# CS1011: 數位電子導論

# Basic Electric Circuits and Components

# Outline

- Introduction
- SI Units and Common Prefixes
- Electrical Circuits
- Direct Currents and Alternating Currents
- Resistors, Capacitors and Inductors
- Ohm's and Kirchhoff's Laws
- Power Dissipation in Resistors
- Resistors in Series and Parallel
- Resistive Potential Dividers
- Sinusoidal Quantities
- Circuit Symbols

# Introduction

- This lecture outlines the basics of Electrical Circuits
  - For most students, much of this will be familiar…?!
  - If there is any topic that you are unsure of (or that are new to you), you should get to grips with this material as soon as possible
- We will return to look at several of these topics in more detail in later lectures

# SI Units

| Quantity | Quantity symbol | Unit | Unit symbol |
|---|---|---|---|
| Capacitance | $C$ | Farad | F |
| Charge | $Q$ | Coulomb | C |
| Current | $I$ | Ampere | A |
| Electromotive force | $E$ | Volt | V |
| Frequency | $f$ | Hertz | Hz |
| Inductance (self) | $L$ | Henry | H |
| Period | $T$ | Second | s |
| Potential difference | $V$ | Volt | V |
| Power | $P$ | Watt | W |
| Resistance | $R$ | Ohm | Ω |
| Temperature | $T$ | Kelvin | K |
| Time | $t$ | Second | s |

# Common Prefixes

- $2^{10}$ (1,024) / $10^3$ is kilo, denoted "K"
- $2^{20}$ (1,048,576) / $10^6$ is mega, denoted "M"
- $2^{30}$ (1,073,741,824) / $10^9$ is giga, denoted "G"
- $2^{40}$ (1,099,511,627,776) / $10^{12}$ is tera, denoted "T"
- $2^{50}$ (1,125,899,906,842,624) / $10^{15}$ is peta, denoted "P"
- $2^{60}$ (1,152,921,504,606,846,976) / $10^{18}$ is exa, denoted "E"
- $2^{70}$ (1,180,591,620,717,411,303,424) / $10^{21}$ is zetta, denoted "Z"
- $2^{80}$ (1,208,925,819,614,629,174,706,176) / $10^{24}$ is yotta, denoted "Y"
- $10^{-3}$ is milli, denoted "m"
- $10^{-6}$ is micro, denoted "$\mu$"
- $10^{-9}$ is nano, denoted "n"
- $10^{-12}$ is pico, denoted "p"
- $10^{-15}$ is femto, denoted "f"
- $10^{-18}$ is atto, denoted "a"

# Electrical Circuits

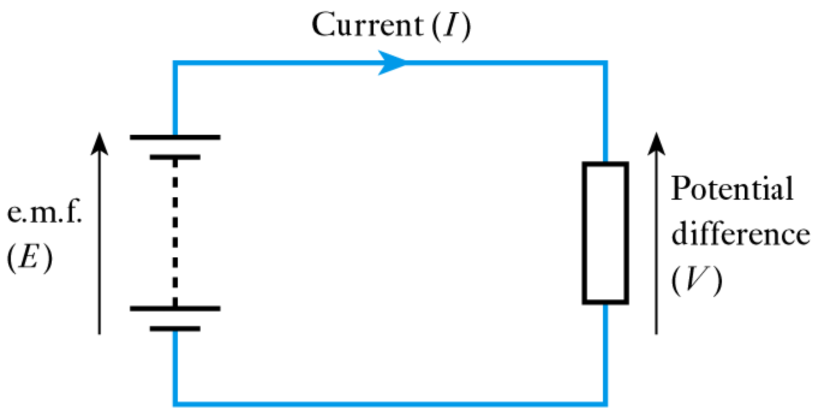
- **Electric charge**
  - **An amount of electrical particles with electrical energy**
  - **Can be positive or negative**
- **Electric current**
  - **A flow of electrical charge, often a flow of electrons**
  - **Conventional current is in the opposite direction to a flow of electrons**
- **Current flow in a circuit**
  - **A sustained current needs a complete circuit**
  - **Also requires a stimulus to cause the charges to flow**

