ENGR 260
Circuits and Devices

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Lesson Objectives and Learning Outcomes

- Lesson Objective(s)
  - Define Fundamental Quantities: Charge, Voltage, Current, Resistance
  - Define Power
- Student Learning Outcomes
  - Describe relations between fundamental quantities
  - Perform basic computations involving fundamental quantities.

Lesson Content
Ch 2 Sec 2.1 – 2.5

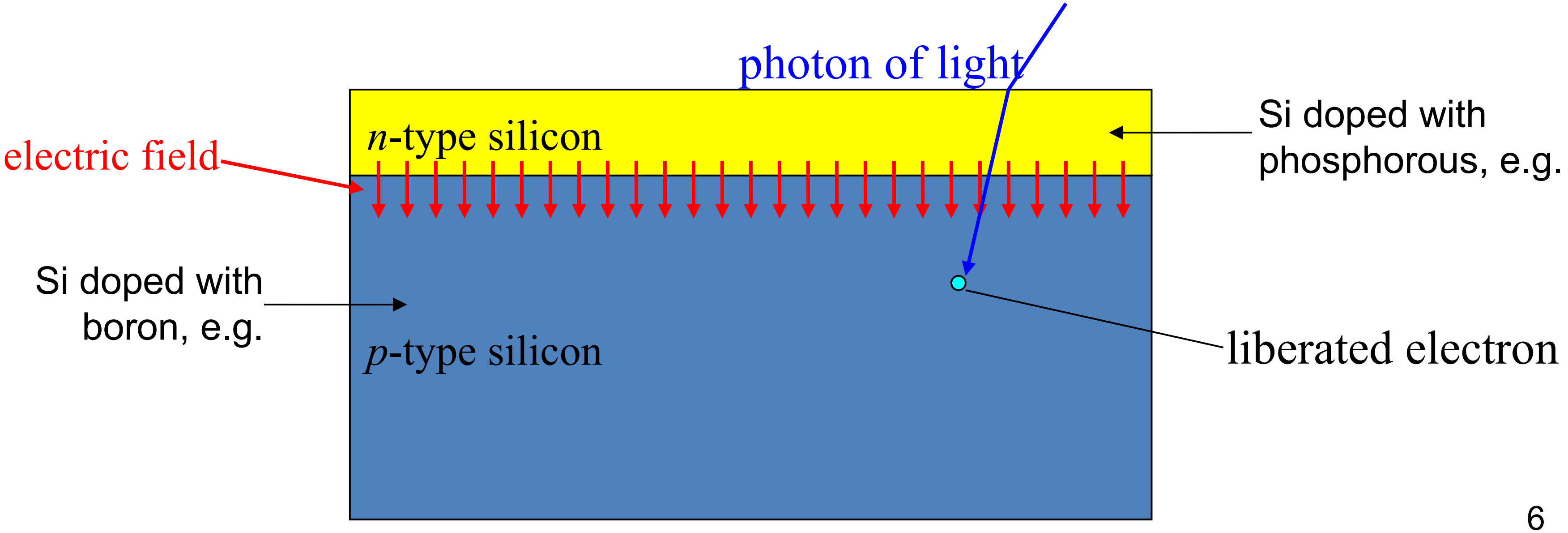
1. Introduction
2. What is a Circuit?
3. Charge, Current, Voltage
4. System of Units
5. Power and Energy

Solar Farm at Cañada College

Making Electricity from Sunlight

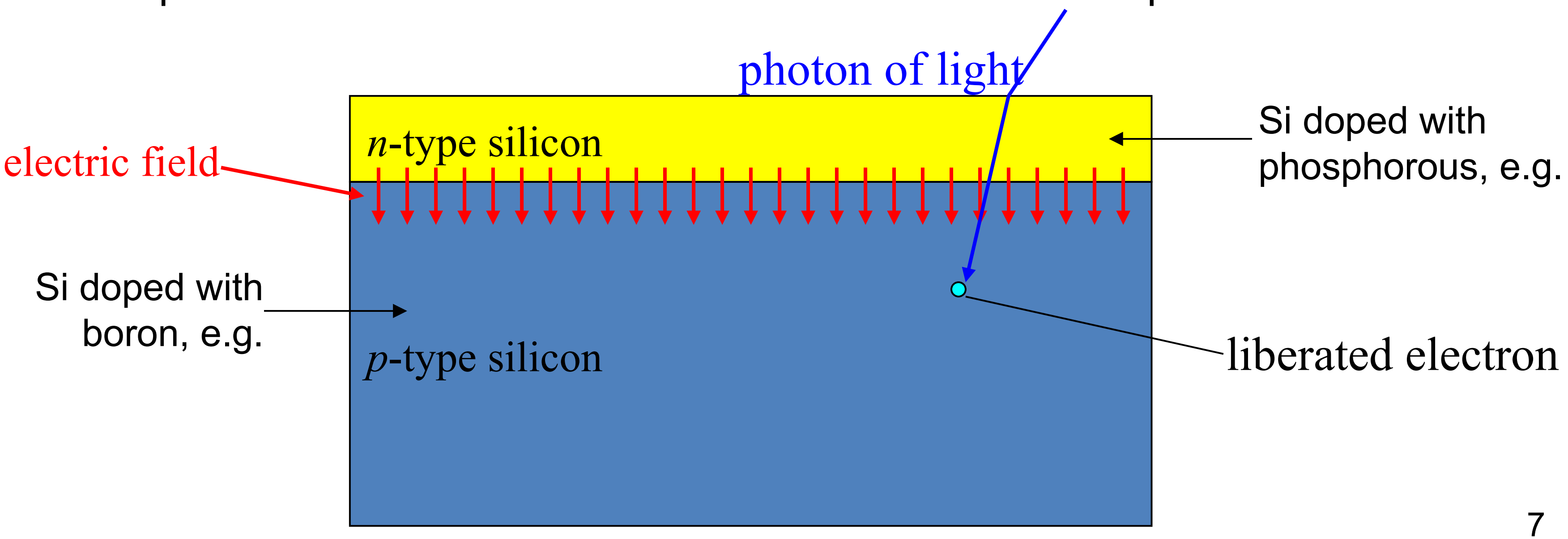
Science of Photovoltaics (PV)

