by a distance of 0.200 cm. Find the force of repulsion between them.

Data:

$$q_1 = q_2 = +6.50\ \mu C = +6.50 \times 10^{-6}\ C$$

$$r = 0.200\ cm = 0.00200\ m = 2.00 \times 10^{-3}\ m$$

$$k = 9.00 \times 10^{9}\ N\,m^2/C^2$$

$$F = ?$$

Basic Equation:

$$F = \frac{kq_1q_2}{r^2}$$

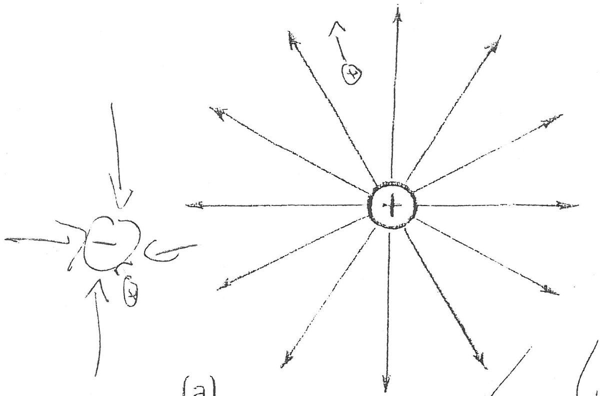
Working Equation: Same

Substitution:

$$F = \frac{(9.00 \times 10^{9}\ N\,m^2/C^2)(6.50 \times 10^{-6}\ C)(6.50 \times 10^{-6}\ C)}{(2.00 \times 10^{-3}\ m)^2}$$

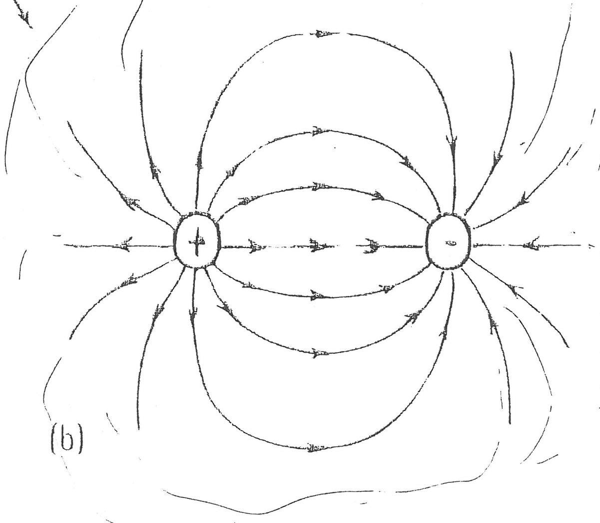
$$= 9.51 \times 10^{4}\ N$$

Some electric-field configurations.



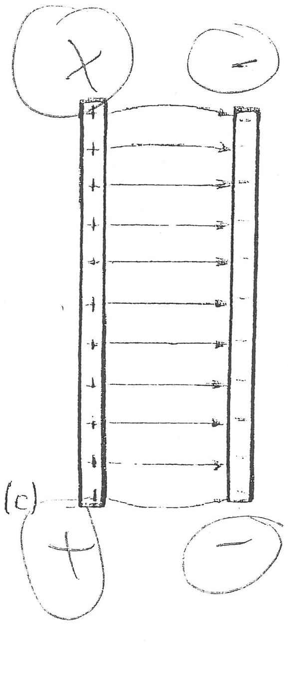
(a)

(a) Lines of force emanating from a single positively charged particle.



(b)

(b) Lines of force for a pair of equal but oppositely charged particles. Note that the lines emanate from the positive particle and terminate on the negative particle.



(c)

(c) Uniform lines of force between two oppositely charged parallel plates.

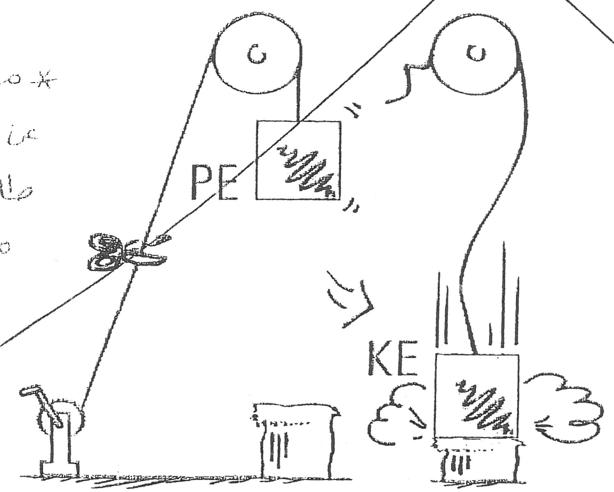
* المجال الكهربائي المنتظم يمكنه الحصول عليه بين لوحين متوازيين مشحونين

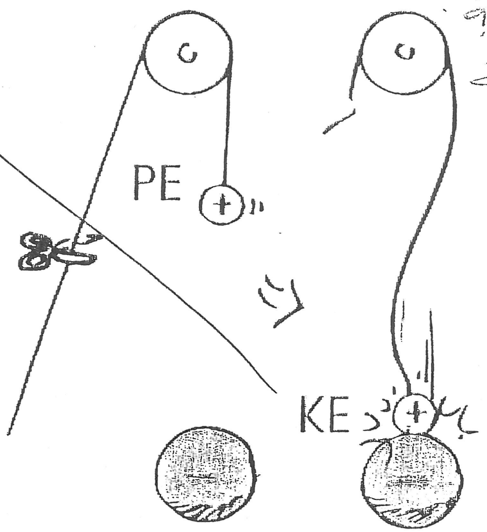
Electric Potential

Electric potential energy (unit: Joule (J))

- Energy possessed by a charged particle due to its location in an electric field. Work is required to push a charged particle against the electric field of a charged body.

* ملاحظة: الجسم المرفوع عن سطح الأرض امتلك طاقة الوضع له بسبب وجود مجال الجذب الأرضي. وينطبق ذلك على الشحنات



