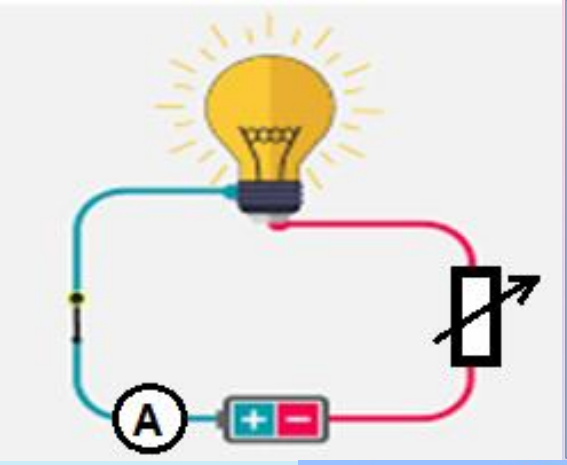
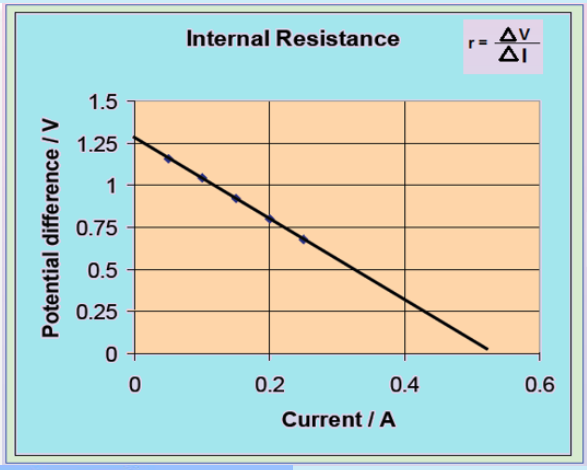
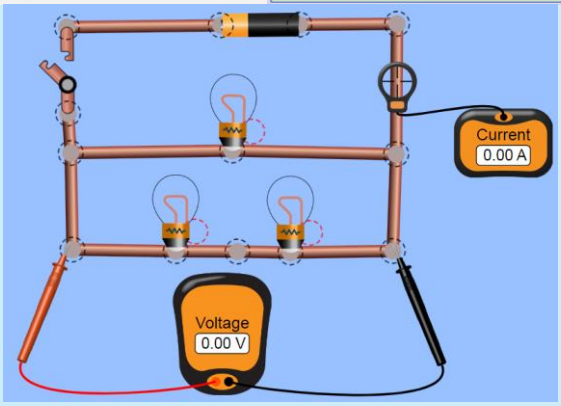
NORTHERN CAPE DEPARTMENT OF EDUCATION

PHISICAL SCIENCES
GRADE 12
PHISICS







CONSOLIDATION
TERM 3
ELECTRIC CIRCUITS

COMPILED BY:
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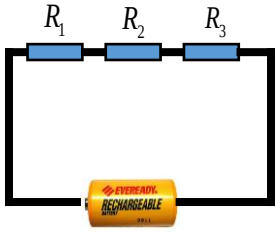
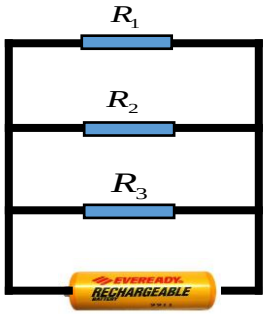
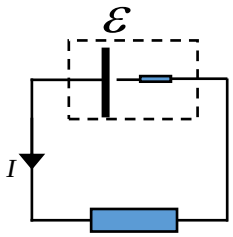
2020

