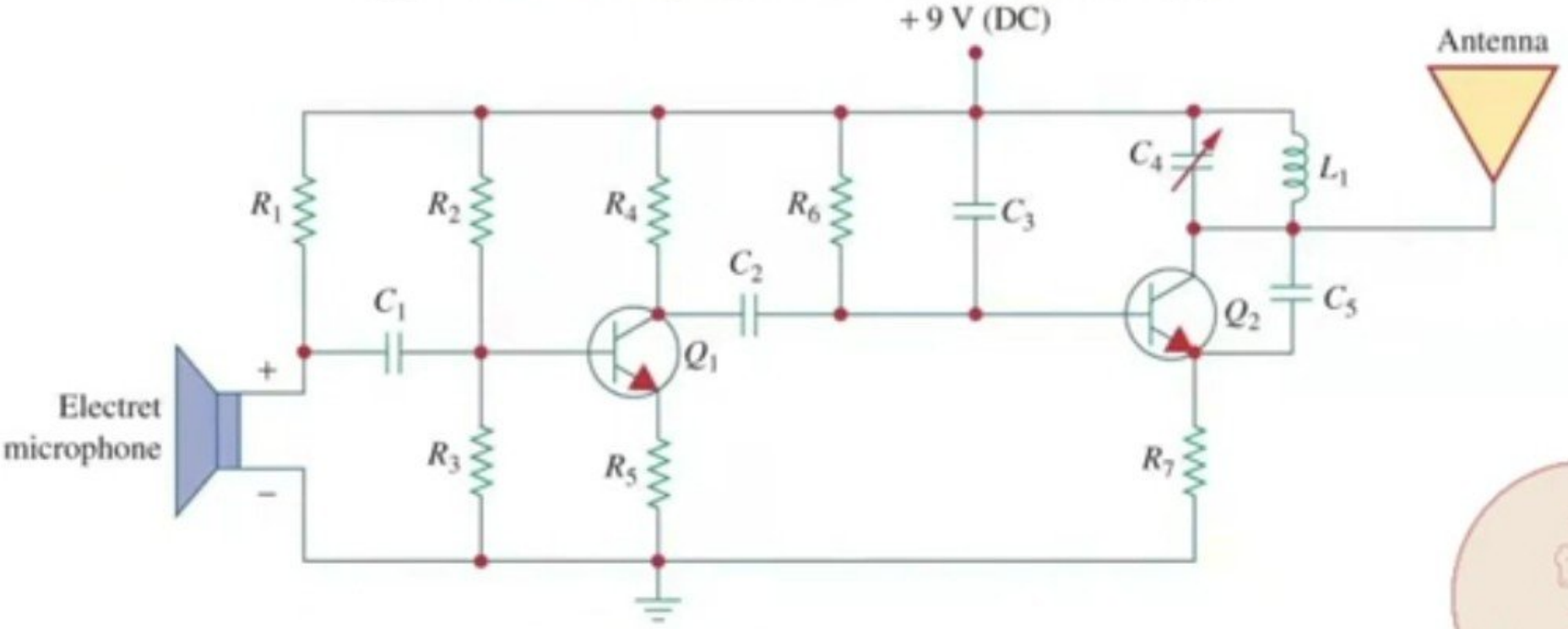
What is an Electric Circuit?

- **An electric circuit (CKT):** ***is an interconnection of electrical elements or devices*****.**
- **Target:** ***to transfer energy from one point to another.***
- **It may consist of only two elements or many more.**



What is an Electric Circuit?

- Three main specializations in Electric Engineering:
  - ✓ Power Systems.
  - ✓ Electronics.
  - ✓ Communications.
- For all of them, analyzing CKTs is essential.

Course objective

- Physical CKTs with quantities to measure like current, voltage, energy, power,… . → Mathematical Model (set of equations to find these quantities).

- Also, to learn the different techniques to analyze electric CKTs.

