Lec3

Wednesday, January 11, 2012
10:40 AM

HW2 due today.
HW3 is assigned. Due Monday.

Solution to Homework 1 is posted on the web
IMPORTANT: please check solution very carefully. The grader can only grade one question out of three. The rest is graded by effort. Hence, it is your responsibility to make sure your answer is correct.

Also, Please make sure you write your PUID on the upper-right corner of the first page!!! This saves enormous amount of time to sort the homework.

Review and Objectives

Wednesday, January 04, 2012
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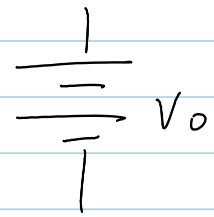
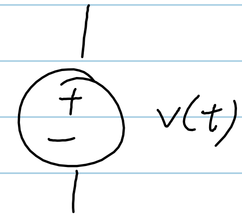
Review:

- Charge Q
- Current I
  - Rate at which charge is transported

$$I = \frac{\Delta Q}{\Delta t} \qquad i(t) = \frac{dq(t)}{dt}$$

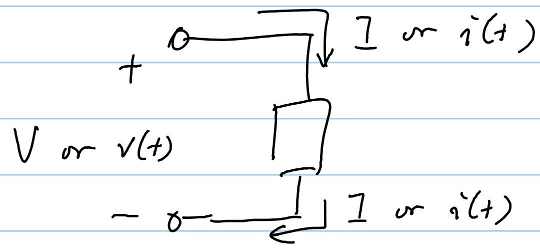
- Voltage V
  - Pressure caused by an electric field, making current flow
- Voltage source





Very Important!

- Passive sign convention: labeling of the reference directions of general two terminal circuit elements
  - Current in = current out



- Ohm's Law with passive sign convention

$$v = IR$$

- Absorbed power with passive sign convention labelling
  - DC case:

$$P_{CE} = VI$$

$$P^{S}_{del} = VI \leftarrow \text{passive sign convention for the other parts (not the source)}$$

- General case:

$$p_{ce}(t) = v(t)\,i(t) = v_{AB}(t)\,i(t) = -v_{BA}(t)\,i(t)$$

- Energy/work: $W(t) = \int_{-\infty}^{t} p(\tau)\,d\tau = \int_{-\infty}^{t} v(\tau)\, i(\tau)\, d\tau$

$$\text{or } \int_{t_0}^{t_1} p(\tau)\,d\tau$$

Objectives:

- Independent and dependent/controlled sources
- Ohm's Law

More example - 10min

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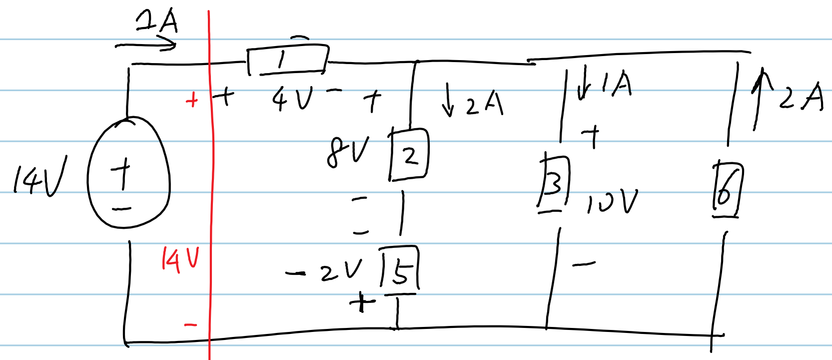
Ex 2.4 (P21)



Find the absorbed power of each CE and the delivered power from the voltage source.