- Highly purified silicon (Si) from sand, quartz, etc. is “doped” with intentional impurities at controlled concentrations to produce a p-n junction
  - p-n junctions are common and useful: diodes, CCDs, photodiodes, transistors



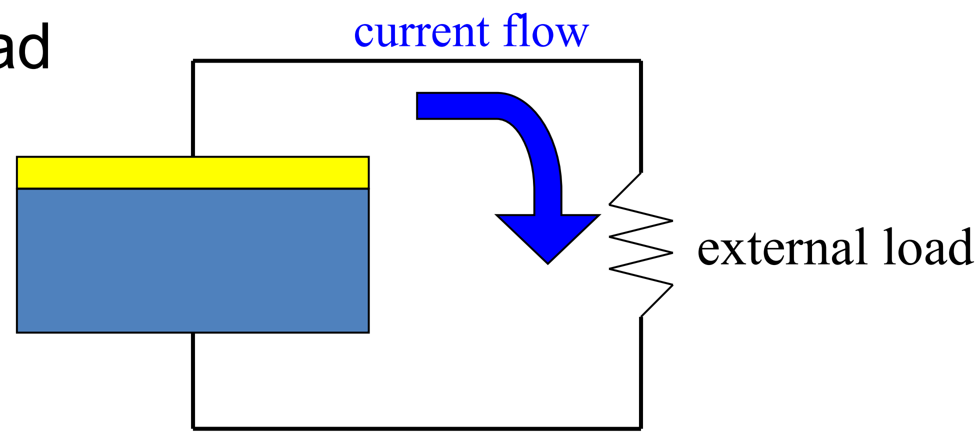
Science of Photovoltaics (PV)

- Highly purified silicon (Si) from sand, quartz, etc. is “doped” with intentional impurities at controlled concentrations to produce a p-n junction
  - p-n junctions are common and useful: diodes, CCDs, photodiodes, transistors
- A photon incident on the p-n junction liberates an electron
  - photon disappears, any excess energy goes into kinetic energy of electron (heat)
  - electron wanders around drunkenly, and might stumble into “depletion region” where electric field exists (electrons, being negative, move *against* field arrows)
  - electric field sweeps electron across the junction, constituting a current
  - more photons → more electrons → more current → more power



