Kirchhoff's Rules

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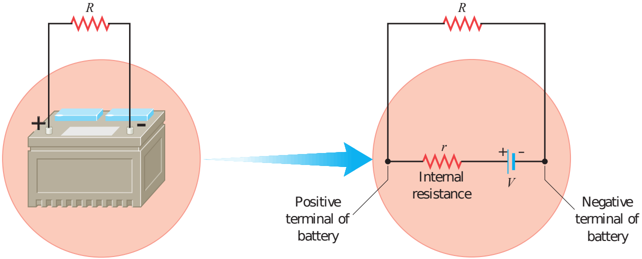
University of Arizona

PHYS 103 - Lecture 5

Internal Resistance



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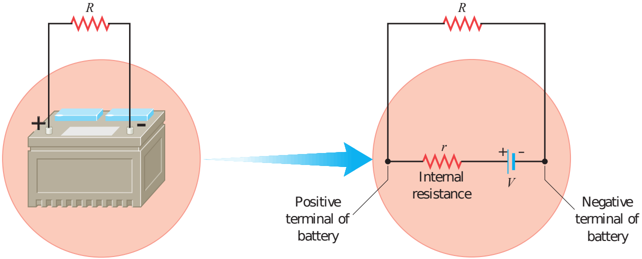

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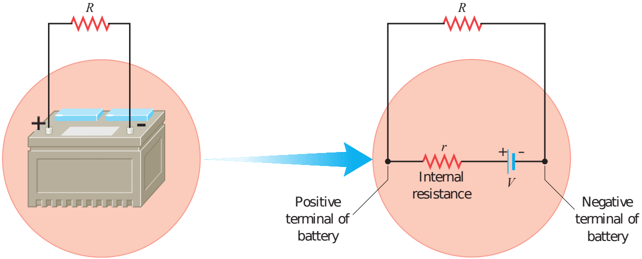

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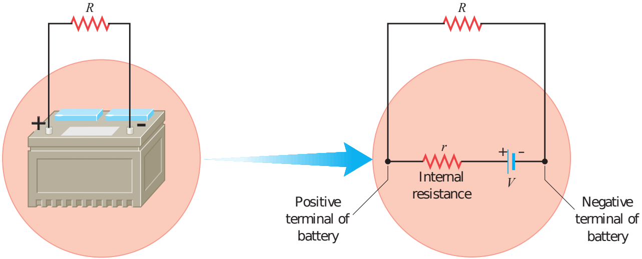

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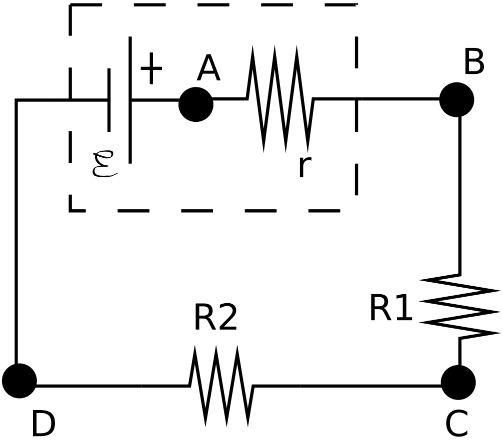
- A real battery will have a small resistance due to its internal structure.
- Typically very small, around the order of $r \sim 0.001\,\Omega$.
- We can model this internal resistance as a resistor that will be in series with the rest of the circuit.

Real battery and two resistors in series

For the next few questions consider the circuit below containing a real battery with emf $\mathcal{E}$ and internal resistance r. Beyond the battery, there are two resistors with resistances R_1 and R_2



Q: Real battery and two resistors in series I

Where would you define $V \equiv 0$?

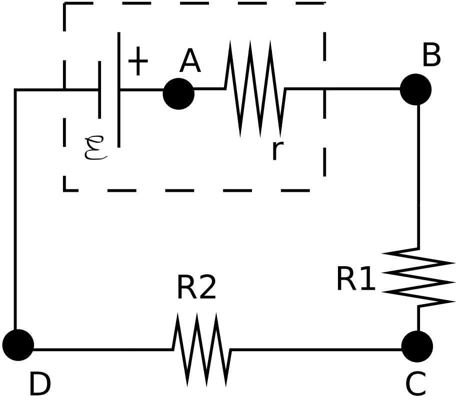
(A) A

(B) B

(C) C

(D) D

(E) Infinitely far away from the battery



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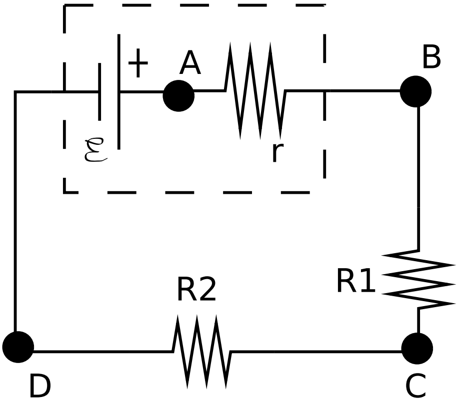


Q: Real battery and two resistors in series II

Given that definition of $V = 0$, at what point is the electric potential the largest?