(1) Electric Charge

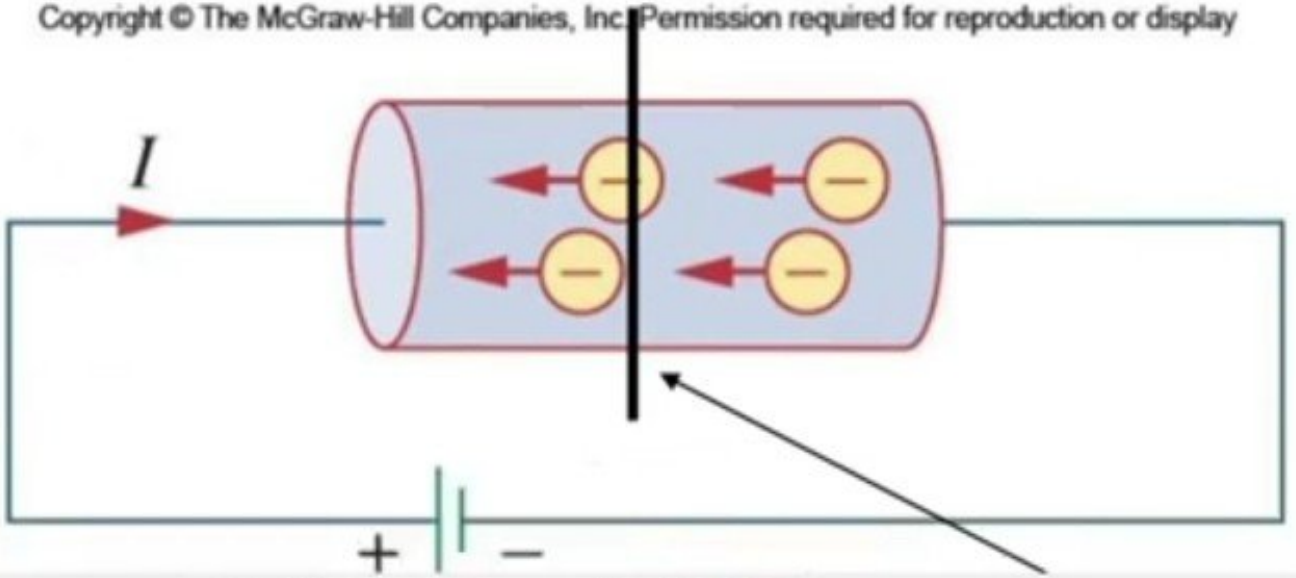
- It is the basic quantity in electricity.
- It is an electrical property of the atomic particles of which matter consists.
- It is a basic SI unit, measured in Coulombs (C).
- Electrons (-ve charge), Protons (+ve charges).
- Charge of single electron is $e = -1.602*10^{-19}$ C.
- Charge of single proton is $p = +1.602*10^{-19}$ C.
- How many electrons in one coulomb? Ans: One Coulomb is quite large, $6.24*10^{18}$ electrons (1/e).

(1) Electric Charge

- In the lab, one typically sees (mC, μC , nC, or pC)
- Charge is always multiple of electron charge.
- Charge cannot be created or destroyed, only transferred.