PV cells Provide a circuit for the electron flow

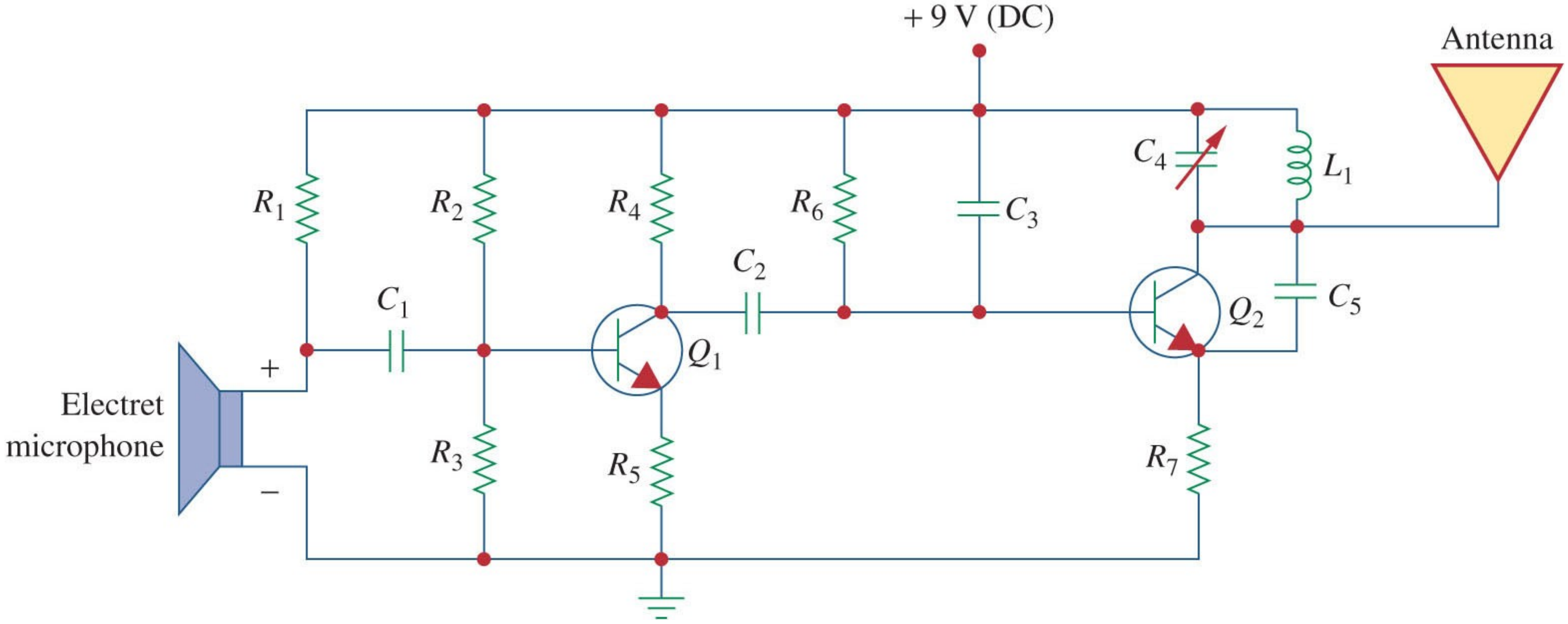
- Without a path for the electrons to flow out, charge would build up and end up canceling electric field
  - must provide a way out
  - direct through external load



  - PV cell acts like a battery

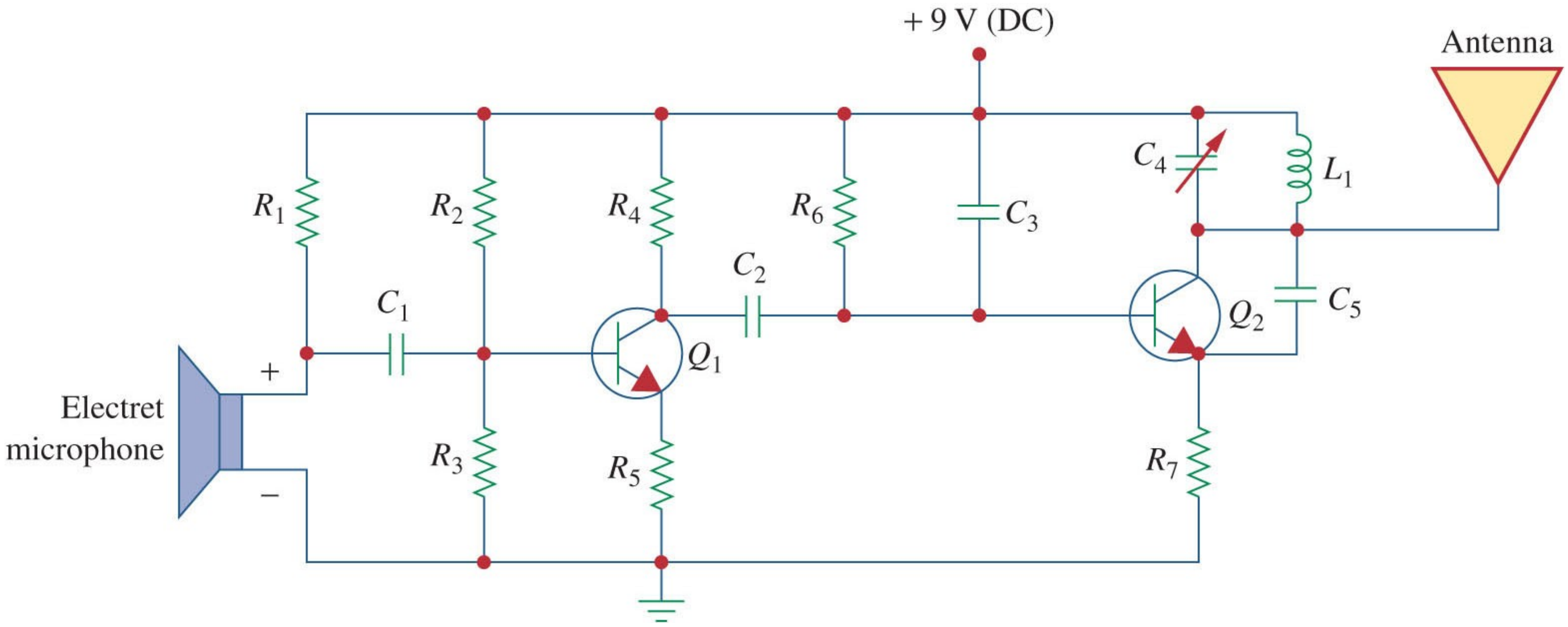
What is a circuit?

- Circuit: Any path along which electrons can flow
  - Electrons will only flow if the circuit is complete with no gaps



What is a circuit?