# Electromotive Force

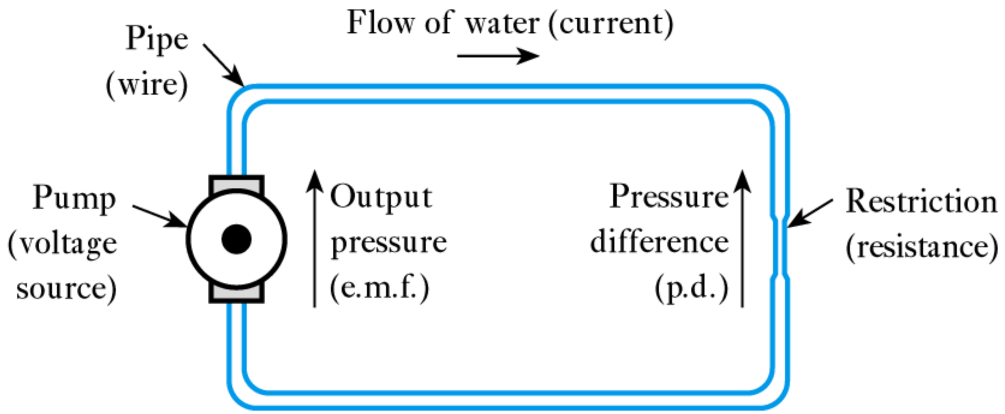
- **Electromotive force and potential difference**
  - **The stimulus that causes a current to flow is an e.m.f.**
  - **This represents the energy introduced into the circuit by a battery or generator**
  - **This results in an electric potential at each point in the circuit**
  - **Between any two points in the circuit there may exist a potential difference**
  - **Both e.m.f. and potential difference are measured in volts**