Absorbed power

$P_1 = 4 \times 1 = 4W$

$P_2 = 8 \times 2 = 16W$

$P_3 = 10 \times 1 = 10W$

$P_5 = 2 \times 2 = 4W$

$P_6 = 10 \times (-2) = -20W$ (probably a source too)

Delivered power from source

$P_{del} = 14 \times 1 = 14W$

$$\boxed{P_{del} = P_1 + P_2 + P_3 + P_4 + P_6}$$

"Conservation of power"

"Conservation of power"

- Actually $P_6 = -20W < 0$

Total delivered power from all sources

$$= P_{del} + (-P_6) = 34W$$

Total absorbed power by all (other) circuit elements

$$= 34W$$

$$\boxed{\sum_{\substack{\text{over all} \\ \text{sources}}} P_{delivered} = \sum_{\substack{\text{over} \\ \text{all CEs}}} P_{absorbed}}$$

- If we treat the absorbed power of the source

$$= (-P_{del})$$

Then

$$-P_{del} + P_1 + P_2 + P_3 + P_5 + P_6 = 0$$

$$\boxed{\sum_{\substack{\text{over} \\ \text{both sources} \\ \text{\& CEs}}} P_{absorbed} = 0}$$

$$\boxed{\sum P_{delivered} = 0}$$

over both sources & CEs

2 terminal circuit element

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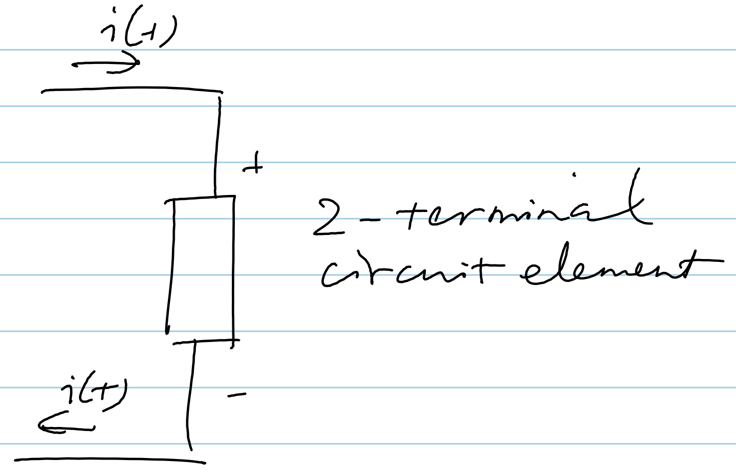
- Battery & resistors are examples of a 2-terminal circuit element



current in = current out

Analogy: Water into a pipe = water out of a pipe

Current source

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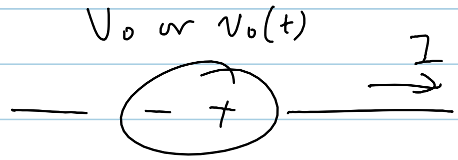
- We have seen the battery, which is a voltage source.

- An ideal / independent voltage source produces a constant voltage drop under all operating conditions, i.e. independent of load.

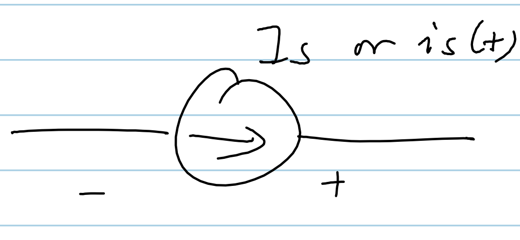


regardless I

- Note that we often do not apply the passive-sign convention to the source

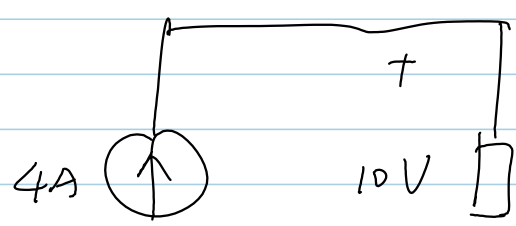
Current Source

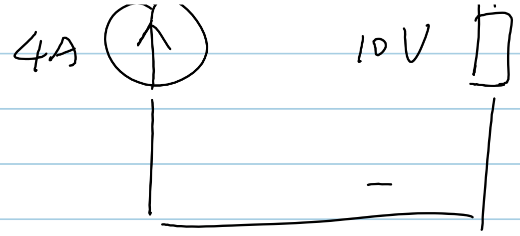
- Similarly, a ideal current source provides a constant current I_s, or a time-varying current $i_s(t)$, to a circuit under all operating conditions.



regardless of the voltage drop

Ex





What is the power supplied by the current source?