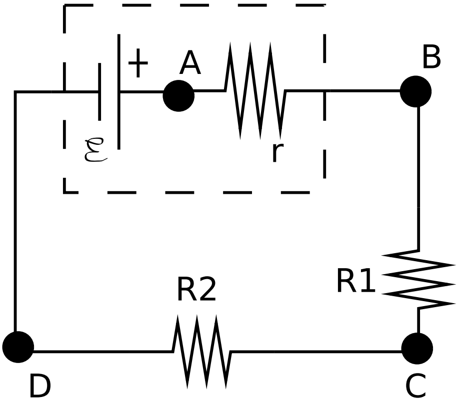
(A) A

(B) B

(C) C

(D) D

(E) A and B (they are the same)



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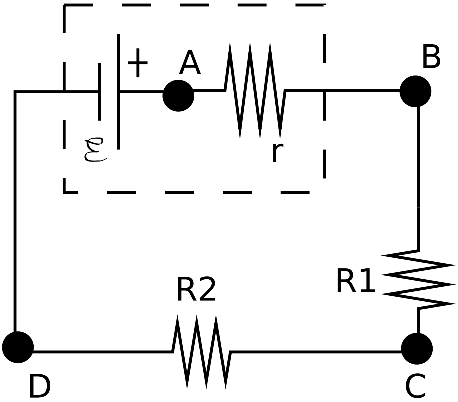
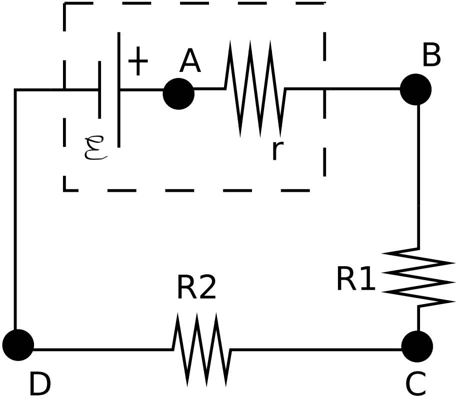


Q: Real battery and two resistors in series III

Where is the current the largest?

(A) A
(B) B
(C) C
(D) D
(E) A and B (they are the same)
(F) It is the same at all points



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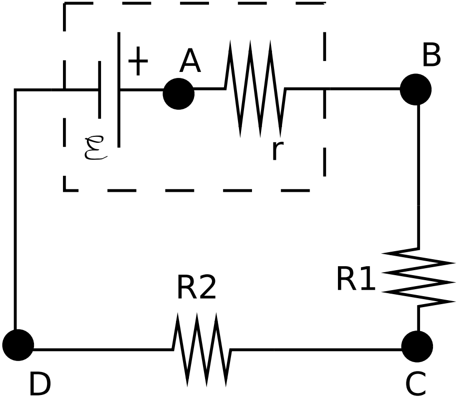
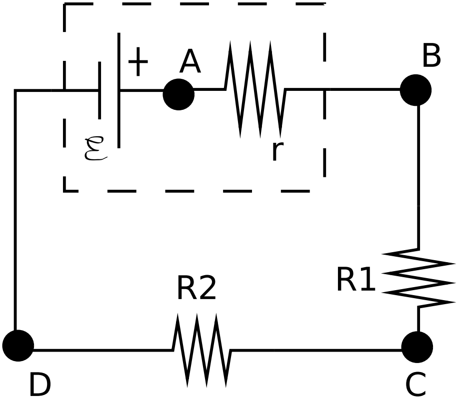


Q: Real battery and two resistors in series IV

Given these values, and our definition of $V = 0$ at point D, what is the potential at point B?