# A Simple Circuit Example

- A simple circuit

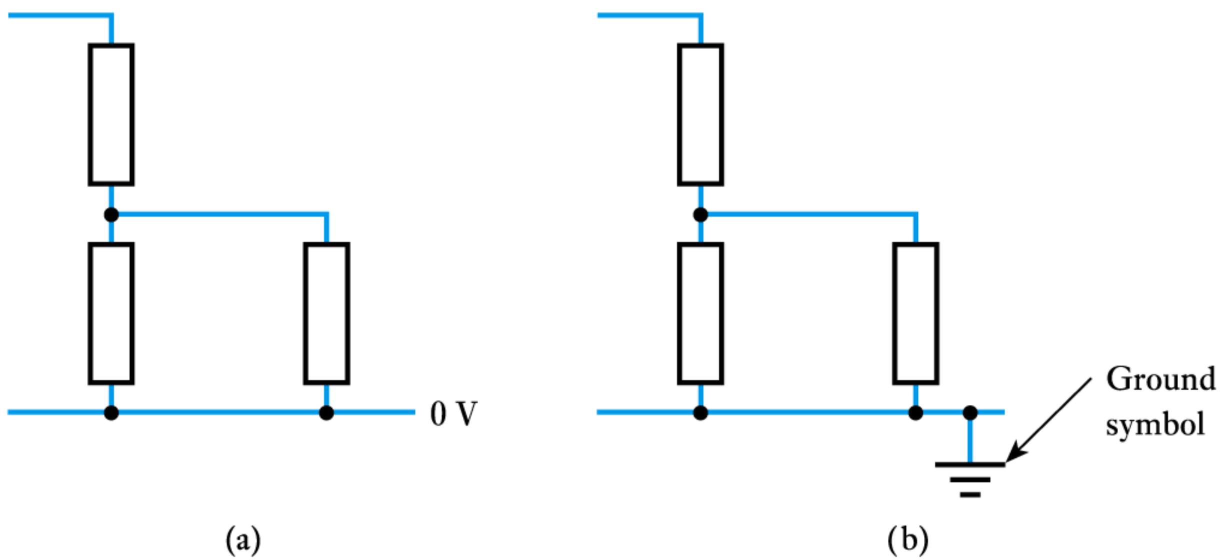



- A water-based analogy



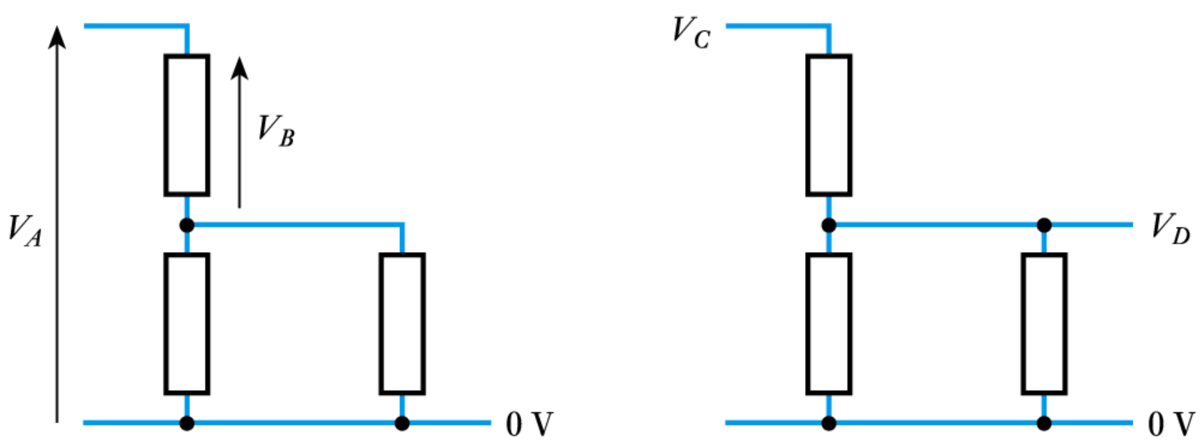
# Voltage Reference Points

- All potentials within a circuit must be measured with respect to some other point (reference point)
- We often measure voltages with respect to a zero volt reference called the ground or earth



# Representing Voltages

- Conventions vary around the world
- We normally use an arrow, which is taken to represent the voltage on the head with respect to the tail
- Labels represent voltages with respect to earth (0V)




(a) (b)

# Direct Current and Alternating Current

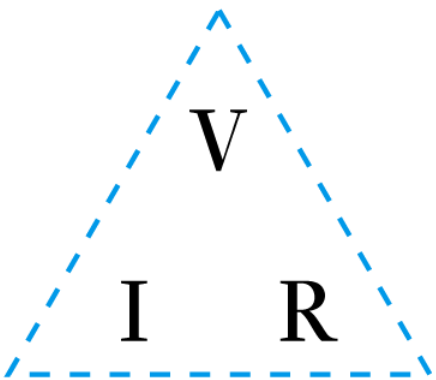
- **Currents in electrical circuits may be constant or may vary with time**
- **When currents vary with time they may be unidirectional or alternating**
- **When the current flowing in a conductor always flows in the same direction, this is direct current (DC)**
- **When the direction of the current periodically changes, this is alternating current (AC)**

# Resistors, Capacitors, and Inductors

- **Resistors** provide resistance
  - They oppose the flow of electricity
  - Measured in Ohms ($\Omega$)
- **Capacitors** provide capacitance
  - They store energy in an electric field
  - Measured in Farads (F)
- **Inductors** provide inductance
  - They store energy in a magnetic field
  - Measured in Henry (H)
- We will look at each component in later lectures

# Ohm's Law

- **The current flowing in a conductor is directly proportional to the applied voltage *V* and inversely proportional to its resistance *R***



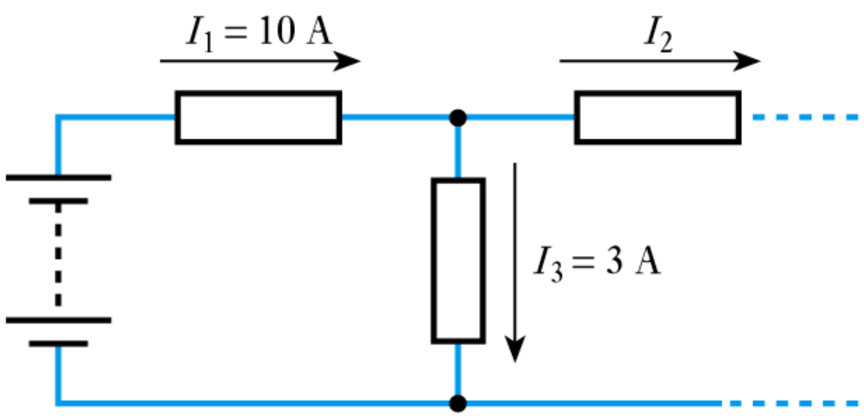

$$V = IR$$

$$I = V/R$$

$$R = V/I$$

# Kirchhoff's Current Law (KCL)

- At any instant the algebraic sum of the currents flowing into any junction in a circuit is zero
- KCL example, derive $I_2$