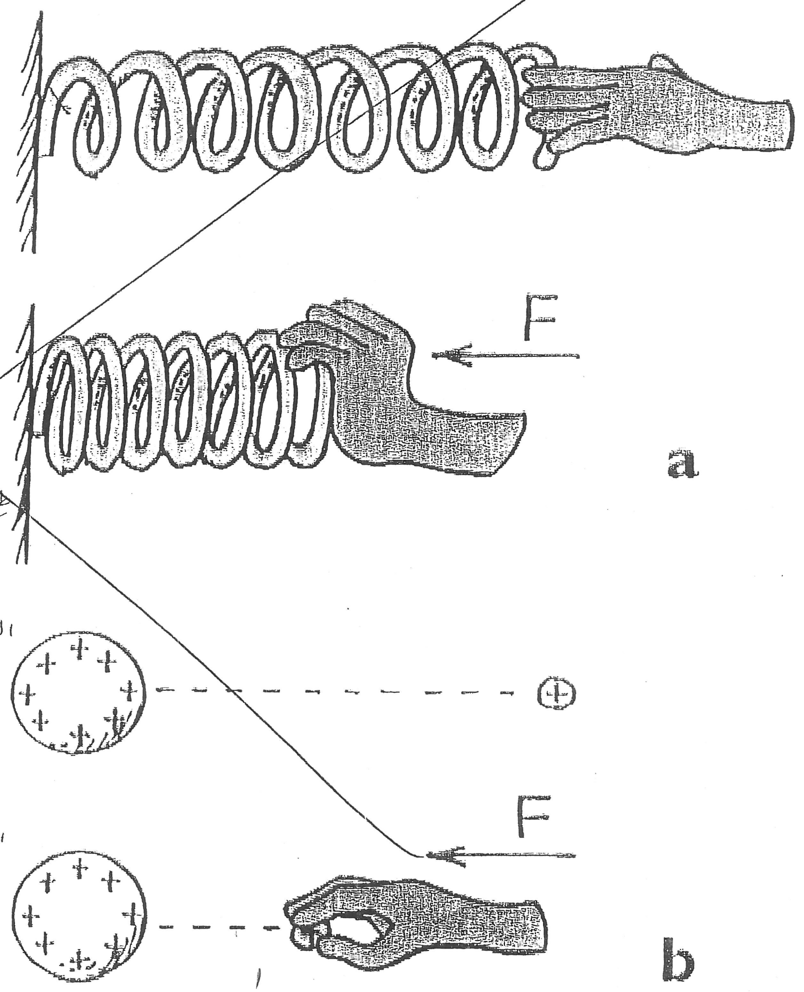


* طاقة الوضع الكهربائية هي الطاقة التي تملكها الشحنة من خلال موضعها في المجال الكهربائي لشحنة أخرى

Electric Potential

الجهد الكهربائي

* كذلك تعتمد طاقة الوضع الكهربائية على موقع الشحنة في المجال الكهربائي



(a) The spring has more elastic PE when compressed. (b) The small charge similarly has more PE when pushed closer to the charged sphere. In both cases, the increased PE is the result of work input.

Electric Potential

Electric potential (voltage)

- Energy per charge possessed by a charged particle due to its location
- ~~May be called *voltage* — potential energy per charge~~
- In equation form:

$$\text{Electric potential} = \frac{\text{electric potential energy}}{\text{amount of charge}}$$

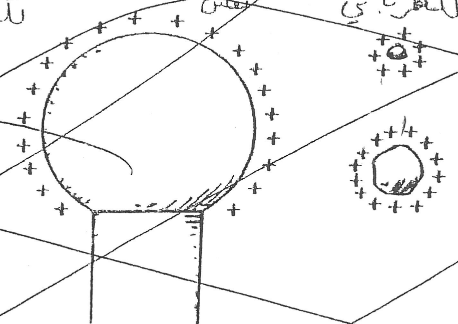
Electric Potential

Electric potential (voltage) (continued)

- Unit of measurement: volt, $1 \text{ volt} = \dfrac{1 \text{ joule}}{1 \text{ coulomb}}$

Example:

- Twice the charge in same location has twice the electric potential energy but the same electric potential.



- 3 times the charge in same location has 3 times the electric potential energy but the same electric potential ($2E/2q = 3E/3q = V$)

Electric Potential
CHECK YOUR NEIGHBOR

Electric potential energy is measured in joules. Electric potential, on the other hand (electric potential energy per charge), is measured

A. in volts.
B. in watts.
C. in amperes.
D. also in joules.

$$V = \frac{E_p}{q}$$

$$V = \frac{J}{C} = V$$

Electric Potential
CHECK YOUR ANSWER

Electric potential energy is measured in joules. Electric potential, on the other hand (electric potential energy per charge), is measured

A. **in volts.**

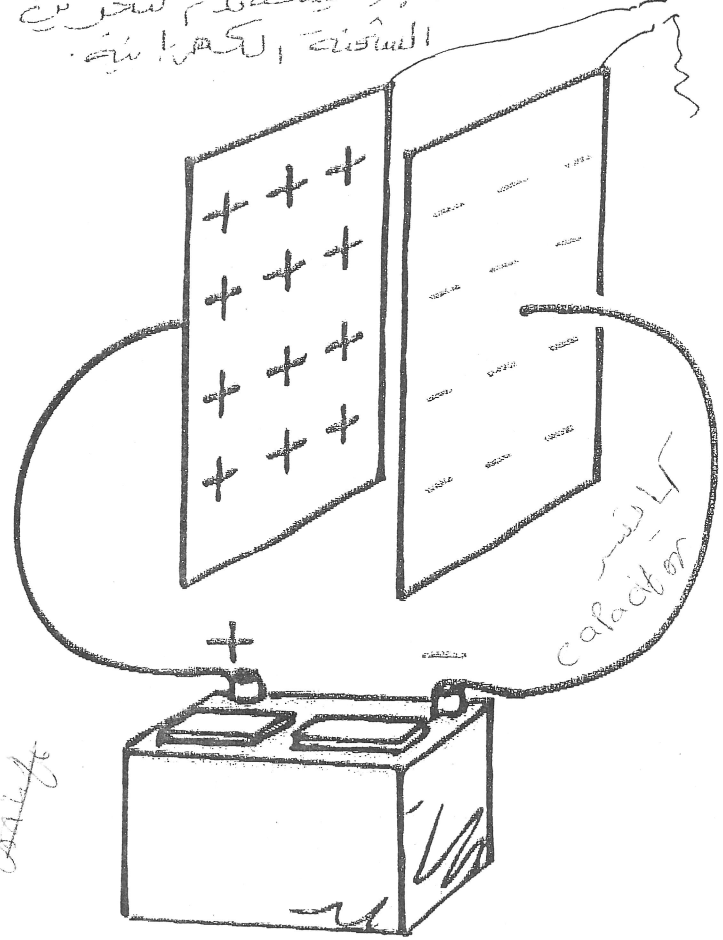
B. in watts.

C. in amperes.

D. also in joules.

Electric Energy Storage

- Electrical energy can be stored in a common device called a **capacitor.**
- The simplest capacitor is a pair of conducting plates separated by a small distance, but not touching each other.
- When the plates are connected to a charging device, such as the battery, electrons are transferred from one plate to the other.



* المكثف: جهاز يستخدم لتخزين الشحنة الكهربائية.

* أبسط مكثف تكون من زوج من الالواح الموصلة، مفصوله بمسافة، لكن لا تتلامس مع بعضها

* عندما يتم وصل الالواح مع جهاز شاحن مثل البطارية، فإن الالكترونات تنتقل من أحد الالواح للآخر

metal plate (conductor) لوح معدني (موصل)

Plate لوح

e.g. metal معدن

Conductor موصل

Electric Energy Storage

- This occurs as the positive battery terminal pulls electrons from the plate connected to it.
- These electrons, in effect, are pumped through the battery and through the negative terminal to the opposite plate.
- The capacitor plates then have equal and opposite charges:
  - The positive plate connected to the positive battery terminal, and
  - The negative plate connected to the negative terminal.