$10 \times 4 = 40\,W$

Short circuit and open circuit - 10min

Monday, January 09, 2012
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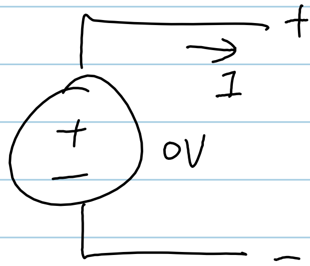
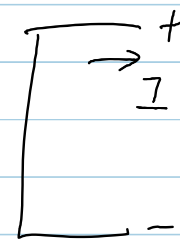
- What happens to a voltage source with a voltage of 0V?

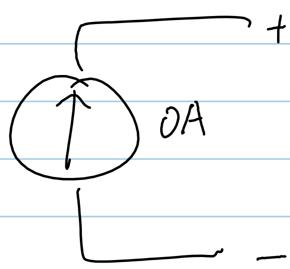


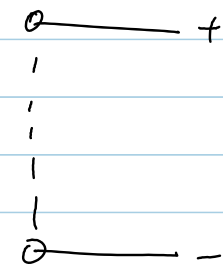


short circuit

- No matter what current flows through, the voltage drop is zero

- A current source with 0A





open circuit

Dependent/controlled sources-10min

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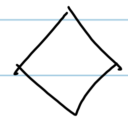
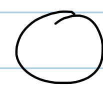
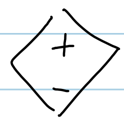
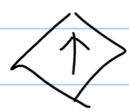
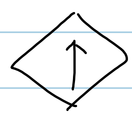
- The voltage or current of the controlled sources depend explicitly on the voltage or current in some other part of the circuit

  - e.g. an amplifier
  - an analogy: the interest rate at which banks lend money to customers depends on the rate set by the Federal Reserve

-  : dependent source  : independent source

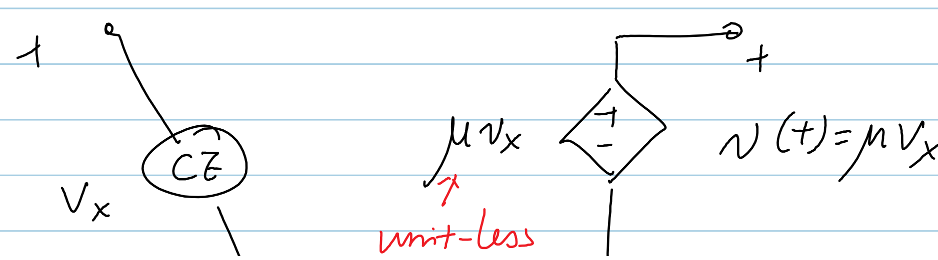
 : dependent voltage source

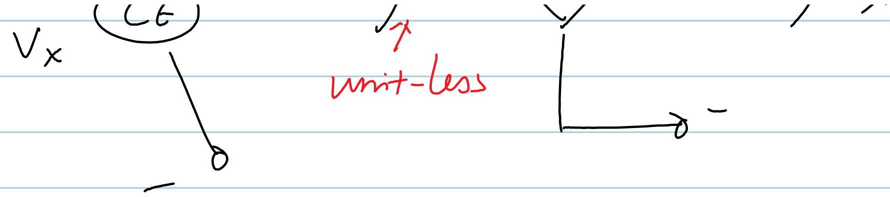
 : dependent current source

$2V_a$  : dependent relationship

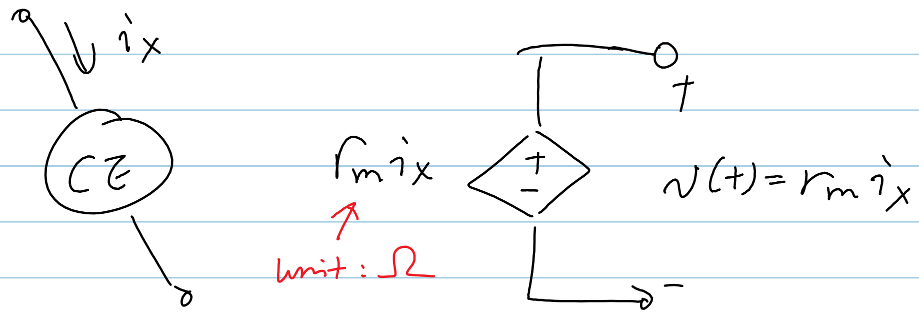
Four types

- VCVS (voltage controlled voltage source)