PHYSICS

ELECTRIC CIRCUITS

CURRENT	*EMF &* POTENTIAL DIFFERENCE	Resistors in Series	Resistors in Parallel	Ohm's Law	Internal Resistance	Work (energy transferred)	Power
The total charge that passes through a conductor per unit of time. $I = \frac{Q}{\Delta t}$ Measured in amperes (A)	Emf is the work done (energy transferred) per unit charge to move the charge from the negative electrode to the positive electrode in the battery. $\varepsilon = \frac{W}{q}$ ***Potential defference*** is the work done per unit charge between two points in a circuit. $V = \frac{W}{Q}$ Measured in volts (V)	 $R_T = R_1 + R_2 + R_3$ $I_1 = I_2 = I_3$ $V_T = V_1 + V_2 + V_3$ (Resistors act as potential dividers.)	 $\frac{1}{R_E} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ $V_1 = V_2 = V_3$ $I_T = I_1 + I_2 + I_3$ (Resistors act as current dividers.)	**Ohm's Law *states that the potential difference across a conductor is directly proportional to the current in the conductor at constant temperature.*** $R = \frac{V}{I}$ ***Whole circuit:***  *A real battery has internal resistance.* $I = \frac{\varepsilon}{R + r}$	When current flows through a voltage source (battery/generator) a resistance to current flow arises due to the resistance of the materials (chemicals/conductors) from which the source is made. **Internal resistance is the resistance offered to the electron flow by the electrolyte/medium of the cell/generator** Measured in ohms (Ω)	General: $W = VIt$ Series: $W = I^2Rt$ Parallel: $W = \frac{V^2}{R}t$ **Whole circuit:** $W = \varepsilon It$ Measured in jouls (J)	**The rate at which electrical work is done or electrical energy is transferred.** $\boldsymbol{P = \frac{W}{\Delta t}}$ $\boldsymbol{P = VI}$ $\boldsymbol{P = \frac{V^2}{R}}$ $\boldsymbol{P = I^2R}$ Measured in watts (W)

STRATEGY TO SOLVE PROBLEMS ON ELECTRIC CIRCUITS

- ▶ Read the problem carefully as many times as you need.
- ▶ If not given, draw a circuit diagram.
- ▶ Write down the data in symbolic form.
- ▶ Indicate the conventional direction of the current from high-potential to low-potential (+ to -).
- ▶ Re-draw the circuit diagram to simplify it if necessary.
- ▶ Identify the type of connection (series/parallel).
- ▶ Analysing circuits

1 – The algebraic sum of the changes in potential in a complete transversal of any loop of a circuit must be zero. ($\varepsilon = IR + Ir$)

2. The sum of the currents entering any junction must be equal to the sum of the currents leaving that junction. ($I = I_1 + I_2 + \ldots + I_n$)

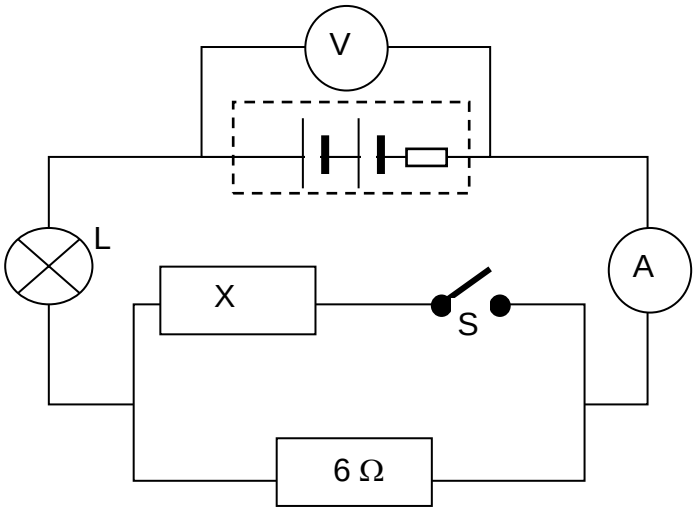
- ▶ Write down the formula/ equation that solves the question.
- ▶ Find the unknowns if needed (multi-concept problems)
- ▶ Do the calculations and write down the final answer.
- ▶ Check your answer

1- Does it have the correct dimensions (units)?
2- Is the numerical value reasonable?

EXAMPLE

QUESTION 1

In the circuit represented the battery has an emf of 24 V and an unknown internal resistance, r. The resistance of resistor X is also unknown.



When switch S is open the ammeter has a reading of 1,5 A.

1.1 Calculate the resistance of bulb L if the power dissipated in it is equal to 18 W.

1.2 Calculate the internal resistance of the battery.

When switch S is closed the ammeter has a reading of 2,0 A.

1.3 Calculate the reading on voltmeter V.

1.4 Calculate the resistance of resistor X.

SOLUTION

Remember

emf is the maximum amount of energy a battery can transfer per coulomb charge (V=W/q). It is the voltmeter reading across the battery when the battery is NOT delivering current (with the switch open). The emf of a battery does not change – it is a property of a battery.

When the battery is delivering current to a circuit, the voltmeter reading across the battery drops. This is as a result of the internal resistance in the battery.