* عملية شحنة لوحي المكثف تعني سحب الالكترونات من اللوح السالب ثم دفعها الى اللوح الموجب.
* لوحي المكثف تحتوي على نفس مقدار الشحنة، لكن متعاكسي النوع (+) و(−)
* ملاحظة: اللوح الذي يوصل مع القطب الموجب يصبح موجب، والذي يوصل مع القطب السالب يصبح سالب

القوة الدافعة الكهربائية (emf)

emf "electromotive force" → القوة الدافعة الكهربائية

"Volt" → فولت

voltage → الفولطية

Potential difference → فرق الجهد

Potential drop → هبوط الجهد

voltage → الفولطية

electromotive force (emf) → القوة الدافعة الكهربائية

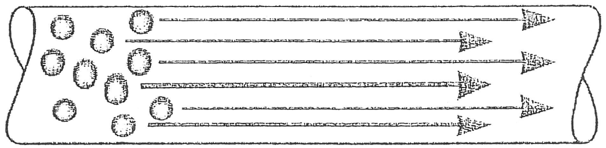
فولت = Volt

Electric Current

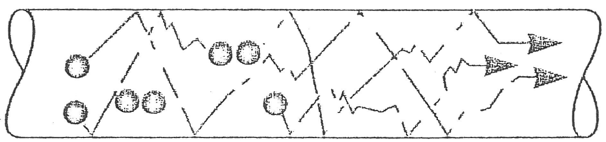
Rate of electric flow

- Measured in ampere (1 coulomb of charge per second).
- ~~Speed of electrons (drift speed) through a wire is slow because of continuous bumping of electrons in wire.~~
- ~~Charge flows *through* a circuit; voltage is established *across* a circuit.~~

$$1 \text{ ampere (A)} = \frac{1 \text{ coulomb (C)}}{1 \text{ second (s)}}$$



(a) Good conductor



(b) Poor conductor

VOLTAGE

The *potential difference* between two points in an electric field is the work done per unit of charge as the charge is moved between two points. That is,

$$\text{potential difference} = \frac{\text{work}}{\text{charge}}$$

$$V = \frac{W}{q}$$

In *sources*, the raising of the potential energy of electrons that results in a potential difference across a source is called **emf** (*E*). In *circuits*, the lowering of the potential difference across a load is called **voltage drop**.

The *volt* (V), named after **Allessandro Volta**, is the unit of both emf and voltage drop. We define the volt as the potential difference between two points if 1 J of work is produced or used in moving 1 C of charge from one point to another:

$$1 \text{ volt (V)} = \frac{1 \text{ joule (J)}}{1 \text{ coulomb (C)}}$$

(٢٦)

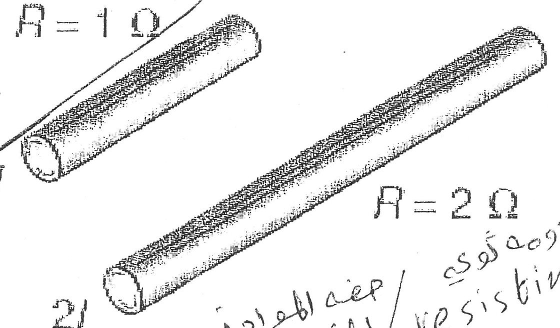
RESISTANCE

The opposition to current flow is called **resistance**. The unit of resistance is the *ohm* (Ω).

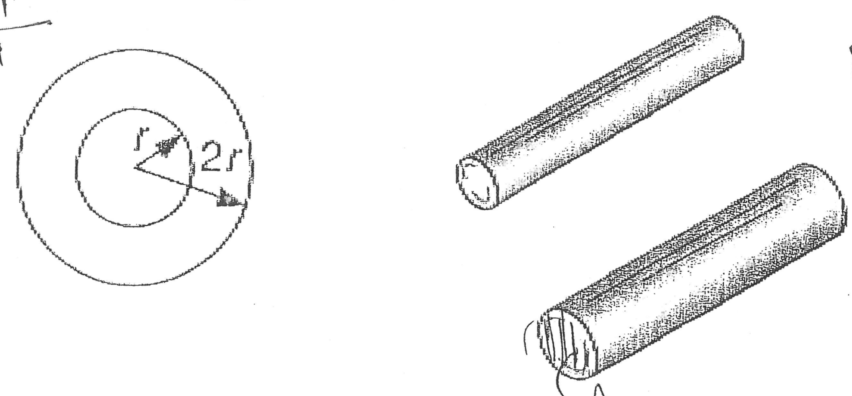
The resistance of a wire depends mainly on its length (L), cross-sectional area (A) and a property of the material called resistivity.

These factors are related by the equation

$$R = \frac{\rho l}{A}$$



(a) Resistance varies directly with length.



(b) Doubling the radius more than doubles the cross-sectional area.

EXAMPLE 4.2

Find the resistance of a copper wire 20.0 m long with cross-sectional area of $6.56 \times 10^{-3}\ \text{cm}^2$ at 20°C. The resistivity of copper at 20°C is $1.72 \times 10^{-6}\ \Omega\ \text{cm}$.

Data:

$$l = 20.0\ \text{m} = 2.00 \times 10^3\ \text{cm}$$

$$A = 6.56 \times 10^{-3}\ \text{cm}^2$$

$$\rho = 1.72 \times 10^{-6}\ \Omega\ \text{cm}$$

$$R = ?$$

Basic Equation:

$$R = \frac{\rho l}{A}$$

Working Equation: Same

Substitution:

$$R = \frac{(1.72 \times 10^{-6}\ \Omega\ \text{cm})(2.00 \times 10^3\ \text{cm})}{6.56 \times 10^{-3}\ \text{cm}^2}$$

$$= 0.524\ \Omega$$

Ohm's Law

Ohm's law

$$I = \frac{V}{R}$$

where I = current through the resistance

V = voltage drop across the resistance

R = resistance

Ohm's law can also be written

$$I = \frac{E}{R}$$

where E = emf of the source of electrical energy

EXAMPLE 4.3

A heating element on an electric range operating on 240 V has a resistance of 30.0 Ω. What current does it draw?

Data:

$$E = 240\ \text{V}$$
$$R = 30.0\ \Omega$$
$$I = ?$$

Basic Equation:

$$I = \frac{E}{R}$$

Working Equation: Same

Substitution:

$$I = \frac{240\ \text{V}}{30.0\ \Omega}$$
$$= 8.0\ \text{V}/\Omega$$
$$= 8.0\ \text{A}$$

$$\boxed{\frac{\text{V}}{\Omega} = \text{A}}$$

Electric Power

The rate of consuming energy is called **power.**

Unit = ***Watt*** (W)

$$P = VI \Rightarrow VA = \frac{J}{C} \cdot \frac{C}{s} = \frac{J}{s}$$

P = power (watts)

V = voltage drop (V)

I = current (A)

Thus, 1 W = 1 J/s

Since the watt is a relatively small unit, the kilowatt (1 kW = 1000 W) is commonly used in industry.

Electric Power

Recalling Ohm's law, $I = V/R$, we find two other equations for power:

Given

$$P = VI$$

substitute for V using $V = IR$ to obtain

$$P = (IR)I = I^2R$$

$$\boxed{P = I^2R}$$

Note from the following unit analysis that amps squared times ohms gives watts:

$$\boxed{A^2\,\Omega = A^2 \cdot \frac{V}{A} = AV = \frac{C}{s} \cdot \frac{J}{C} = \frac{J}{s} = W}$$

$$I = \frac{V}{R} \Rightarrow P = I^2R \Rightarrow P = \left(\frac{V}{R}\right)^2 R = \frac{V^2}{R^2} \cdot R \Rightarrow \boxed{P = \frac{V^2}{R}}$$

EXAMPLE

A soldering iron draws 7.50 A in a 115-V circuit. What is its wattage rating?