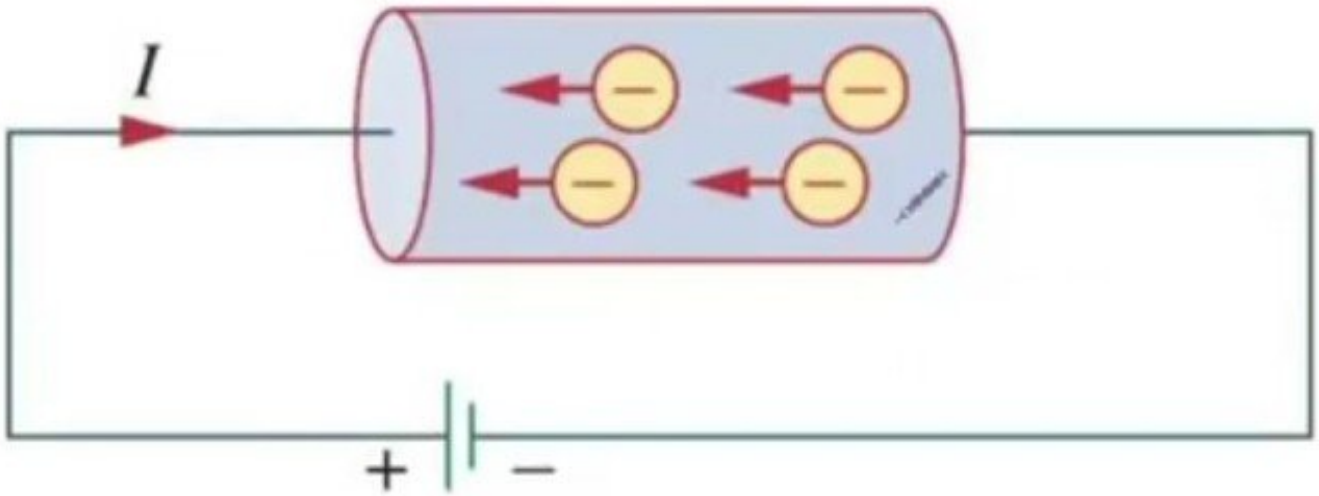
(2) Electric Current

- **Symbol:**
  - ***I*** **if constant**
  - ***i*** **or** ***i*****(t) if time-varying.**
- **Unit: Ampere , A.**
- **Def:** ***current means charges in motion (flow of charges).***



(2) Electric Current

- **Current Direction:** ***Historically the moving charges were thought to be positive. Thus, the current direction is the same as the direction of the equivalent positive charges, even if the moving charges are negative.***



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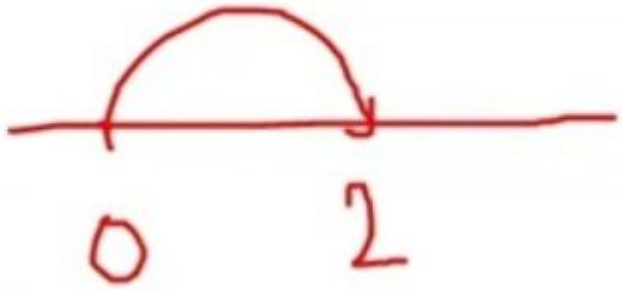
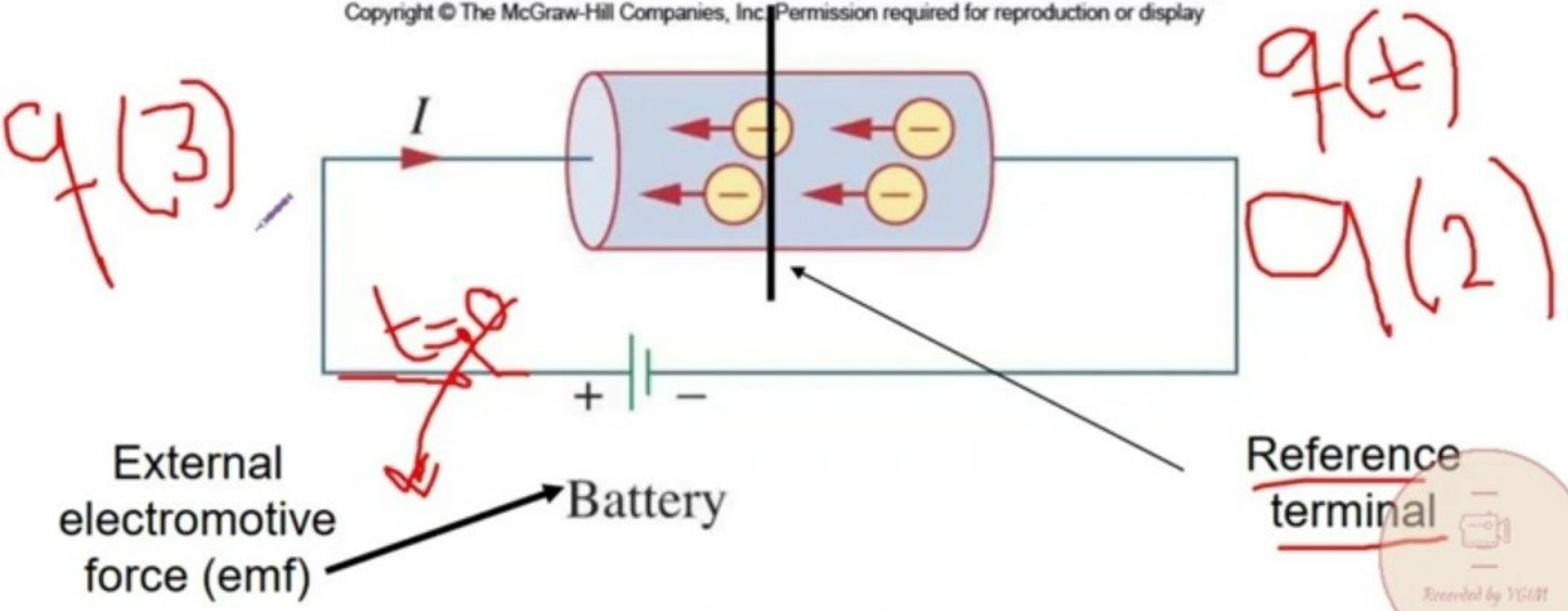