$\mathcal{E} = 28\text{V}$, $I = 2\text{A}$
$r = 3\Omega$, $R_1 = 6\Omega$



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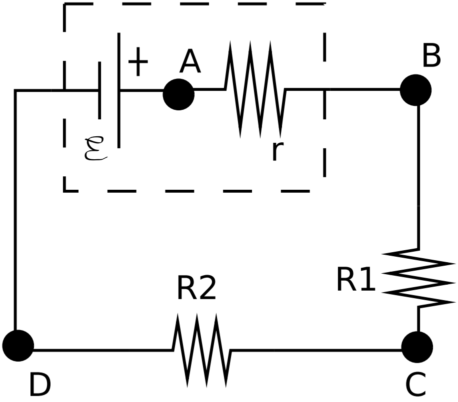
$V_A = +28\text{V}$
$V_A - V_B = Ir$
$V_B = V_A - Ir$
$V_B = +28 - (2)(3)$
$V_B = 22\text{V}$



Q: Real battery and two resistors in series V

What is the potential *difference* $V_A - V_C$ in terms of I, r, and R_1?

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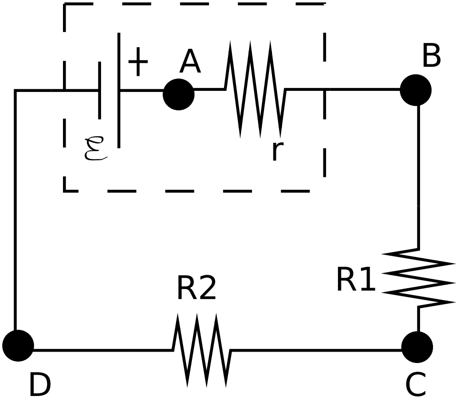

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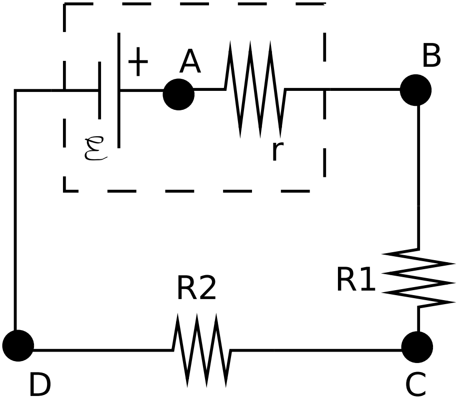
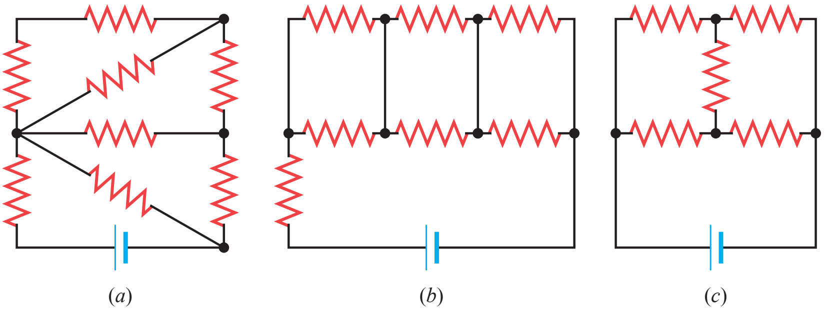


$V_A - V_C = I(r + R_1) = 18\text{V}$

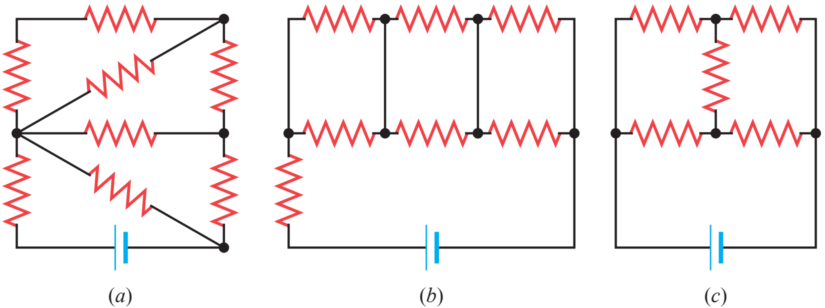
This is a general result. Any number of resistors in series behaves as a single resistor of *equivalent resistance*:
$R^{\text{tot}}_{\text{series}} = \Sigma R_i$

Series and Parallel Resistors



Which of the above circuits do not have any resistors in series or in parallel?

Series and Parallel Resistors



Which of the above circuits do not have any resistors in series or in parallel?

Circuit (C) does not have any resistors in series or parallel.

Kirchhoff's Rules

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- **Loop Rule:** The sum of all of the potential drops and rises around a closed loop is equal to zero.

$$\sum_{loop} V_k = 0 \tag{2}$$

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- Since charge must be conserved, any charge that flows into a junction must flow out.

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- There are generally extra loops that are just combinations of the other loops. These provide no additional information and can be ignored.

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6. Repeat steps 4 and 5 until you have as many equations as unknowns and solve.