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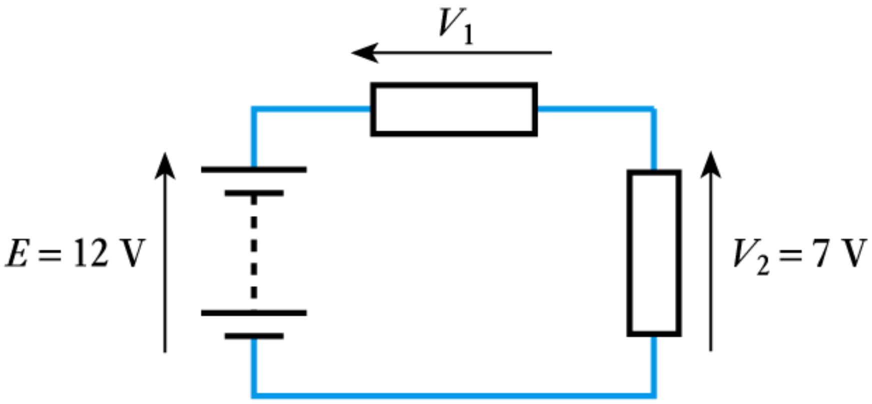
# Kirchhoff's Voltage Law (KVL)

- At any instant the algebraic sum of the voltages around any loop in a circuit is zero
- KVL example, derive $V_1$



# Power Dissipation in Resistors

- The instantaneous power dissipation $P$ of a resistor is given by the product of the voltage across it and the current passing through it. Combining this result with Ohm's law gives:

$$P = VI$$

$$P = I^2R$$

$$P = V^2/R$$

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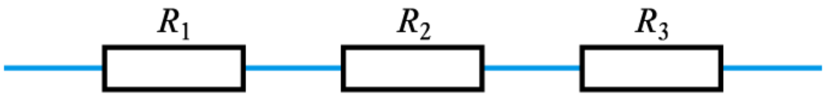
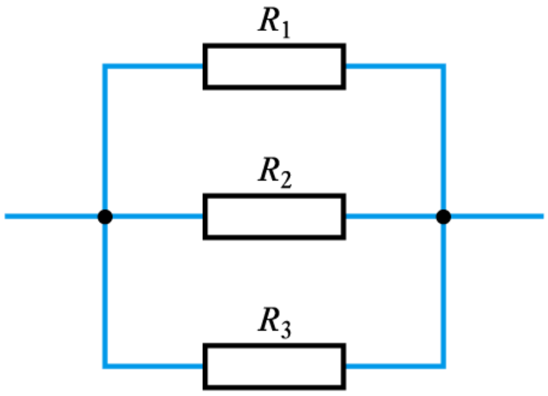
# Resistors in Series and Parallel

- **Series**




$$R = R_1 + R_2 + R_3$$

- **Parallel**




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

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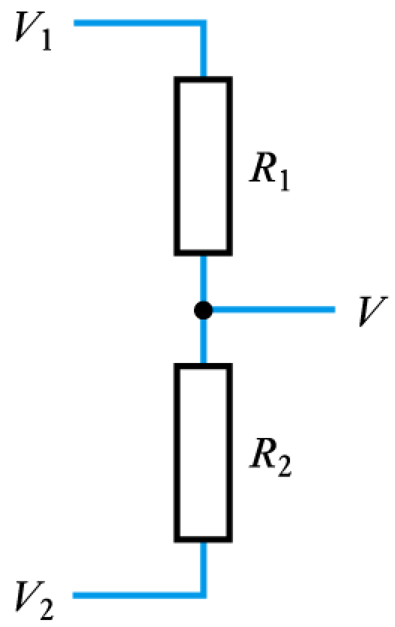
# Resistive Potential Dividers