(2) Electric Current

- Let q or $q(\mathrm{t})$ is the total (net) instantaneous amount of charges that has passed the reference terminal since the initial time $\mathrm{t} = 0$ sec in a specific direction.

Example:

$$q(\mathrm{t}) = Q = 2\,mC$$

In this case, do you think that there is an electric current??

(2) Electric Current

- **Now,** ***Electric current is the time rate of change of charge.***

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

- **So**

1 ampere = 1 coulomb/second

(2) Electric Current

Example:

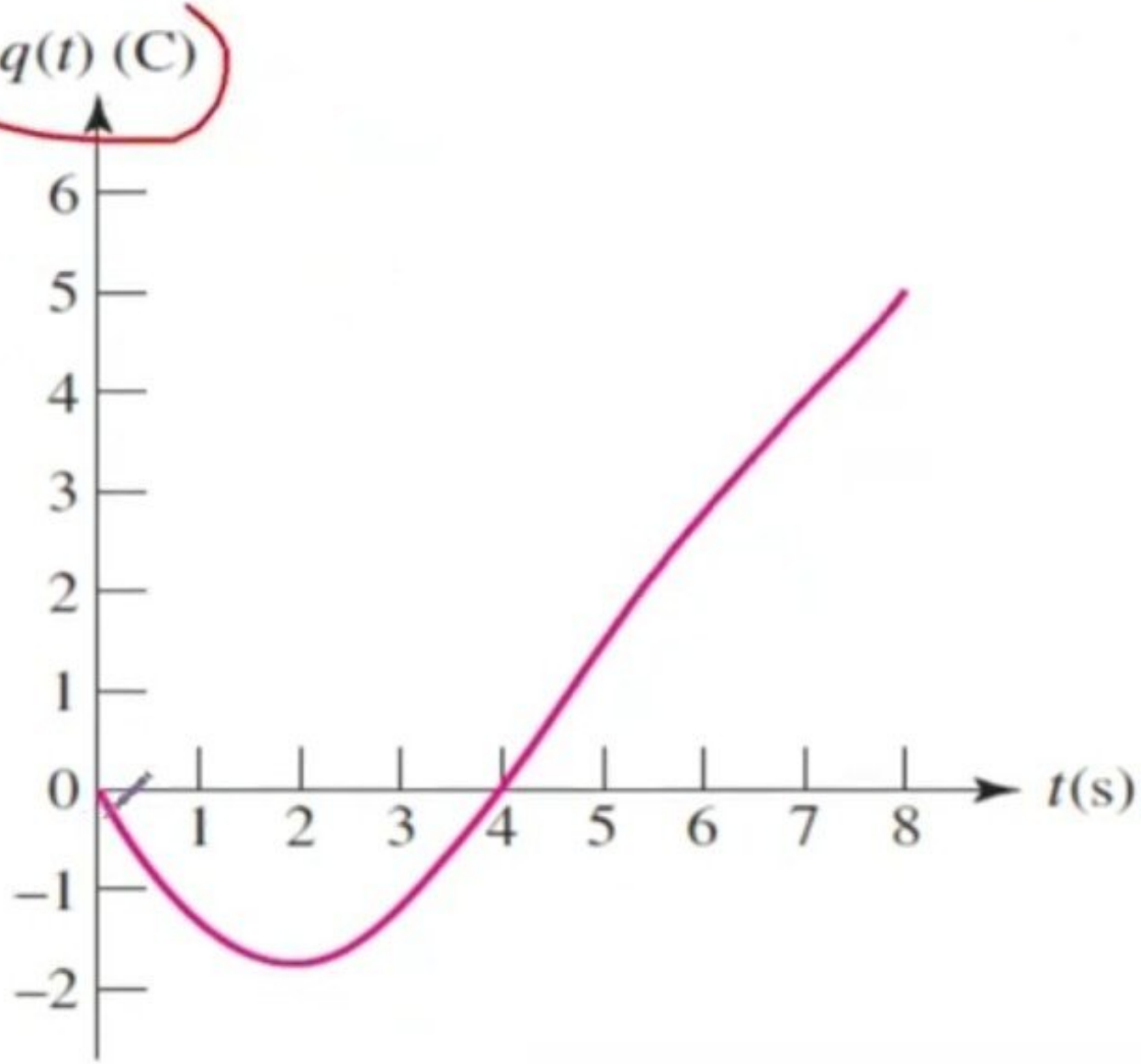


FIGURE 2.2 A graph of the instantaneous value of

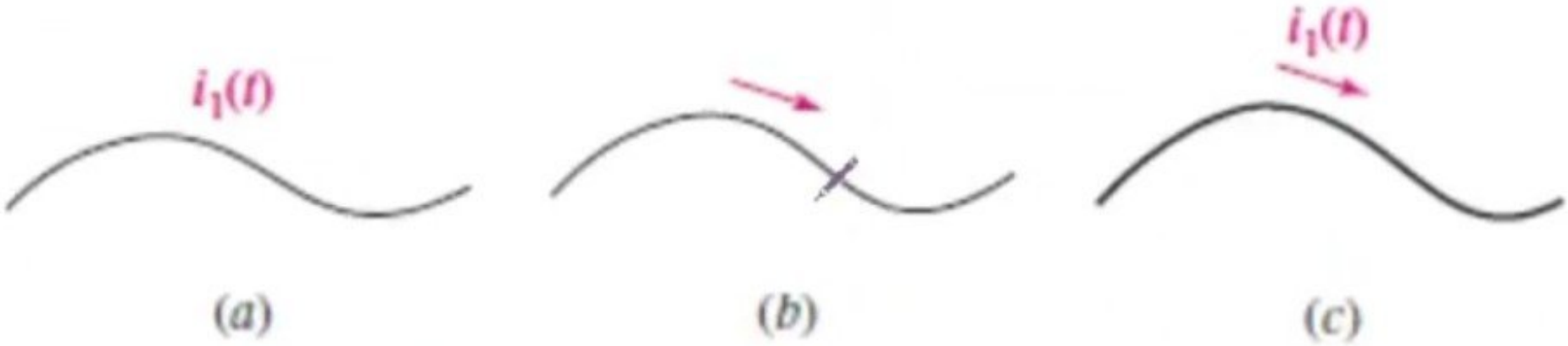
(2) Electric Current

- **The current has:**
  - ✓ **Numerical value (+ve or -ve).**
  - ✓ **Direction.**

(a) (b)