Consider the equation:

emf = I (R + r)

Total external resistance

Internal resistance

$\varepsilon = IR + Ir$

$\varepsilon = V_{external} + V_{"internal\ resistance"}$

1.1 $P = I^2R$
$18 = (1,5)^2R$
$R = 18/1,5^2 = 8\ \Omega$

1.1 The current in a series circuit is everywhere the same

1.2 emf = I(R + r)
24 = (1,5)(8+6) + (1,5)(r)
= 21 + 1,5r
r = 2 Ω

1.2 The resistance of the battery is the internal resistance, r. Remember R in this formula is TOTAL external resistance.
From this calculation you can see that the $V_{external}$ is 21 V and the V_{int} is (1,5)(2) =3 Ω

1.3 $emf = V_{ext} + Ir$
$24 = V_{ext} + (2)(2)$
$V_{ext} = 24 - 4$
$= 20\ V$

1.3 Remember that the emf of the battery remains 24 V and its internal resistance remains 2 Ω, irrespective what is done to the circuit!! Why does the current increase from 1,5 A to 2 A? Because now we have a parallel connection of resistors, which lowers the external resistance, increasing the current.

1.4 $V_{over\ L} = IR = 2(8) = 16\ V$
$V_{over\ //\ comp} = 20 - 16 = 4\ V$

$R_{//} = V/I = 4/2 = 2\ \Omega$

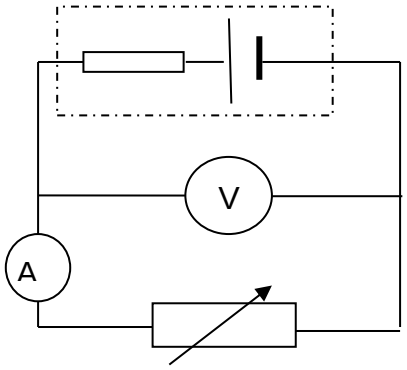
1.4 Potential difference relationships!

$1/R_{//} = 1/x + 1/6$
$½ = 1/x + 1/6$
$1/x = ½ - 1/6 = (3-1)/6 = 2/6$
$x = 6/2 = 3\ \Omega$

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Choose the answer and write only the letter (A–D) next to the question number (1.1–1.10) in the ANSWER BOOK, for example 1.11 D.

1.1 In the circuit represented below, the resistance of the variable resistor is decreased. How does this affect the reading of the ammeter and voltmeter?



	AMMETER READING	VOLTMETER READING
A	Unchanged	decreases
B	increases	decreases
C	decreases	decreases
D	decreases	increases

(2)

1.2 The minimum value of the resistance that can be obtained by connecting two 4 Ω resistors is ...

A 8 Ω.

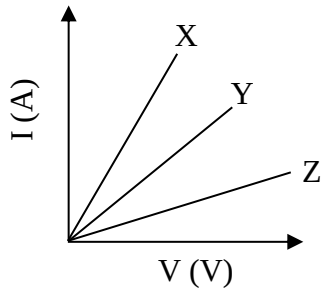
B 4 Ω.

C 2 Ω.

D 1 Ω. (2)

1.3 Learners investigate the relationship between current (I) and potential difference (V) at a constant temperature for three different resistors, **X**, **Y** and **Z**.

They obtain the graphs shown below.



The resistances of **X**, **Y** and **Z** are R_X, R_Y and R_Z respectively.

Which ONE of the following conclusions regarding the resistances of the resistors is CORRECT?

A $R_Z > R_Y > R_X$

B $R_X = R_Y = R_Z$

C $R_X > R_Y > R_Z$

D $R_X > R_Y$ and $R_Y < R_Z$ (2)

1.4 When a resistor of resistance R is connected to a battery of emf Ɛ and negligible internal resistance, the power dissipated in the resistor is P.