Data:

$$I = 7.50\ A$$
$$V = 115\ V$$
$$P = ?$$

Basic Equation:

$$P = VI$$

Working Equation: Same

Substitution:

$$P = (115\ V)(7.50\ A)$$
$$= 863\ W$$

Therefore, a soldering iron drawing 7.50 A in a 115-V circuit has a rating of 863 W.

EXAMPLE 4.5

A hand drill draws 4.00 A and has a resistance of 14.6 Ω. What power does it use?

Data:

$$I = 4.00\ \text{A}$$
$$R = 14.6\ \Omega$$
$$P = ?$$

Basic Equation:

$$P = I^2R$$

Working Equation: Same

Substitution:

$$P = (4.00\ \text{A})^2(14.6\ \Omega)$$
$$= 234\ \text{W}$$

Thus, a drill that draws 4.00 A with a resistance of 14.6 Ω has a rating of 234 W.

* من تعريف   ٤ - ٢

* حساب الطاقة الكهربائية المستهلكة .

The amount of energy consumed is

$$\text{energy} = \text{power} \times \text{time}$$

$E = P \cdot t$

$$\text{energy (in kWh)} = (VI)t$$

$$\text{number of kWh} = VIt$$

V (in volts), I (in Amperes), and t (in seconds)

$1J = watt \cdot s$

$\frac{KW}{1000} \cdot \frac{h}{3600}$ ⟹ $1 Kw \cdot h = 3.6 MJ$.

حساب التكاليف

* تعتمد شركات الكهرباء وحدة لحساب الطاقة الكهربائية تسمى (k.w.h).

* ولحساب تكاليف تشغيل أي جهاز كهربائي

التكاليف = P × t × التعرفة Reat.
(الكيلوواط) (بالساعة) (للكيلوواط ساعة)

The cost of operating an electric device may be found as follows:

$$\text{cost} = \text{energy} \times \text{cost per unit energy}$$

$$\text{cost} = (\text{kWh})\left(\frac{\text{cents}}{\text{kWh}}\right)$$

Halala (h) in KSA هللة

price 0.05 SAR / Kwh

① 40/1000 = 0.04 kw
② t = 30 × 24 = 720 h
③ Kwh = 0.04 × 720 = 28.8 Kwh
④ Kwh = 28.8 ⟹ price = 28.8 × 0.05 SAR

$$\text{cost (in cents)} = \text{power (in W)} \times \text{hours} \times \frac{1\ \text{kW}}{1000\ \text{W}} \times \frac{\text{cents}}{\text{kWh}}$$

conversion factor

price calculations?

حسابات سعر الكهرباء

Kw.h كيلوواط.س

① Find the number of Kw.
② " " " in (h)
③ multiply (Kw.h) (①, ②)
④ multiply (Kwh) by the price (#/Kw.h

price in SAR

الشركة السعودية للكهرباء
Saudi Electricity Company

فاتورة إستهلاك الطاقة الكهربائية

إدارة كهرباء — منطقة حائل
مكتب خدمات — حائل

رقم الفاتورة	6[illegible]
بداية الفترة	1431/10/17
نهاية الفترة	1431/11/15

رقم الحساب	[illegible]
المبلغ المطلوب	1937.49
آخر موعد للسداد	

تاريخ الفاتورة	1431/11/18
تاريخ التوزيع	1431/11/19
تاريخ فصل الكهرباء	

التيار متصل

رقم الاشتراك	[illegible]	
رقم العداد	[illegible]	
سعة القاطع	60	
القراءة الحالية	3942	
القراءة السابقة	98717	
معامل الضرب	1	
كمية الإستهلاك	5225	
إجمالي الإستهلاك	5225	
نوع التعرفة	سكني	
رقم المنطقة	أبو الرمزي 16	

قيمة الاستهلاك	459.06
خدمة العداد	10
إستحقاق الفترة	469.06
رصيد سابق	1468.43
عدد الأيام	28
رصيد دائن	0
المبلغ المطلوب	1937.49

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شرائح الإستهلاك السكنية

فئة	ك.و.س
5	1 - 2000
10	2001 - 4000
12	4001 - 6000
15	6001 - 7000
20	7001 - 8000
22	8001 - 9000
24	9001 - 10 000
26	أكثر من 10 000

الفئة بالهللة لكل كيلو وات ساعة

شرائح الإستهلاك السكنية

فئة	ك.و.س
5	1 - 2000
10	2001 - 4000
12	4001 - 6000
15	6001 - 7000
20	7001 - 8000
22	8001 - 9000
24	9001 - 10 000
26	أكثر من 10 000

Example:
1500 kw.h ⇒ 1500 kw.h × 5h = 75 RS

تفويض بنكي:

السادة بنك ---------------------
أرجو خصم قيمة هذه الفاتورة من حسابي لديكم رقم: -----------

رقم الحساب	رقم الفاتورة	تاريخ الفاتورة
[illegible]	[illegible]	1431/11/18
المبلغ المطلوب	1937.49	

قسيمة تحصيل

رقم الحساب	رقم الفاتورة	تاريخ الفاتورة
[illegible]	[illegible]	1431/11/18
المبلغ المطلوب	1937.49	

An iron is rated at 550 W. How much would it cost to operate it for 2.50 h at \$0.08/kWh?

Data:

$$P = 550\ \text{W}$$

$$t = 2.50\ \text{h}$$

$$\text{rate} = \$0.08/\text{kWh}$$

$$\text{cost} = ?$$

Basic Equation:

$$\text{cost} = Pt\left(\frac{1\ \text{kW}}{1000\ \text{W}}\right)\left(\frac{\text{cents}}{\text{kWh}}\right)$$

Working Equation: Same

Substitution:

$$\text{cost} = (550\ \text{W})(2.50\ \text{h})\left(\frac{1\ \text{kW}}{1000\ \text{W}}\right)\left(\frac{\$0.08}{\text{kWh}}\right)$$