(2) Electric Current

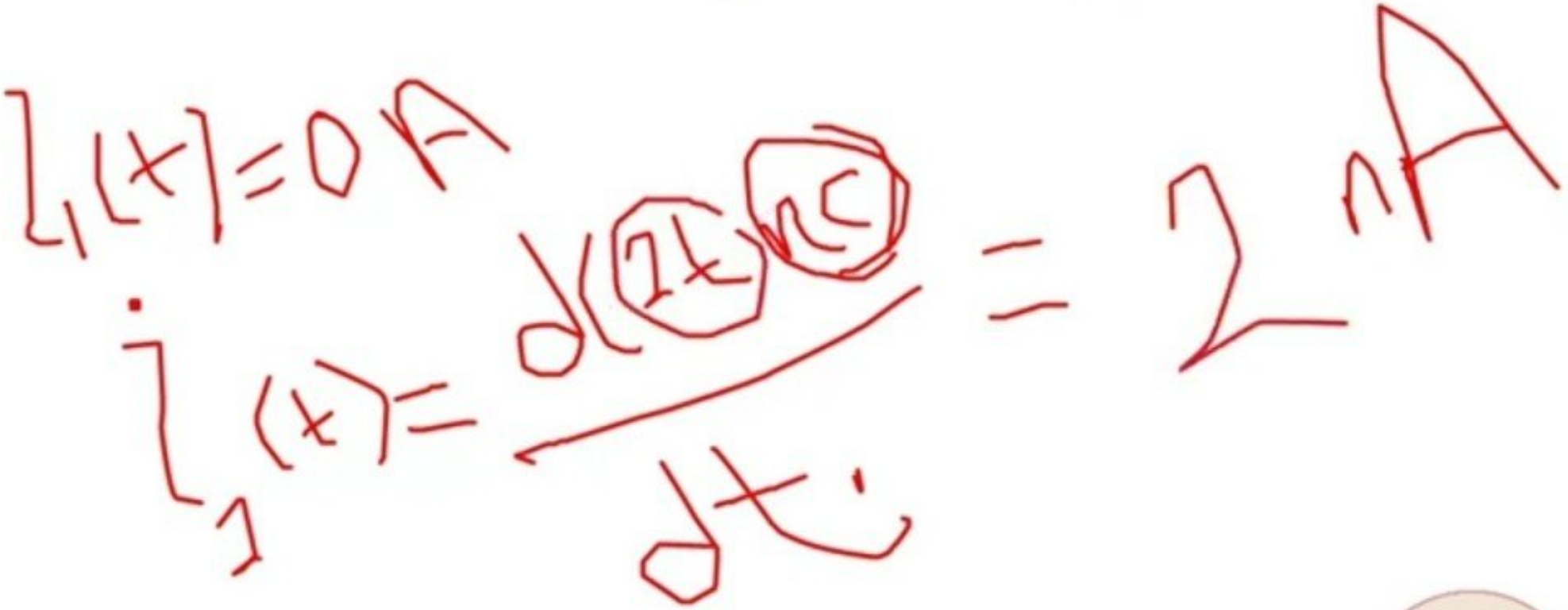
- ❑ **The current has:**
- ✓ **Numerical value (+ve or -ve).**
- ✓ **Direction.**



■ **FIGURE 2.6** (*a*, *b*) Incomplete, improper, and incorrect definitions of a current. (*c*) The correct definition of $i_1(t)$.

(2) Electric Current

- **Example: find $i(t)$ if $q(t) = 4\ mC$, $q(t) = 2t\ nC$**



Example 1.2

The total charge entering a terminal is given by $q = 5t \sin 4\pi t$ mC. Calculate the current at $t = 0.5$ s.

Solution:

$$i = \frac{dq}{dt} = \frac{d}{dt}(5t \sin 4\pi t) \text{ mC/s} = (5 \sin 4\pi t + 20\pi t \cos 4\pi t) \text{ mA}$$

At $t = 0.5$,

$$i = 5 \sin 2\pi + 10\pi \cos 2\pi = 0 + 10\pi = 31.42 \text{ mA}$$

(2) Electric Current

- Find $q(\mathrm{t})$ from $i(\mathrm{t})$?

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

$$\int_{q(t_0)}^{q(t)} dq = \int_{t_0}^{t} i\, dt'$$

$$q(t) = \int_{t_0}^{t} i\, dt' + q(t_0)$$

- Where $q(t_o)$ is the amount of energy at initial time t_o.

(2) Electric Current

- **Find charge Q transferred between time t_1 and t_2?**

  Ans: find $q(t)$ from $i(t)$, then

$$Q = q(t_2) - q(t_1).$$

Or

$$Q = q(t_2) - q(t_1) = \int_{t_1}^{t_2} i\, dt.$$

Example 1.3

Determine the total charge entering a terminal between $t = 1$ s and $t = 2$ s if the current passing the terminal is $i = (3t^2 - t)$ A.

Solution:

$$Q = \int_{t=1}^{2} i\,dt = \int_{1}^{2} (3t^2 - t)\,dt$$

$$= \left(t^3 - \frac{t^2}{2}\right)\Big|_1^2 = (8 - 2) - \left(1 - \frac{1}{2}\right) = 5.5\ \text{C}$$

(2) Electric Current

❑ **Example: Find $q(t)$ from $i(t)$,**

For Prob. 1.7.

1.8 The current flowing past a point in a device is shown in Fig. 1.25. Calculate the total charge through the point.