- Circuit: Any path along which electrons can flow
  - Electrons will only flow if the circuit is complete with no gaps
- An electric circuit is an interconnection of electrical elements.
- It may consist of only two elements or many more:



Charge

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  - Charge is a derived SI unit, measured in Coulombs (C)
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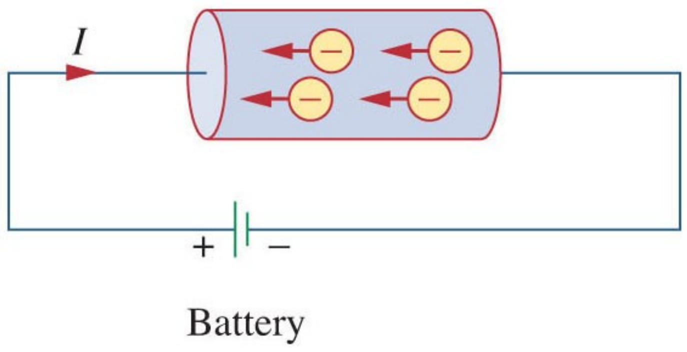
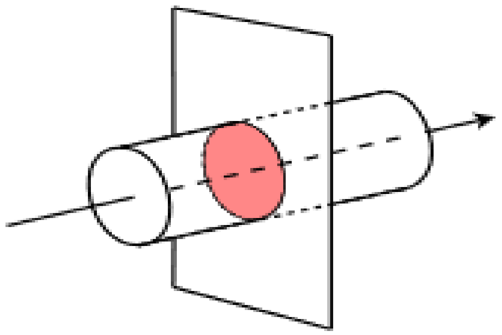
- Charge of single electron is: 1.602×10^{-19} C
- How many electrons does 1 C contain?
  - One Coulomb is quite large: 6.023×10^{18} electrons.
- Charge cannot be created or destroyed, only transferred.
- Example: In the lab, one typically sees
  - pC = 10^{-12} C
  - nC = 10^{-9} C
  - μC = 10^{-6} C

Electric Current

- The movement of charge is called a current
- Historically the moving charges were thought to be positive





Electric Current

- The movement of charge is called a current
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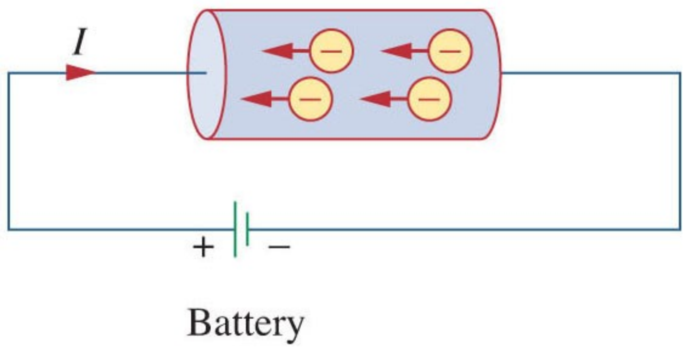
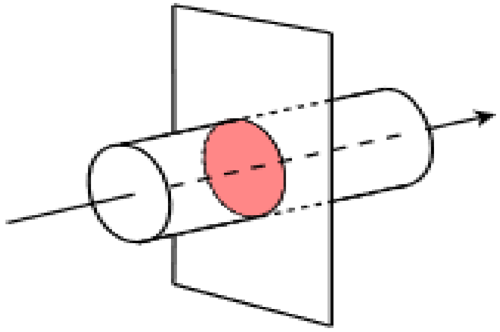
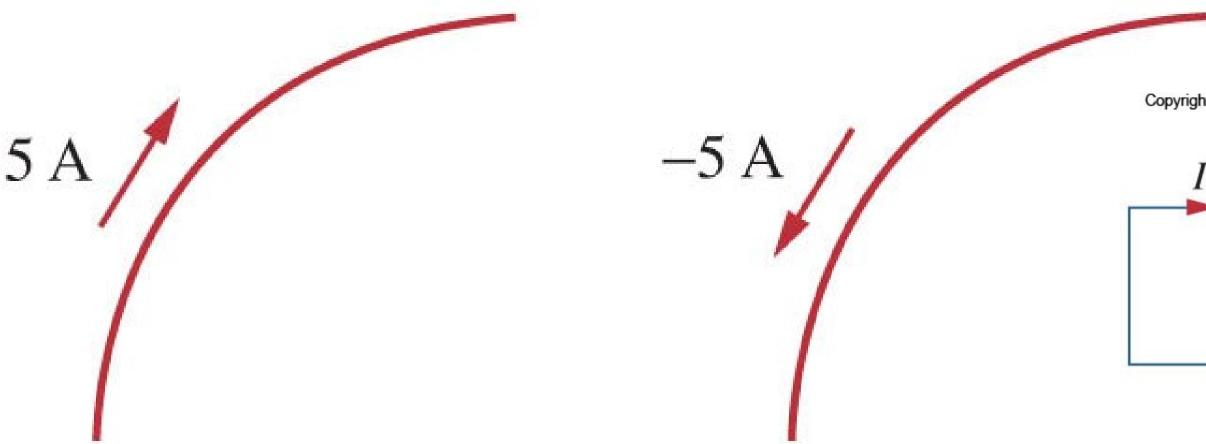
- Thus we always note the direction of the equivalent positive charges, even if the moving charges are negative.