If the resistor is replaced with a resistor of resistance 2R, without changing the battery, the power dissipated will be …

A ¼P

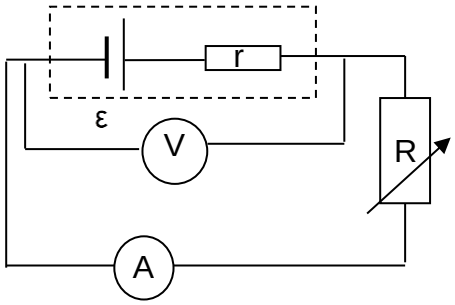
B ½P

C 2P

D 4P

(2)

1.5 In the circuit represented below, the resistance of the variable resistor is decreased.

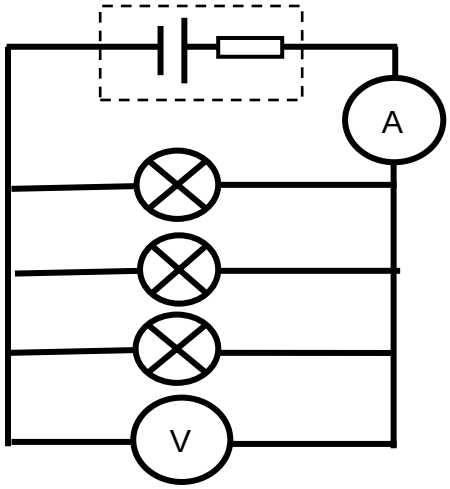


How would this decrease affect the readings on the voltmeter and ammeter?

	Voltmeter reading	**Ammeter reading**
A	unchanged	unchanged
B	decreases	increases
C	decreases	unchanged
D	increases	increases

(3)

1.6 Consider the following circuit diagram with three identical bulbs connected as shown below.

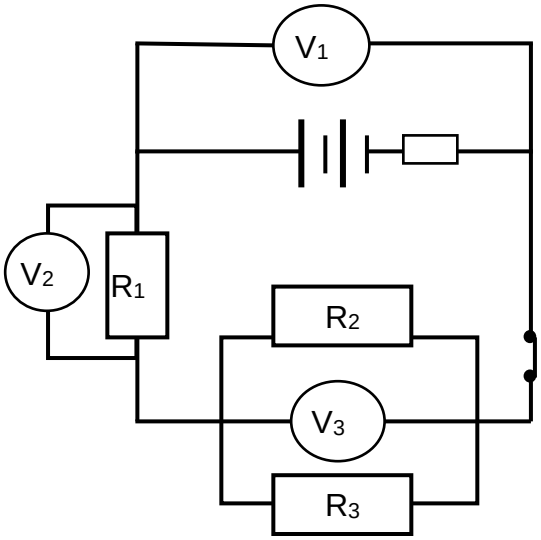


If one of the bulbs is burnt out. How would this change affect the readings on the voltmeter and ammeter?

	AMMETER READING	**VOLTMETER READING**
A	decreases	unchanged
B	decreases	decreases
C	increases	unchanged
D	decreases	increases

(2)

1.7 In the given circuit the internal resistance of the cell CANNOT be ignored. The resistance of the resistors are all equal.



Which one of the following statements is true concerning the voltmeter readings?

A $V_1 = V_2 + V_3$

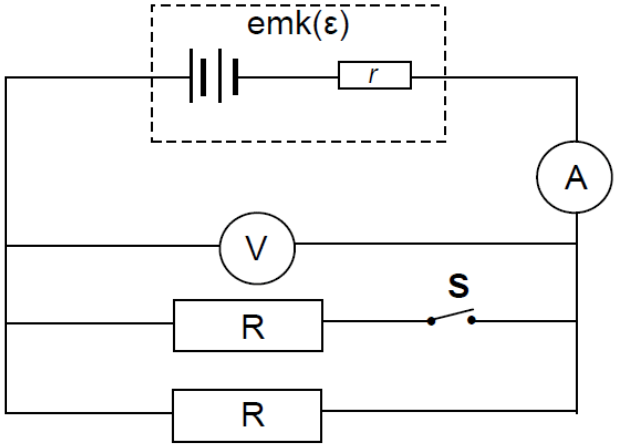
B $emf = V_1 + V_2 + V_3$

C $emf = V_1$

D $V_1 = V_3$

(2)

1.8 In the circuit below the battery has an emf (ε) and internal resistance *r*. With switch **S** open, readings are registered on the ammeter and voltmeter.

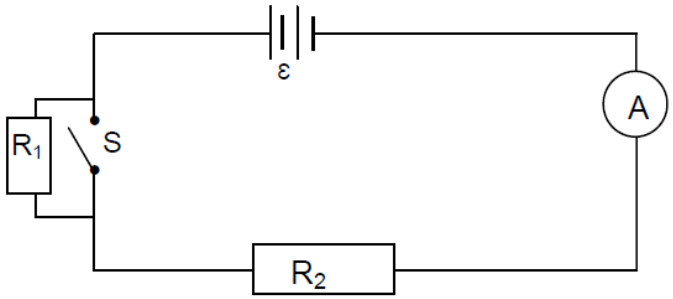


Switch **S** is now closed. How do the readings on the ammeter and voltmeter change?