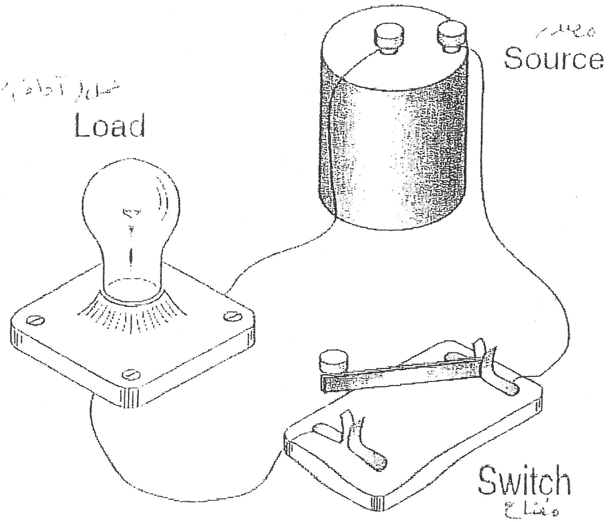
$$= \$0.11$$

Electric Circuits

الدوائر الكهربائية

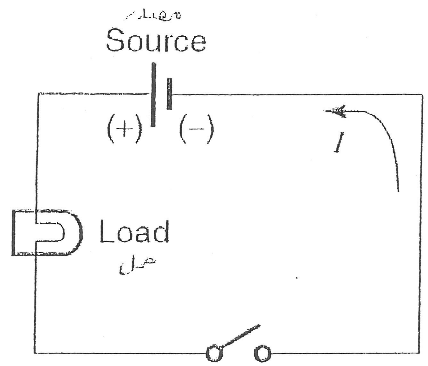
تتكون الدائرة الكهربائية من:
① مصدر للطاقة الكهربائية مثل (بطارية)
② جهاز مستهلك للطاقة (مقاومة) [الحمل]
③ مفتاح
④ اسلاك لتوصيل التيار

يمثل كل جزء من أجزاء الدائرة رمز.



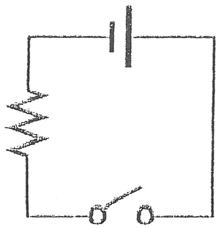
Picture diagram

(a)

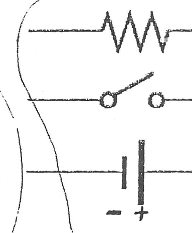


Symbol diagram

(b)



Circuit diagram



represents the resistance (load)

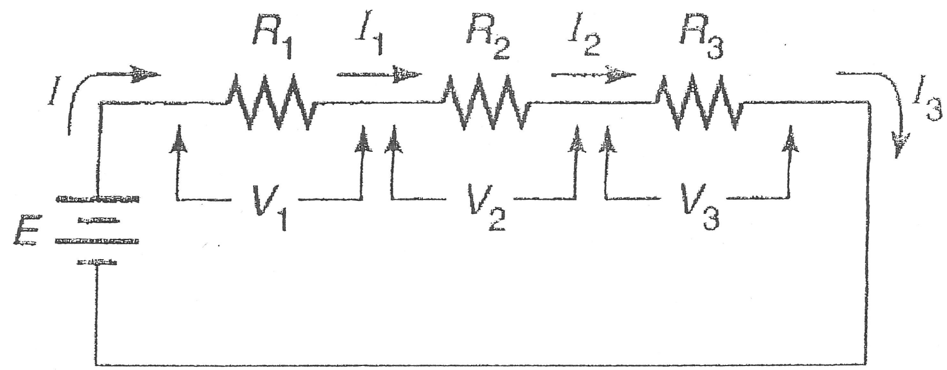
represents the switch

represents the source (the short line represents the negative terminal and the long line represents the positive terminal)

(c)

SERIES CIRCUITS

دوائر التوالي



An electric circuit with only one path for the current to flow is called a *series circuit*.

SERIES

$$I = I_1 = I_2 = I_3 = \cdots$$

I = total current I_1 = current through R_1

I_2 = current through R_2 I_3 = current through R_3

SERIES

$$E = V_1 + V_2 + V_3 + \cdots$$

E = emf of the source V_1 = voltage drop across R_1

V_2 = voltage drop across R_2 V_3 = voltage drop across R_3

SERIES

$$R = R_1 + R_2 + R_3 + \cdots$$

R = total or equivalent resistance of the circuit R_1 = resistance of first load

R_2 = resistance of second load R_3 = resistance of third load

* في دائرة التوالي : هناك مسار واحد للتيار . فإذا تعطلت إحدى الأجهزة تعطلت باقي الأجهزة وتوقف التيار .

* ملاحظات :

① $I = I_1 = I_2 = \cdots$ ← تيار كلي

② $E = V_1 + V_2 + \cdots$ ← جهد كلي

③ $R = R_1 + R_2 + \cdots$

EXAMPLE 4.7

Find the total resistance of the circuit shown in Figure 4.8.
أوجد الكلية المقاومة للدائرة الموضحة في الشكل

Data:

$R_1 = 7.00\ \Omega$

$R_2 = 9.00\ \Omega$

$R_3 = 21.0\ \Omega$

$R = ?$

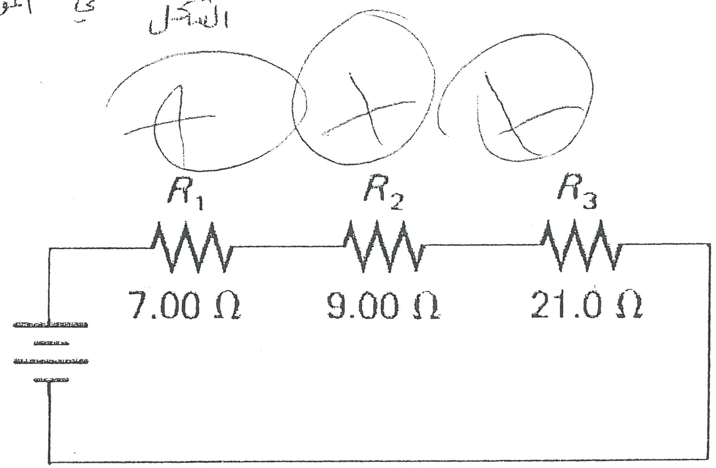


FIGURE 4.8

Basic Equation:

$$R = R_1 + R_2 + R_3$$

Working Equation: Same

Substitution:

$$R = 7.00\ \Omega + 9.00\ \Omega + 21.0\ \Omega$$

$$= 37.0\ \Omega$$

EXAMPLE 4.8

Find the current in the circuit shown in Figure 4.9.

Data:

$R_1 = 5.00\ \Omega$ $R_4 = 96.0\ \Omega$

$R_2 = 13.0\ \Omega$ $E = 90.0\ V$

$R_3 = 12.0\ \Omega$ $I = ?$

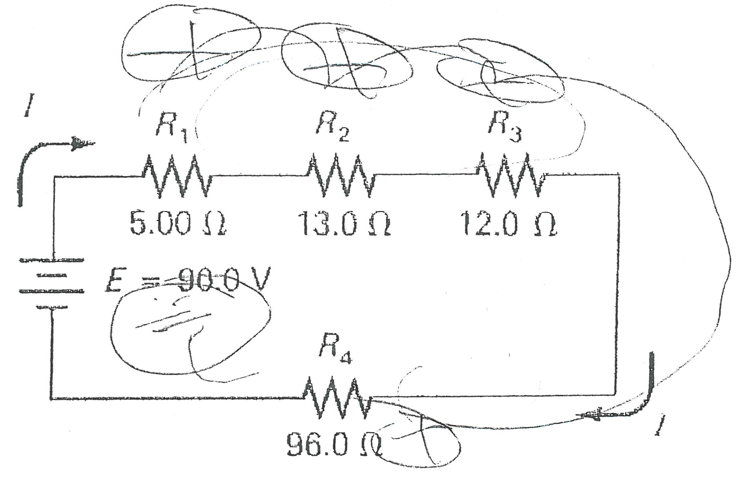


FIGURE 4.9

Basic Equations: $R = R_1 + R_2 + R_3 + R_4$ and $I = \frac{E}{R}$

Working Equations: Same

Substitutions:

$$R = 5.00\ \Omega + 13.0\ \Omega + 12.0\ \Omega + 96.0\ \Omega$$

$$= 126.0\ \Omega$$

$$I = \frac{90.0\ V}{126.0\ \Omega}$$

$$= 0.714\ A$$

EXAMPLE 4.9

Find the value of R_3 in the circuit shown in Figure 4.10.