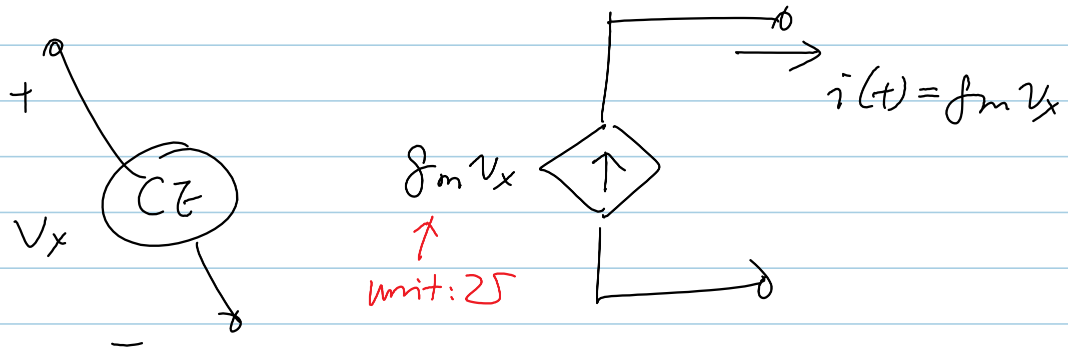


– CCVS (current controlled voltage source)

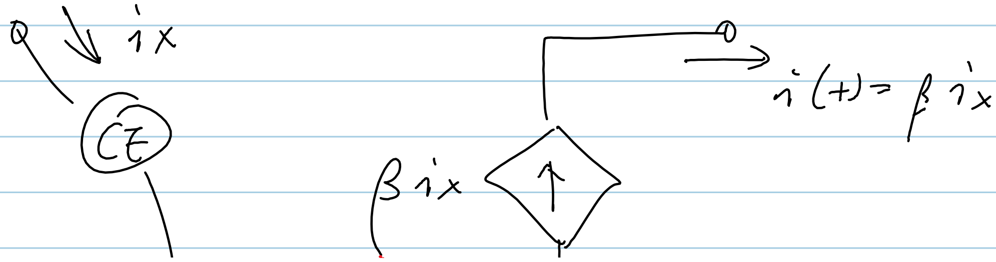


common mistake: thinking that this is a current source.

– VCCS (Voltage controlled current source



– CCCS (current controlled current source)



$\beta i x$

unitless

Examples-10min

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- We have known a number of relationships

  - Ohm's Law: $I = \frac{V}{R}$

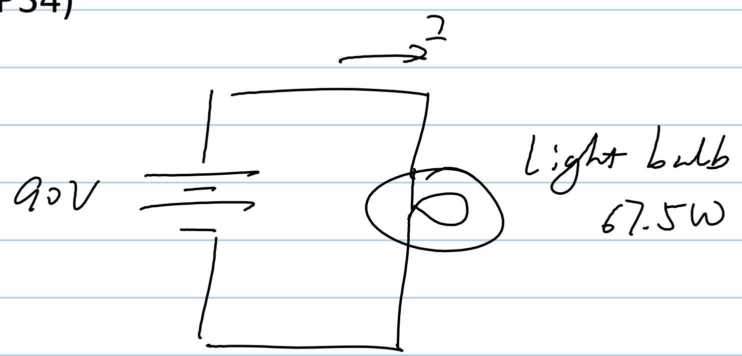
  - power: $P = VI$

  - Conservation of power

$$P_{del} = P_{abs}$$

It turns out that with these we can already compute many interesting results.

Ex 3.1 (P34)



Find the current I and the "hot" resistance of the light bulb.