	AMMETER READING	**VOLTMETER READING**
A	Increases	Remains the same
B	Increases	Decreases
C	Decreases	Remains the same
D	Decreases	Decreases

(2)

1.9 A battery of emf Ɛ and negligible internal resistance is connected in a circuit, as shown below. The resistances of R_1 and R_2 are high.

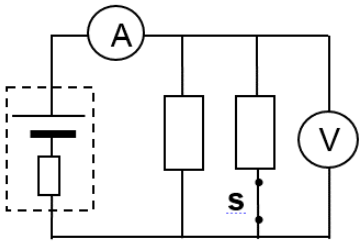


Which ONE of the following combinations about the ammeter readings will be CORRECT when switch S is open and when switch S is closed?

	SWITCH OPEN	SWITCH CLOSED
A	Ammeter reads only the current in R_1	Ammeter reads only the current in R_2
B	Ammeter reads only the current in R_2	Ammeter reads the current in both R_1 and R_2
C	Ammeter reads the current in both R_1 and R_2	Ammeter reads the current in both R_1 and R_2
D	Ammeter reads the current in both R_1 and R_2	Ammeter reads the current in R_2 only

(2)

1.10 A circuit with two parallel resistors is shown below.



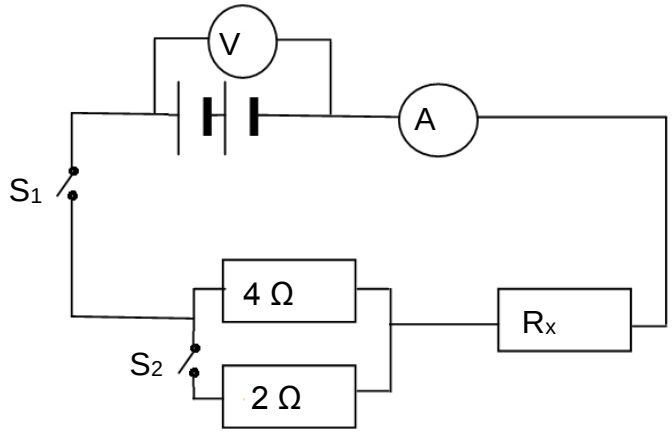
How will the ammeter and voltmeter readings be affected if switch **S** is opened?

	AMMETER READING	VOLTMETER READING
A	Increase	Decrease
B	Decrease	Increase
C	Stays the same	Stays the same
D	Decrease	Decrease

(2)
[20]

QUESTION 2

Three resistors, 2 Ω, 4 Ω and R_x are connected to a battery as shown in the circuit diagram below. With switch S_1 open and S_2 closed the reading on the voltmeter is 10 V. With both switches closed the reading on the voltmeter is 8 V and the ammeter is 1 A.