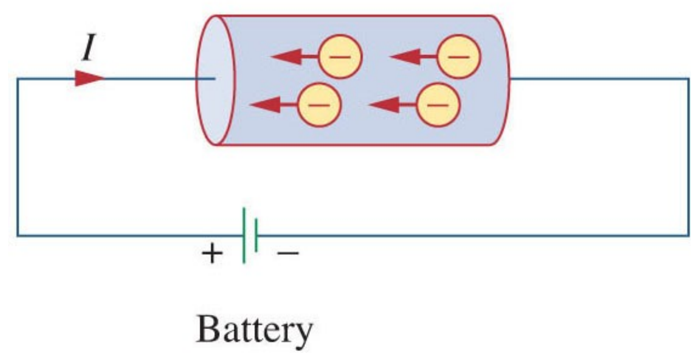


Direction of current

- The sign of the current indicates the direction in which the positive charge is moving with reference to the direction of interest we define.
- A positive current through a component is the same as a negative current flowing in the opposite direction.



(a) (b)



Charge (Q or q) and Current (I or i)

- Electric Current, *i*, is the time rate of change of charge, measured in Amperes (A)

$$i = \frac{dq}{dt}$$

Andre-Marie Ampere (1775-1836)
French Mathematician and Physicist, Inventor: Electromagnet, Ammeter

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- Alternate Form (generally for DC)
  - I = Q/t
- Unit is Ampere (A)
  - 1 Ampere = 1 Coulomb/ 1 second

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SI system of Units

Fundamental units in the SI system: meter (m), kilogram (kg), second (s), ampere (A). also: kelvin, mole, and candela
Derived Units in SI: Any combination of the fundamental units

Quantity	Basic unit	Symbol
Length	meter	m
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Time	second	s
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Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
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Q. How can Charge C be obtained from the basic units?

SI: Units and Prefixes

Any measurement can be expressed in terms of a unit, or a unit with a “prefix” modifier.

FACTOR	NAME	SYMBOL
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m
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Example: 12.3 mW = 0.0123 W =1.23×10^{-2} W

Exercise 1: Units and Dimensions

- Prefixes on SI units allow for easy relationships between large and small values
- Examples

1) How can 2,000,000 V be best expressed?
   a) 2 mV
   b) 2 kV
   c) 2 MV
   d) 2 GV
2) What is the best way to express 1000 nanometers?
   a) 10^{-9} m; b) 10^{-6} m; (c) 10^{-3} m

The SI prefixes.

Multiplier	Prefix	Symbol
10^{18}	exa	E
10^{15}	Peta	P
10^{12}	Tera	T
10^{9}	Giga	G
10^{6}	Mega	M
10^{3}	Kilo	k
10^{2}	Hecto	h
10	Deka	da
10^{-1}	Deci	d
10^{-2}	Centi	c
10^{-3}	Milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	P
10^{-15}	femto	f
10^{-18}	atto	a

Answer to Exercise 1

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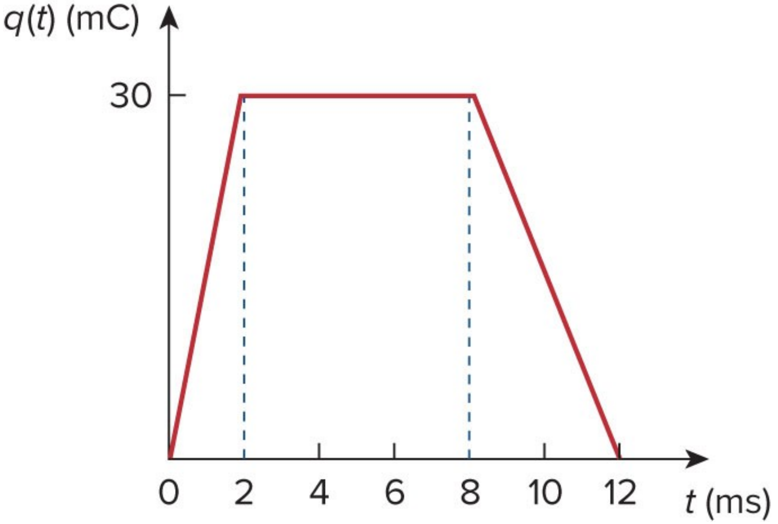
Exercise 2

The charge entering a certain element is shown in the figure. Find the current at:

(a) t = 1 ms

(b) t = 6 ms

(c) t = 10 ms



Solution to Exercise 2

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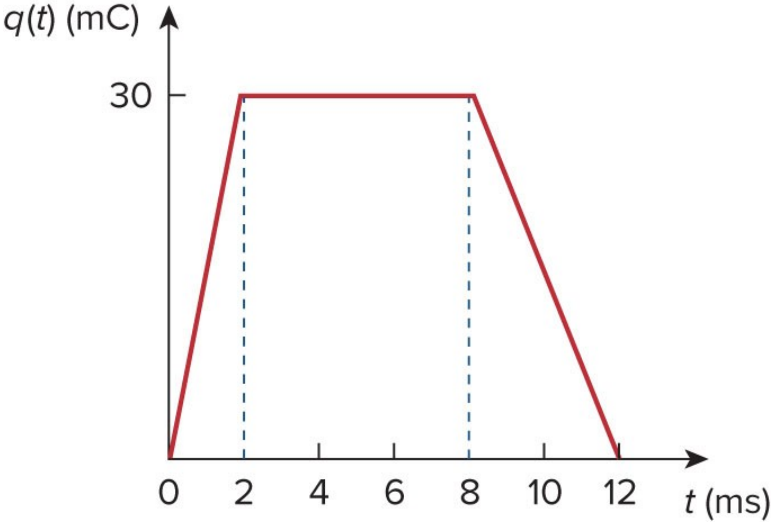


Answers

(a) at t = 1 ms, i=dq/dt = 30/2 = 15 A

(b) at t = 6 ms, i=dq/dt = 0 A

(c) at t = 10 ms, i=dq/dt = (0-30)/(12-8) = -7.5 A

Voltage (V) [1]

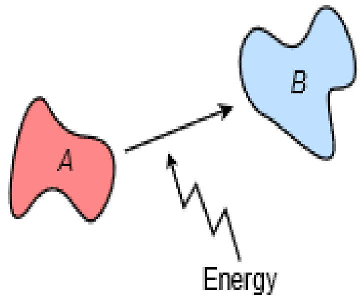
- Electrons move when there is a difference in charge between two locations.

Voltage (V) 1

- Electrons move when there is a difference in charge between two locations.
- <u>Voltage</u>: Is energy/work that pushes the charge through the circuit (in this picture it would be equivalent to potential energy)

Voltage (V) 2

- Electrons move when there is a difference in charge between two locations.
- Voltage or potential difference is the work or energy to move unit charge between points A and B and is measured in Volts (V)
  - 1 Volt = 1 Joule/ 1 Coulomb
  - Alternate Form: $V_{BA} = V_B - V_A = = W/Q$



$$V_{BA} = \frac{dW}{dq}$$

Alessandro Volta (1745-1827) Italian Physicist – invented the battery

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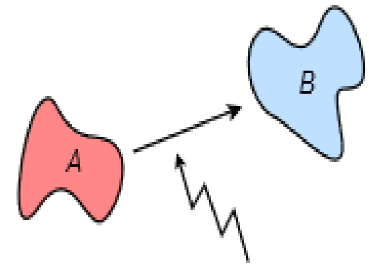
  - 1 Volt = 1 Joule/ 1 Coulomb
  - Alternate Form: $V_{BA} = V_B - V_A = = W/Q$
- Voltage is always expressed with reference to two locations
  - Positive charge moving from a higher potential to a lower yields energy.
  - Moving from negative to positive requires energy.



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Exercise 3 (1.4.1)

100 joules are expended to move a 20 coulomb charge from point A to point B. Determine the resulting voltage.

Solution to Exercise 3 (1.4.1)

100 joules are expended to move a 20 coulomb charge from point *A* to point *B*. Determine the resulting voltage.

Solution

$$V_{BA} = W/Q$$

$$V_{BA} = 100\ \text{J} / 20\ \text{C} = 5\ \text{V}$$

Power (P) and Energy (W)

- Power is the product of voltage and current
  - p=V.I

Power (P) and Energy (W)

- Power is the product of voltage and current
  - $p = V.I$
- It is also equal to the rate of **energy or work** provided or consumed per unit time.
  - $p = dW/dt$ or W/t -> here dW or W represents energy/work
    - It is measured in Watts (W)
    - Alternate Form: $P = W/t$

Units of Power (P)

- You will/could encounter different units for power
- Unit 1: power = voltage-ampere (from p = VI)

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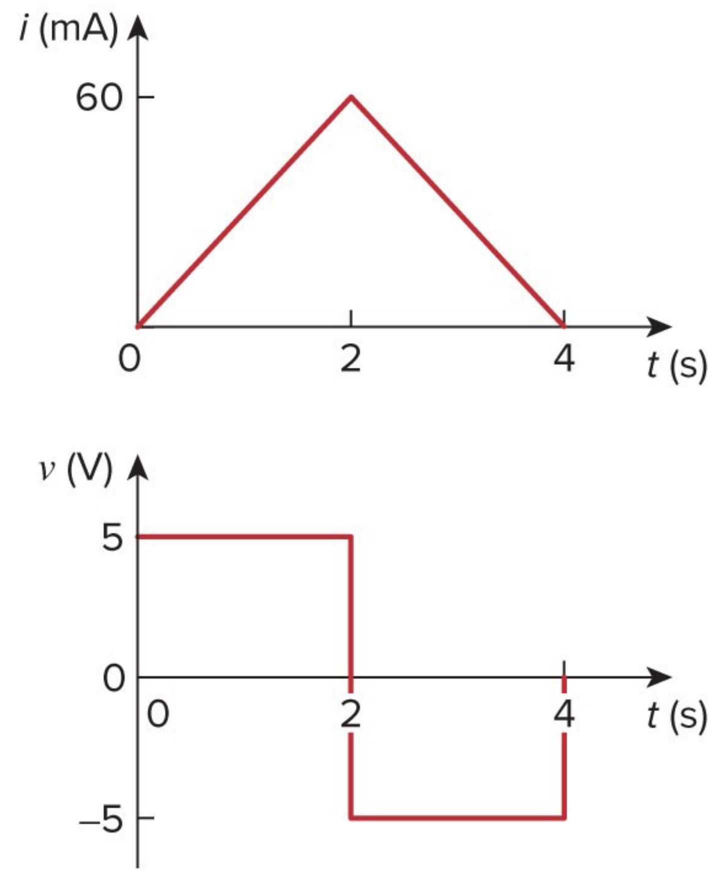
- Unit 3: The Horsepower (hp)
  - 1 hp =760 Watts