Solution:

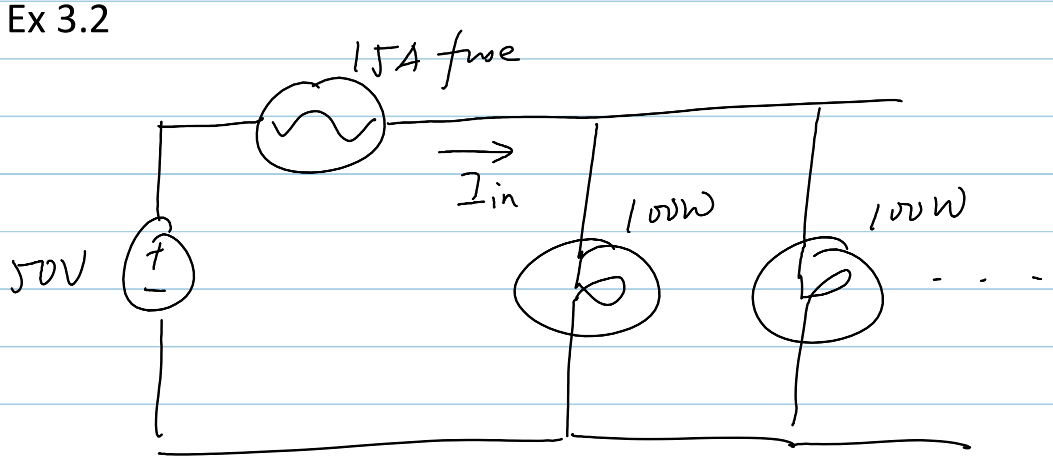
Step 1: Find I using power relationship

$$I = \frac{P_{bulb}}{V_{in}} = \frac{67.5}{90} = 0.75A$$

Step 2: Find R using Ohm's Law

$$R = \frac{V_{in}}{I} = \frac{90}{0.75} = 120\,\Omega$$

Ex 3.2



How many 100W bulbs can be connected in parallel before the fuse will blow?

Solution:

- Step 1: Compute the max power delivered by the source

$$P_{max} = 50 \times 15 = 750 \text{ Watts}$$

This is also the max power that the bulbs can absorb

- Step 2 : Find the max # of bulbs

$$N \times 100 \leq 750$$

$$N \leq 7.5$$

$$\Rightarrow \quad N = 7$$

More examples-10min

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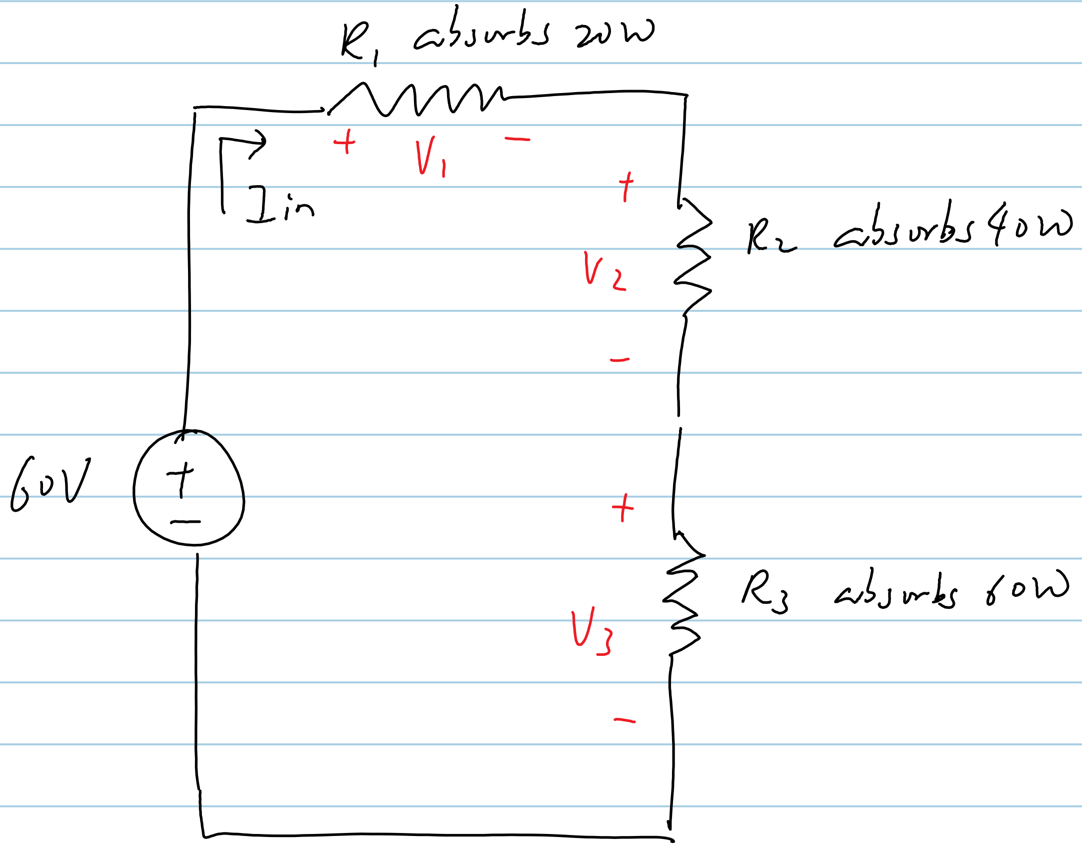
Ex 3.3