2.1 Write down the value of the emf of the battery. (1)

2.2 Calculate the:

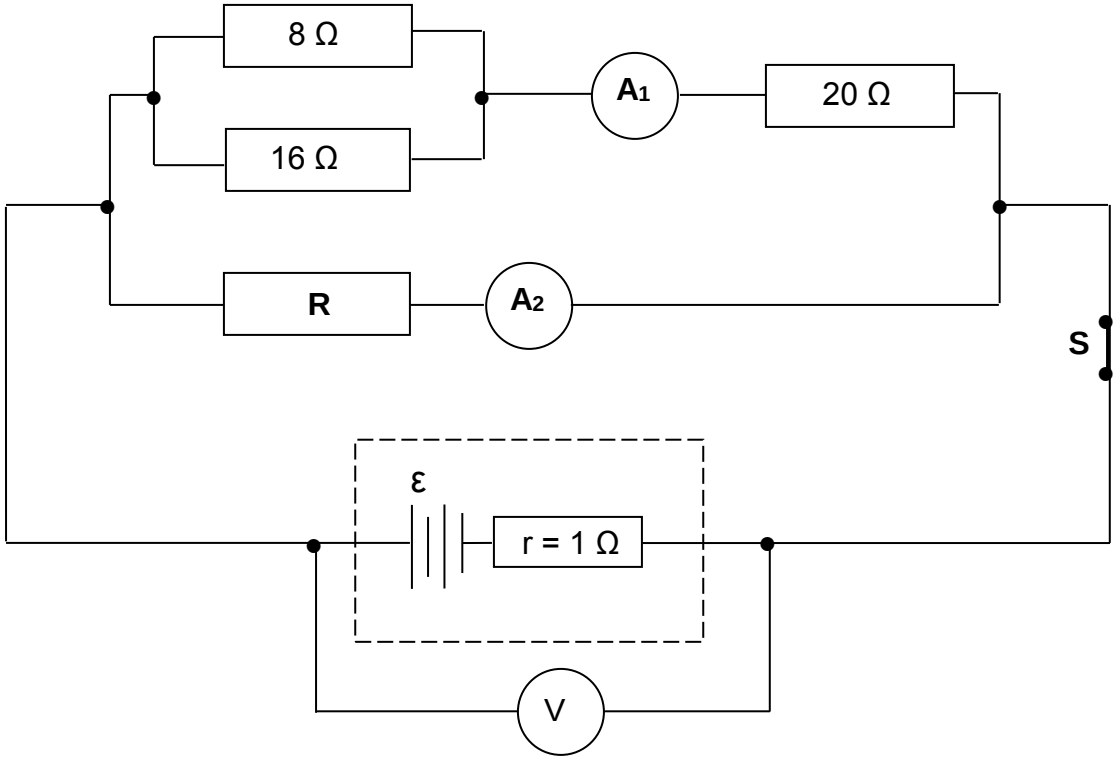
2.2.1 resistance of the unknown resistor $\mathbf{R_x}$. (7)

2.2.2 internal resistance of the battery. (3)

2.3 How will the reading on the voltmeter be affected if the switch S_1 is closed while S_2 is opened.
Write down only INCREASES, DECREASES or REMAINS THE SAME.
Briefly explain the answer. (4)
[15]

QUESTION 3 (DBE/November 2015)

A battery with an internal resistance of 1 Ω and an unknown emf (ε) is connected in a circuit, as shown below. A high-resistance voltmeter (V) is connected across the battery. **A_1** and **A_2** represent ammeters of negligible resistance.



With switch **S** closed, the current passing through the 8 Ω resistor is 0,5 A.

3.1 State Ohm's law in words. (2)

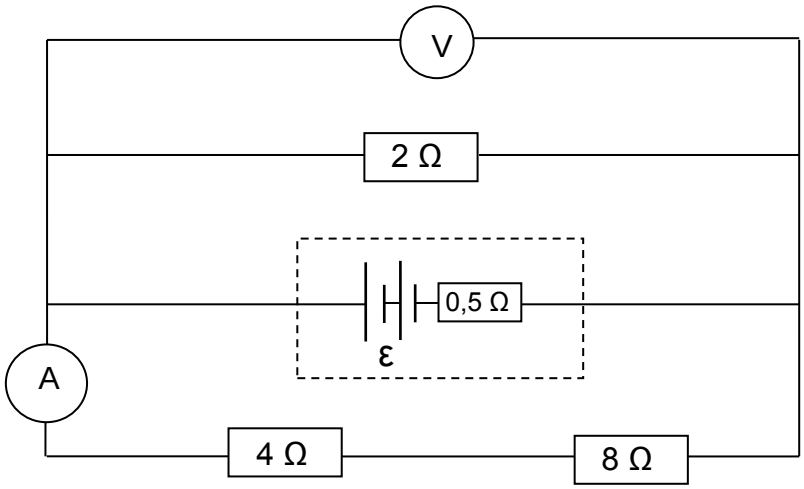
3.2 Calculate the reading on ammeter **A_1**. (4)

3.3 If device **R** delivers power of 12 W, calculate the reading on ammeter **A_2**. (5)

3.4 Calculate the reading on the voltmeter when switch **S** is open. (3)
[14]

QUESTION 4 (DBE/Feb.–Mar. 2016)

A battery of an unknown emf and an internal resistance of 0,5 Ω is connected to three resistors, a high-resistance voltmeter and an ammeter of negligible resistance, as shown below.



The reading on the ammeter is 0,2 A.