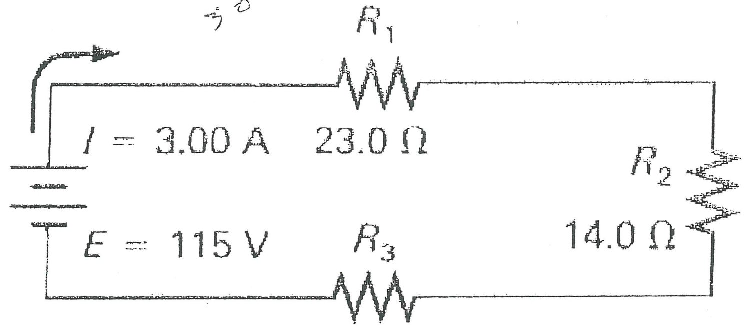


FIGURE 4.10

Data: $I = 3.00\ \text{A}$ $\quad R_2 = 14.0\ \Omega$

$E = 115\ \text{V}$ $\quad R_3 = ?$

$R_1 = 23.0\ \Omega$

Basic Equations: $I = \frac{E}{R}$ and $R = R_1 + R_2 + R_3$

Working Equations:

$$R = \frac{E}{I} \quad \text{and} \quad R_3 = R - R_1 - R_2$$

Substitutions:

$$R = \frac{115\ \text{V}}{3.00\ \text{A}}$$

$$= 38.3\ \Omega$$

$$R_3 = 38.3\ \Omega - 23.0\ \Omega - 14.0\ \Omega$$

$$= 1.3\ \Omega$$

$R = R_1 + R_2 + R_3$

$R = 23 + 14 + R_3$

نحسب (R)

$I = \frac{E}{R} \Rightarrow E = I \cdot R$

$R = \frac{E}{I} = \frac{115}{3} = 38.3\ \Omega$

$38.3 = 23 + 14 + R_3$

$38.3 - 23 - 14 = R_3$

$R_3 = 1.3\ \Omega$

EXAMPLE 4.10

Find the voltage drop across R_3 in Figure 4.10.

Data:

$$I = I_3 = 3.00\ \text{A}$$

$$R_3 = 1.3\ \Omega$$

$$V_3 = ?$$

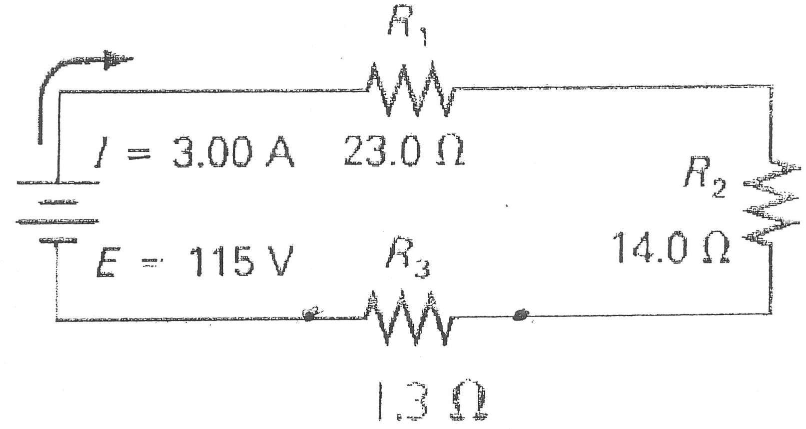


FIGURE 4.10

$I = \frac{V}{R}$

$V = I \cdot R$

Basic Equation:

$$I_3 = \frac{V_3}{R_3}$$

Working Equation:

$$V_3 = I_3 R_3$$

Substitution:

$$V_3 = (3.00\ \text{A})(1.3\ \Omega)$$

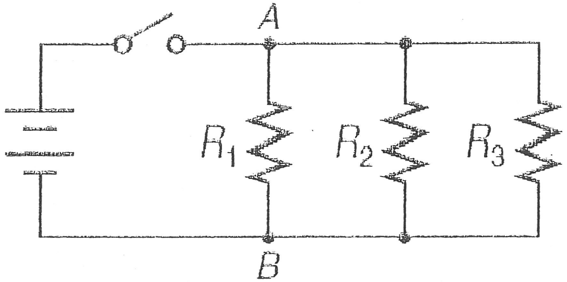
$$= 3.9\ \text{V}$$

PARALLEL CIRCUITS

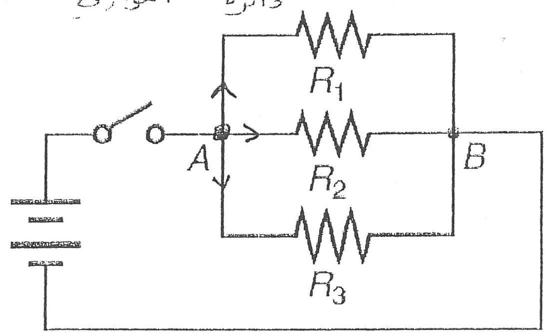
التوازي دوائر

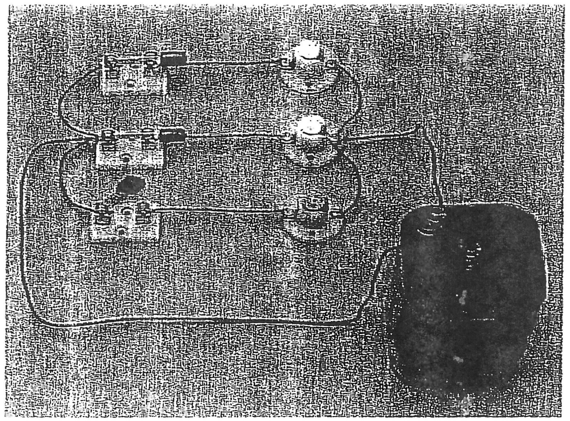
An electric circuit with more than one path for the current to flow is called a parallel circuit.

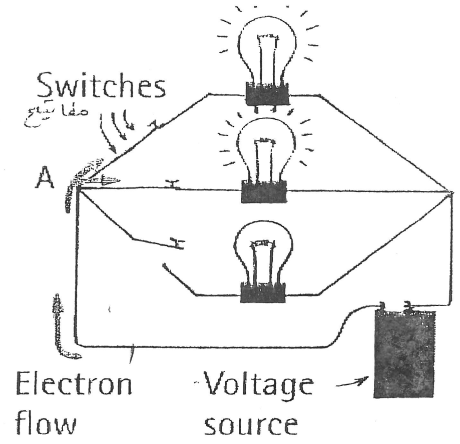
Different ways to represent a parallel circuit



or







* في دائرة التوازي هناك أكثر من مسار للتيار ، فإذا تعطلت إحدى الأجهزة (المقاومات) تبقى الأخرى تعمل.