Find

(i) I_{in}

(ii) V_i, the voltage across each resistor

(iii) Check that the source voltage is the sum of the resistor voltages

(iv) Find the resistance of each resistor

(v) Find the effective resistance seen by the source

Solution:

(i) Compute power delivered by the source using

Conservation

$$P_{del} = 20 + 40 + 60 = 120 \text{ Watts}$$

Compute I_{in} using power relationship

$$I_{in} = \frac{P_{del}}{V_{in}} = \frac{120}{60} = 2A$$

(ii) Since each element is a 2-terminal circuit element, the current entering equals the current leaving

Find voltage V_i using power relationship

$$V_1 = \frac{20}{2} = 10\,V$$

$$V_2 = \frac{40}{2} = 20\,V$$

$$V_3 = \frac{60}{2} = 30\,V$$

Note the passive-sign convention !

(iii) $V_{in} = V_1 + V_2 + V_3 = 60V$ ✓

This is known as KVL, which we will study in further details soon

(iv) Find resistance of each resistor using Ohm's Law.

$$R_1 = \frac{V_1}{I_{in}} = \frac{10}{2} = 5\Omega$$

$$R_2 = \frac{V_2}{I_{in}} = \frac{20}{2} = 10\Omega$$

$$R_3 = \frac{V_3}{I_{in}} = \frac{30}{2} = 15\Omega$$

Alternately, note that

$$P = VI = \frac{V^2}{R} = I^2 R$$

Hence, you can also find R using these formulas

(v) Find the effective resistance seen by source using Ohm's Law

$$R_{eff} = \frac{V_{in}}{I_{in}} = \frac{60}{2} = 30\Omega$$

Note that

$$R_{eff} = R_1 + R_2 + R_3$$

This is a known property of series resistors, which we will also study in Ch. 4.

Take home

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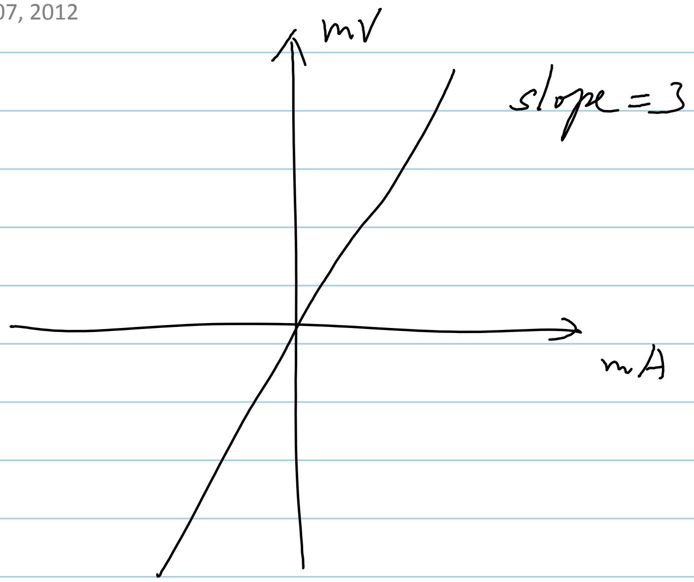

A circuit has the $v-i$ diagram above.

What is the equivalent circuit element that could replace it?

— A resistor with $R = 3\Omega$.