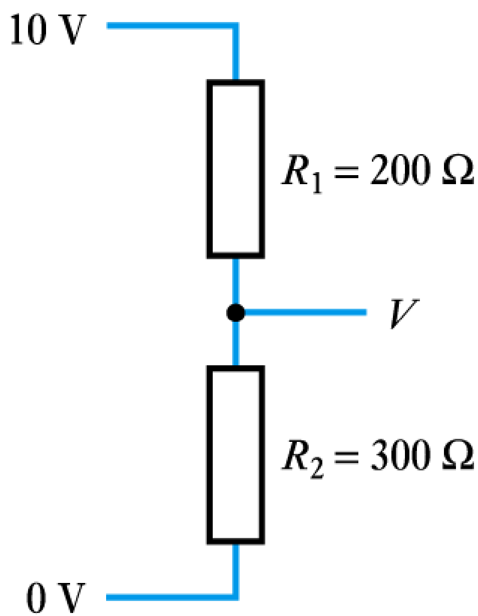
- **General case**




$$V = V_2 + (V_1 - V_2)\frac{R_2}{R_1 + R_2}$$

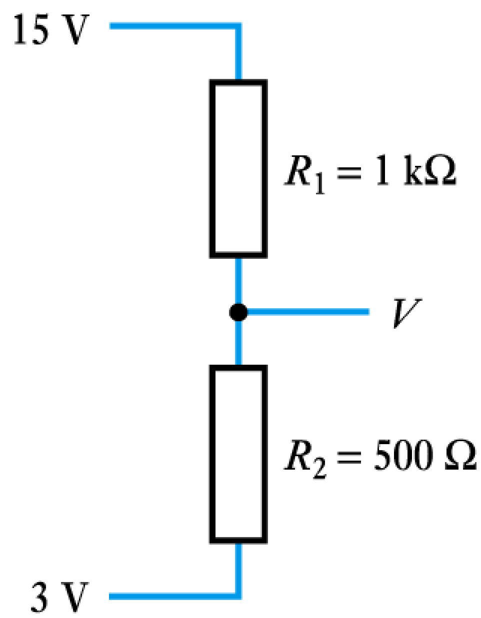
# Potential Divider Example 1

- **Derive *V***



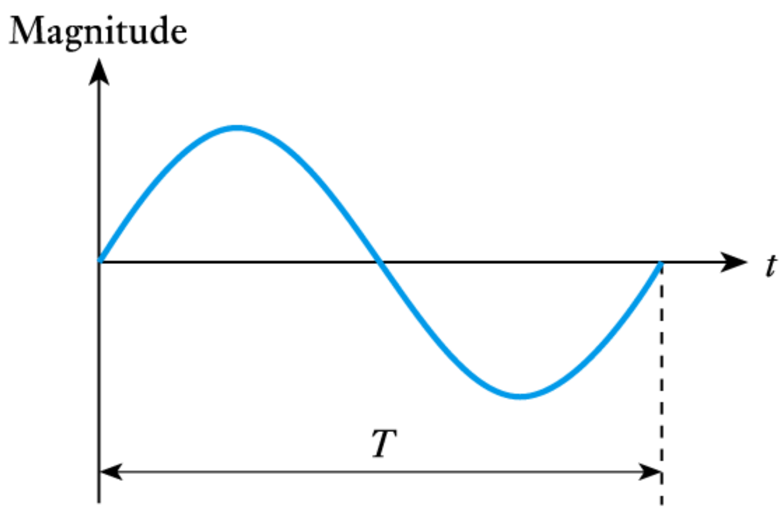
# Potential Divider Example 2

- Derive *V*



# Sinusoidal Quantities

- Length of time between corresponding points in successive cycles is the **period $T$**
- Number of cycles per second is the **frequency $f$**
- $f = 1/T$