* هذه الطريقة تستخدم في البيوت (المنازل)

* ملاحظات :

① $E = V_1 = V_2 = V_3 = \dots$

② $I = I_1 + I_2 + I_3 + \dots$

③ $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$

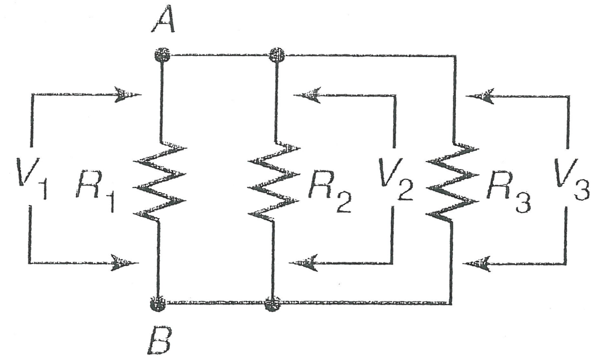
PARALLEL CIRCUITS

PARALLEL

$$I = I_1 + I_2 + I_3 + \cdots$$

I = total current in the circuit
I_1 = current through R_1
I_2 = current through R_2
I_3 = current through R_3

$$I = I_1 + I_2 + I_3.$$



PARALLEL

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$$

R = equivalent resistance
R_1 = resistance of R_1
R_2 = resistance of R_2
R_3 = resistance of R_3

PARALLEL

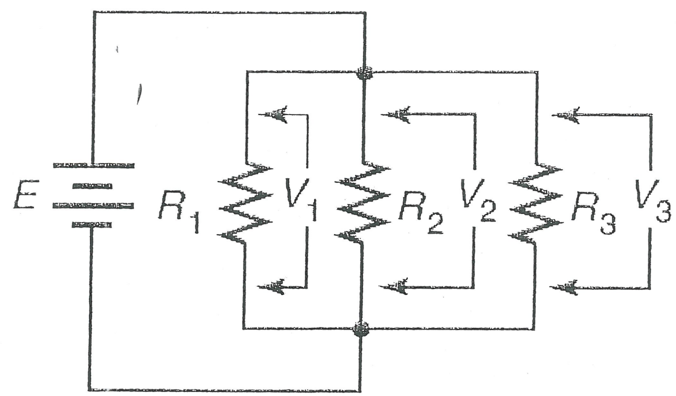
$$V_1 = V_2 = V_3 = \cdots$$

PARALLEL WITH VOLTAGE SOURCE

$$E = V_1 = V_2 = V_3 = \cdots$$

E = emf of the source
V_1 = voltage drop across R_1
V_2 = voltage drop across R_2
V_3 = voltage drop across R_3

$$E = V_1 = V_2 = V_3.$$



If the parallel combination of resistances is replaced by a single resistance with the resistance *R*, the same current flows in the circuit.

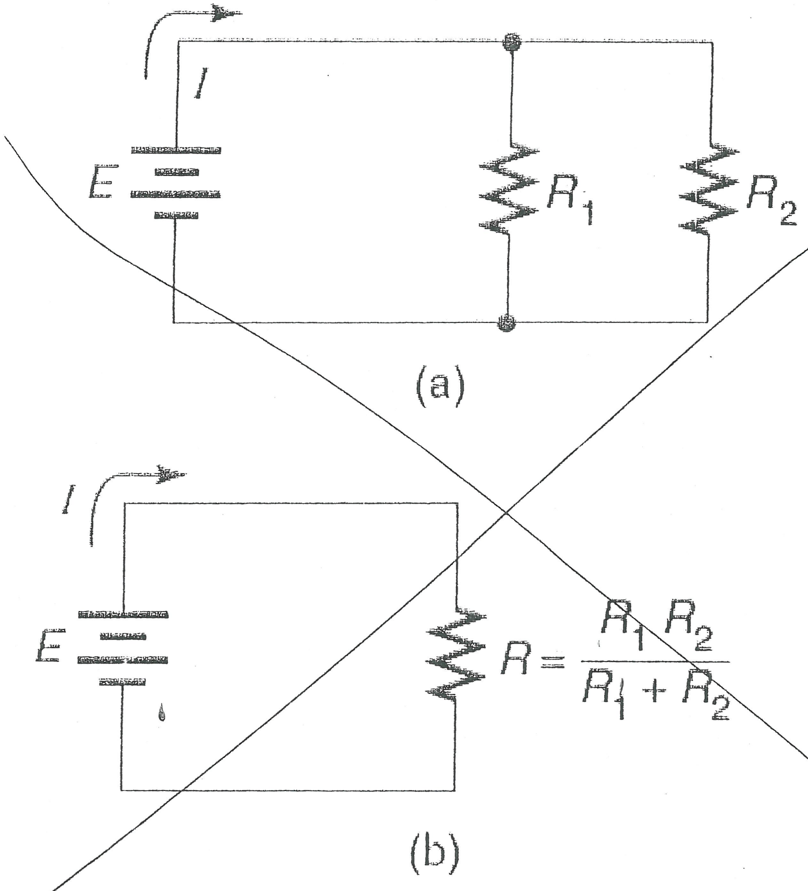
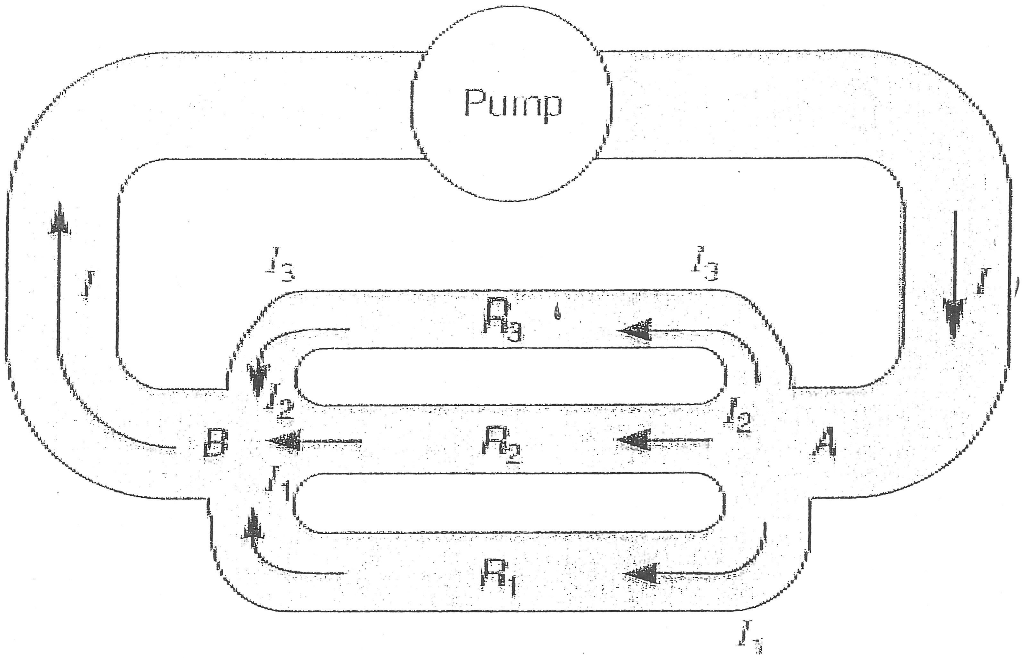
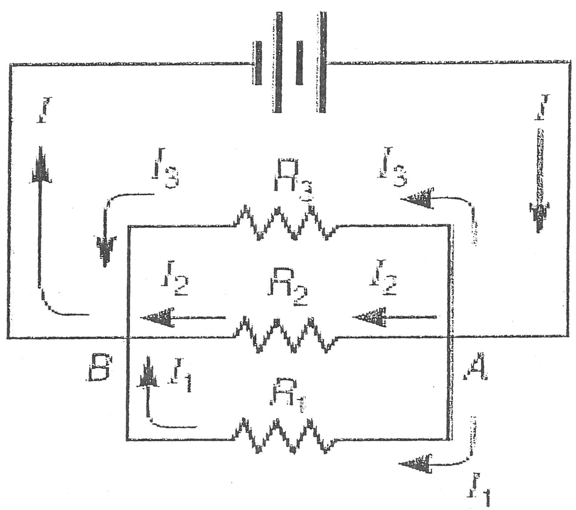


