Inventory of Basic Conceptions in DC Circuits

Taxonomy Themes	*Test Items **
1. State of Inertia	
In the absence of an external agent that continually interacts with charge carriers in a conductor with nonzero resistance, such carriers cannot continuously circulate from one point of the conductor to the other and maintain an electric current between these two points.	16
2. Interaction, EMF and Electric Potential Difference	
Two electric devices can interact with one another only when one of the devices is a seat of emf or emf source (hereafter referred to as "generator"), i.e., a device that causes an electric potential difference (epd: $U = \Delta V$) between, and not a constant electric potential V at, the two terminals of the other device (hereafter referred to as electrical load, or "load").	15
A generator does not interact with an electrical load unless the two constitute, or are part of, a closed circuit.	1
In a steady state, the role of a DC battery is to maintain a constant epd U between its ends, not a constant potential V.	17
When different electrical loads are connected separately to the same DC battery, and because of the internal resistance of the battery, the battery maintains roughly the same emf but not necessarily the same epd between its terminals.	5
3. Interaction Law	
In a closed circuit, charge carriers move through both generator and electrical loads. In a steady state, the number of charge carriers that are pumped out of a battery is equal to the number of those that are pumped in from the circuit. No charge carriers are used up in the circuit loads.	(16, 18), 19
4. Causal Laws	
A generator causes free charge carriers (electrons, protons, ions) to drift in a closed circuit, in different directions, at slow speeds (that are as low as 10^{-5} m/s). [Circulation of electric current at a speed comparable to the speed of light is associated with field propagation and not with drift motion of charge carriers].	18
A constant epd U, and not a constant potential V, between two points of a closed circuit causes the flow of a constant electric current I between these two points. The current I is proportional to the epd U and inversely proportional to the resistance R of any load connected between these two points. This is Ohm's law ($U = IR$). From a practical perspective, different electrical loads of the same nature (e.g., light bulbs) do not necessarily behave the same way when connected between these two points unless they have the same resistance R.	3, 4, 6, (15, 16, 17)
An electrical load operates normally when a generator supplies the rated epd. It may break down when a higher epd is supplied, and does not operate properly when a lower epd is supplied.	7, 8

5. Composition / Conservation Laws (for simple series and parallel circuits)	
Emfs of a number of generators add up only when they are in series with one another in a given circuit. The equivalent generator has an emf equal to the algebraic sum of individual emfs.	9
Kirchhoff's loop rule (Conservation of Energy): The algebraic sum of epds across all elements of a circuit loop is zero.	26
Kirchhoff's node rule (Conservation of Charge): The algebraic sum of all currents at a given node (or junction) in a circuit is zero	27
6. State Laws	
Every electrical load has a characteristic resistance R.	14
The resistance of a conducting wire depends of the material it is made of, its length and its cross-sectional area.	2
In a steady state, the same current, but not the same electric potential, exists at the ends of an electrical load.	17
A number of electrical loads are said to be connected in series with a generator when the epd across all loads, which may not be necessarily the same across each, add up to the epd between the generator terminals. In a steady state, the same electric current flows in all loads in series, and this irrespective of the apparent topology or order of the loads in the circuit. However, the bigger the number of electrical loads in the circuit, the smaller the current.	10, 12, 22, 24
A number of loads are said to be connected in parallel with a generator when the same epd, equal to the epd between the generator terminals, exists between the ends of each load. In a steady state, the same epd, but not necessarily the same current, is maintained between the ends of all loads in parallel, and this irrespective of the apparent topology, number or order of the loads in the circuit.	11, 13, 23, 25
Identical loads behave the same way when all placed in series or in parallel with the same generator that maintains between its terminals the corresponding rated epd. However, they operate normally when in parallel and not in series with the generator. If one of the loads breaks down and results in an open circuit, all other loads in series with it will be shut off, whereas those in parallel stay operational.	20, 21 30, 31, 32, 33
In a given circuit, an ammeter connected in series with a given load measures the current flowing through the load, and a voltmeter connected in parallel with the load measures the epd between its ends.	28, 29

* *Items between parentheses are shared with another theme to which they are more crucial.*

Themes between brackets are not directly assessed.