# Circuit Symbols – 1

wire (conductor)



junctions

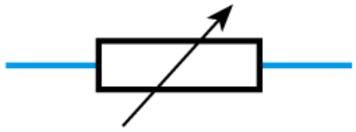
wires crossing (no junction)

resistor

capacitor

inductor

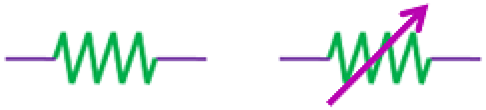
variable resistor



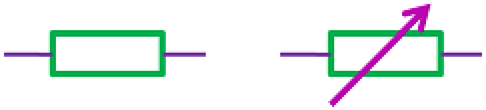
switch

lamp

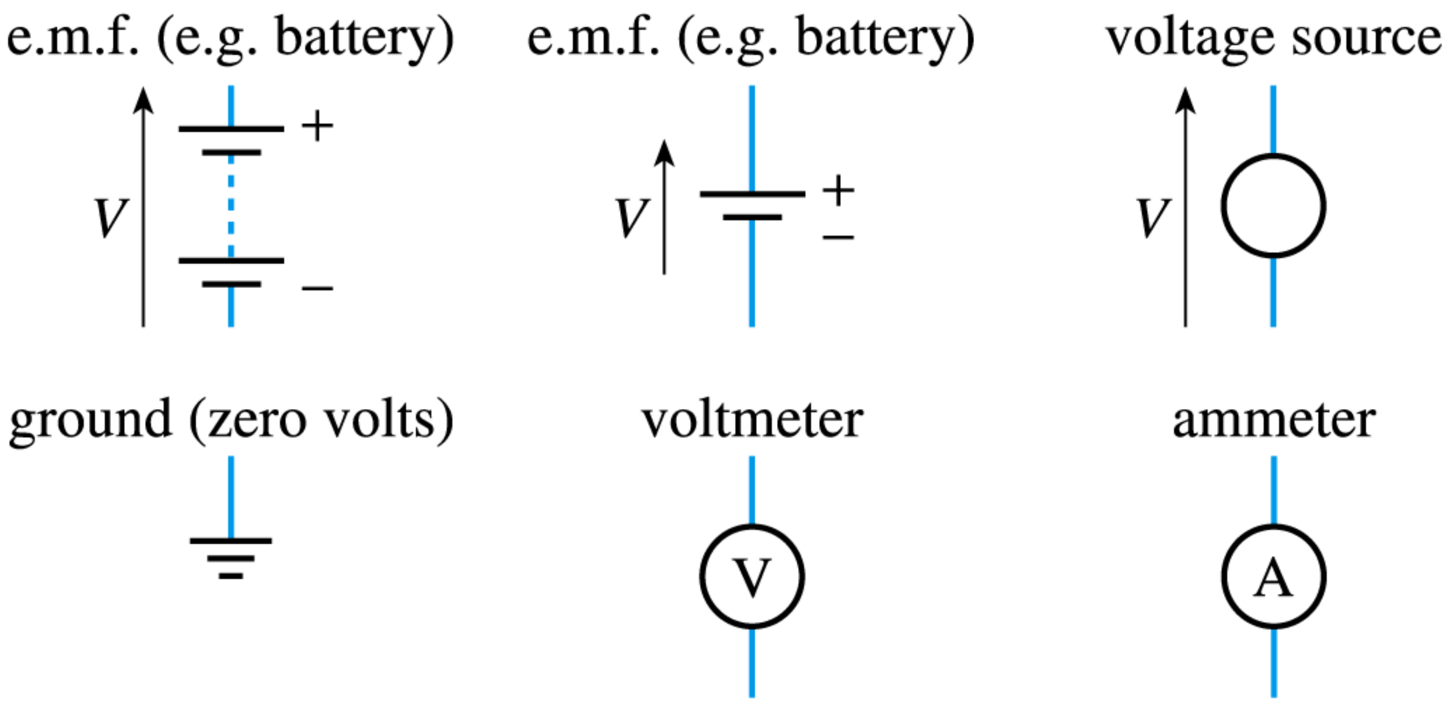
American standard



IEC standard



# Circuit Symbols – 2



# Key Points

- Understanding the next few lectures of this course relies on understanding the various topics covered in this session
- A clear understanding of the concepts of voltage and current is essential
- Ohm's Law and Kirchhoff's Laws are used extensively in later lectures
- Experience shows that students have most problems with potential dividers – a topic that is used widely in the next few lectures