FIGURE 4.14

Resistor R in part (b) is equivalent to the pair of resistances R_1 and R_2 connected in parallel in part (a).

A water system may be compared to a parallel electric circuit.





EXAMPLE 4.11

Find the equivalent resistance of the circuit shown in Figure 4.16.

Data:

$R_1 = 7.00\ \Omega$

$R_2 = 9.00\ \Omega$

$R_3 = 12.0\ \Omega$

$R = ?$

Basic Equation:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Working Equation:

When using this formula, you should solve for the reciprocal of the unknown, then substitute.

Substitution:

$$\frac{1}{R} = \frac{1}{7.00\ \Omega} + \frac{1}{9.00\ \Omega} + \frac{1}{12.0\ \Omega}$$

$R = 2.96\ \Omega$

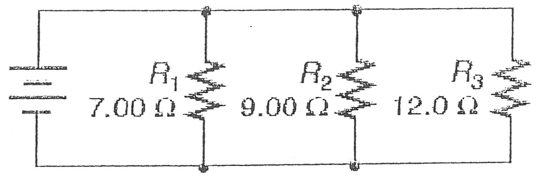


FIGURE 4.16

$$\frac{1}{R} = \frac{1}{7} + \frac{1}{9} + \frac{1}{12}$$

$$\frac{1}{R} = \frac{85}{252}$$

$$\frac{R}{1} = \frac{252}{85}$$

$R = 2.964$

EXAMPLE

Find the total current in the circuit shown in Figure 4.17.

Data:

$R_1 = 23.0\ \Omega$

$R_2 = 14.0\ \Omega$

$R_3 = 5.00\ \Omega$

$E = 90.0\ V$

$I = ?$

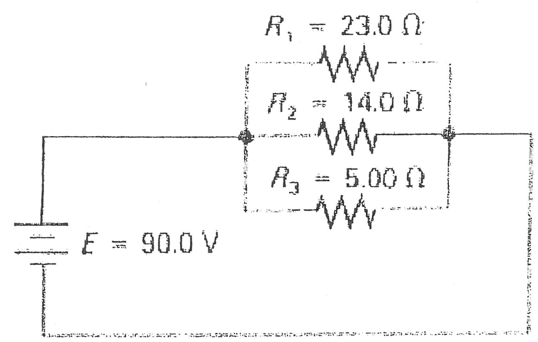


FIGURE 4.17

First, find the equivalent resistance, R. Second, find the total current, I. To find R:

Basic Equation:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Working Equation: Same

Substitution:

$$\frac{1}{R} = \frac{1}{23.0\ \Omega} + \frac{1}{14.0\ \Omega} + \frac{1}{5.00\ \Omega}$$

Using a calculator sequence as in Example 4.11, we find

$$R = 3.18\ \Omega$$

To find I:

Basic Equation:

$$I = \frac{E}{R}$$

Working Equation: Same

Substitution:

$$I = \frac{90.0\ V}{3.18\ \Omega} = 28.3\ A$$

EXAMPLE 4.13

Find the current through R_2 in Figure 4.17 from Example 4.12.

Data:

$$R_2 = 14.0\ \Omega$$

$$E = 90.0\ \text{V} = V_2$$

$$I_2 = ?$$

Basic Equation:

$$I_2 = \frac{V_2}{R_2}$$

Working Equation: Same

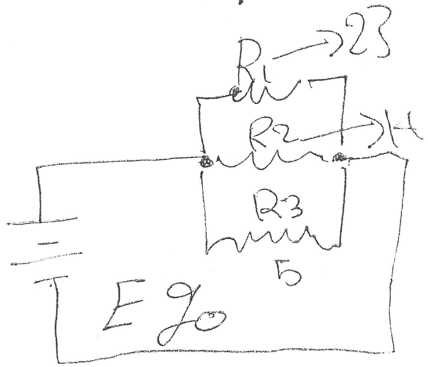
Substitution:

$$I_2 = \frac{90.0\ \text{V}}{14.0\ \Omega}$$

$$= 6.43\ \text{A}$$

$$I = \frac{V}{R_1}$$

$$I_2 = \frac{V_2}{R_2} = \frac{90}{14}$$



$$V = 90 \quad I = \frac{V}{R}$$

51

14

EXAMPLE 4.14

Find the equivalent resistance and the value of R_3 in the circuit shown in Figure 4.18.

Data:

$E = 115\ V$

$I = 7.00\ A$

$R_1 = 38.0\ \Omega$

$R_2 = 49.0\ \Omega$

$R_3 = ?$

First find R:

Basic Equation:

$I = \frac{E}{R}$

Working Equation:

$R = \frac{E}{I}$

$= \frac{115}{7}$

Substitution:

$R = \frac{115\ V}{7.00\ A}$

$= 16.4\ \Omega$

To find R_3:

Basic Equation:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Working Equation:

$$\frac{1}{R_3} = \frac{1}{R} - \frac{1}{R_1} - \frac{1}{R_2}$$

total

Substitution:

$$\frac{1}{R_3} = \frac{1}{16.4\ \Omega} - \frac{1}{38.0\ \Omega} - \frac{1}{49.0\ \Omega}$$

~~$R_3 = 70.2\ \Omega$~~

$\frac{1}{R_3} = \frac{544}{38171}$

$R_3 = \frac{38171}{544} = 70.2\ \Omega$

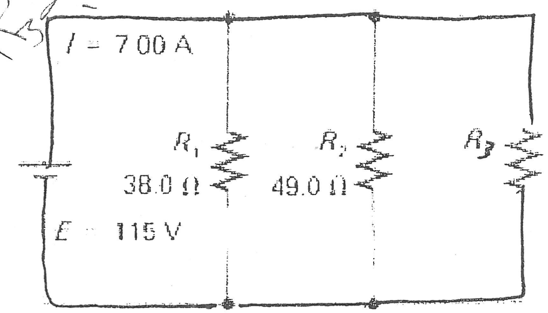


FIGURE 4.18

(52)