Exercise 4

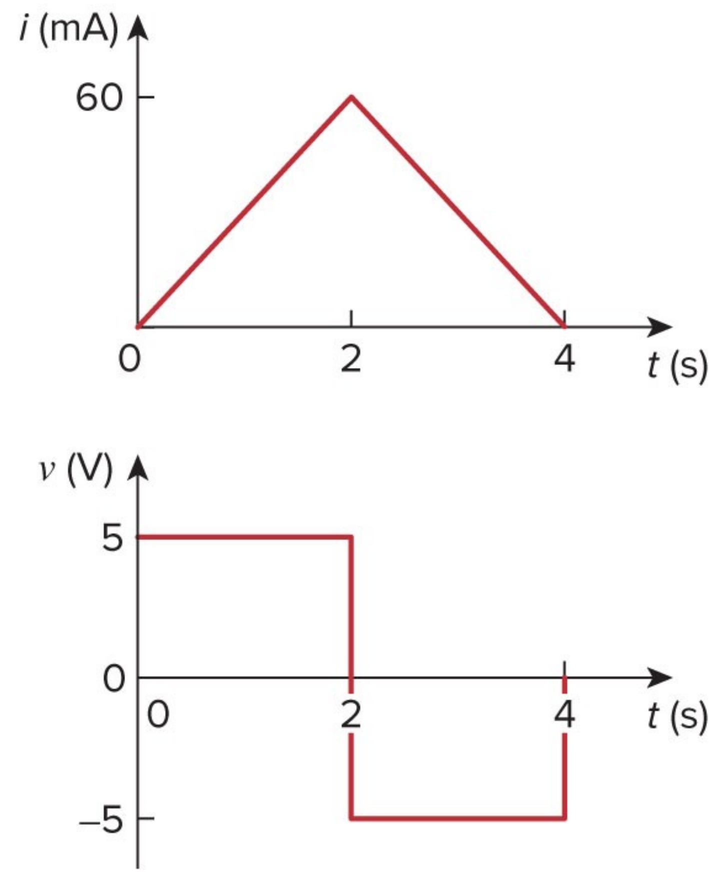
1. The figure shows the current through and voltage across an element. Find the total energy absorbed by the element for the period of 0 < t < 4 s.



Solution to Exercise 4 1

1) Lets express forms of i(t)

- i(t) = 30t mA, 0 < t < 2
- i(t) = 120-30t mA , 2 < t < 4



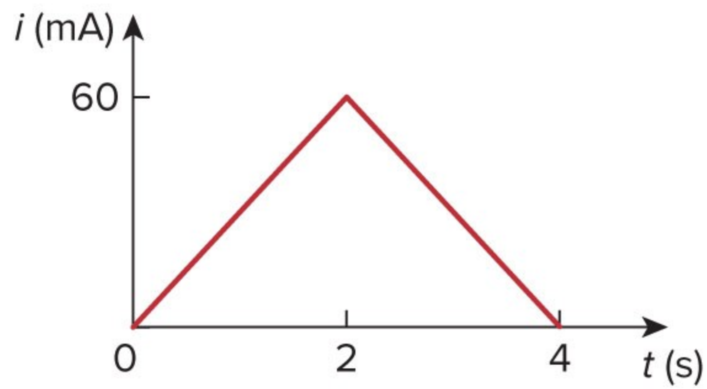
Solution to Exercise 4 2

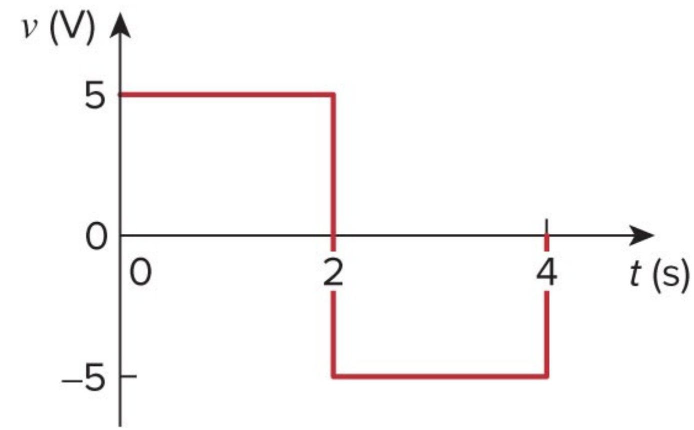
1) Lets express forms of i(t)

- i(t) = 30t mA, 0 < t < 2
- i(t) = 120-30t mA , 2 < t < 4

2) Lets express form of v(t)

- v(t) = 5 V, 0 < t < 2
- v(t) = - 5V, 2 < t < 4

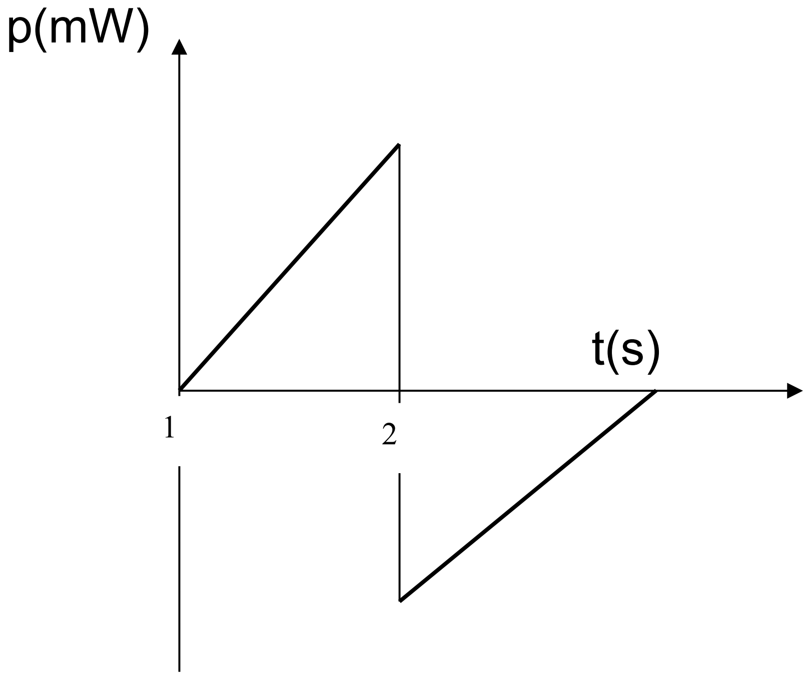




Solution to Exercise 4 3

1) Now the power vs t is:

- p(t) = i(t)v(t) = 150t mW, 0 < t < 2
- p(t) = -600+150t mW, 2 < t < 4



Solution to Exercise 4 4

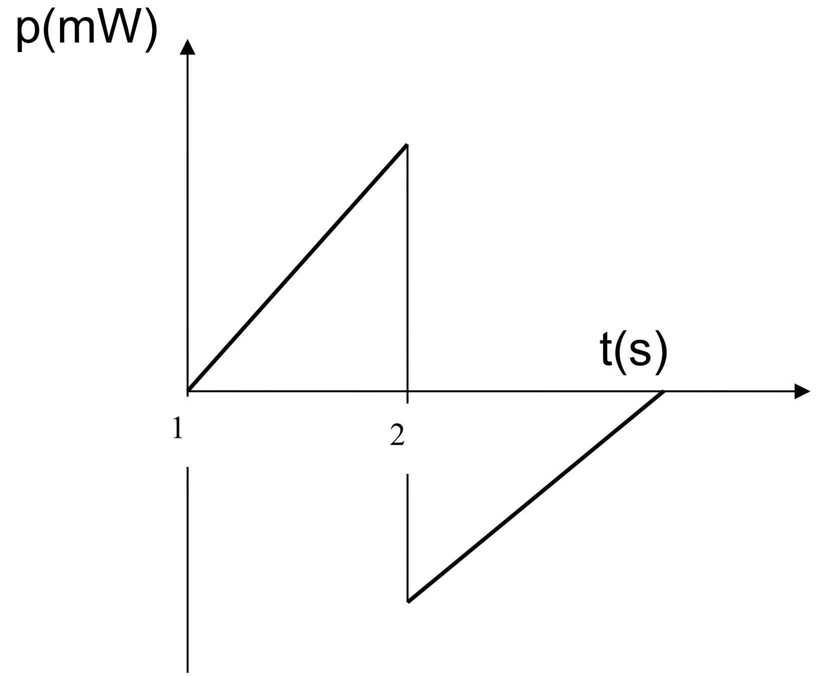
1) Now the power vs t is:

- p(t) = i(t)v(t) = 150t mW, 0 < t < 2
- p(t) = -600+150t mW, 2 < t < 4

2) Finally, the energy abosrbed can be obtained from the graph as:

$$W = \int_0^4 p\,dt$$

= 0 W



Lecture Wrap-up

- Please read the syllabus file on canvas
- Please read/reread the relevant textbook sections and/or the lesson slides/notes
- Remember to work through all example problems in textbook
- Make sure to follow up on any relevant HW or quiz related to this content