4.1 Calculate the:

4.1.1 Reading on the voltmeter (3)

4.1.2 Total current supplied by the battery (4)

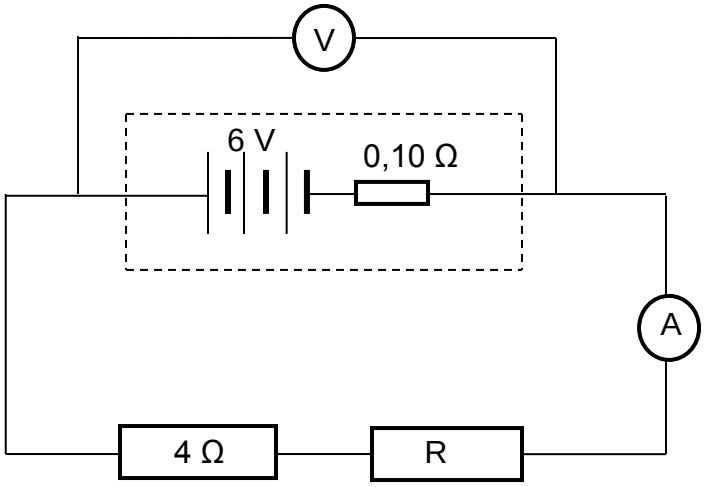
4.1.3 Emf of the battery (5)

4.2 How would the voltmeter reading change if the 2 Ω resistor is removed from the circuit? Write down INCREASE, DECREASE or REMAIN THE SAME. Explain the answer. (3)

[15]

QUESTION 5

In the circuit diagram below the emf of the battery is 6 V and its internal resistance is 0,10 Ω. The resistance R is UNKNOWN.



5.1 Explain the term *internal resistance.* (2)

5.2 Write down an equation for the terminal potential difference using the values given. (2)

8.3 Draw a sketch graph of terminal potential difference versus current. Indicate the following in the graph: (3)

- The value of the emf
- Current at which terminal potential difference is zero.

5.4 The energy dissipated in 4 Ω resistance is 40 J and the energy dissipated in resistance R is 60 J.

Calculate the:

5.4.1 Resistance R (4)

5.4.2 Total current in the circuit (3)

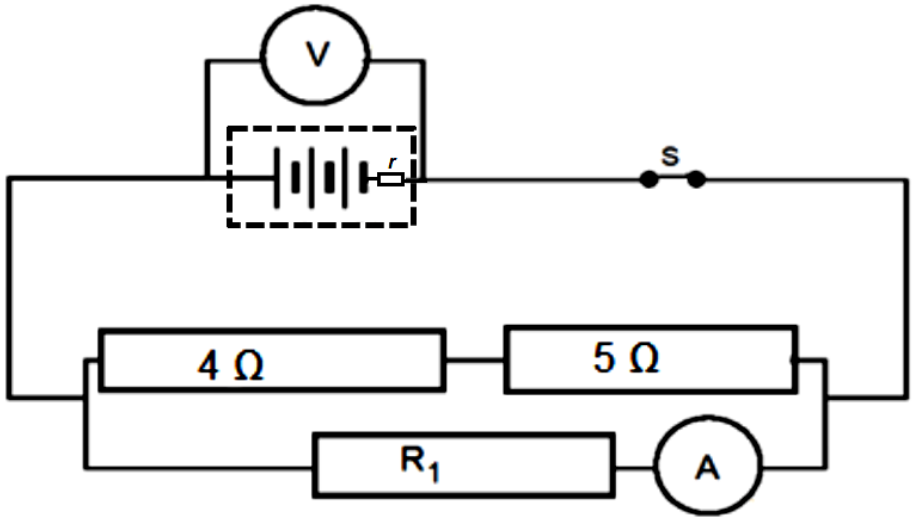
5.4.3 Reading of the voltmeter (3)

5.5 A 7 Ω resistor is now connected in parallel to the 4 Ω resistor. How will this action affect the reading of the voltmeter? Write down only INCREASES, DECREASES or REMAINS THE SAME. Briefly explain the answer. (4)

[21]

QUESTION 6

The circuit diagram below shows two resistors of resistance 4 Ω and 5 Ω each connected in parallel to resistor R_1 of unknown resistance. The battery has an emf of 15 V and an unknown internal resistance (r).



6.1 State *Ohm's law* in words. (2)

The reading on the ammeter is 1,5 A and the voltmeter reading is 12,9 V.

Calculate the:

6.2 resistance of resistor R_1. (3)

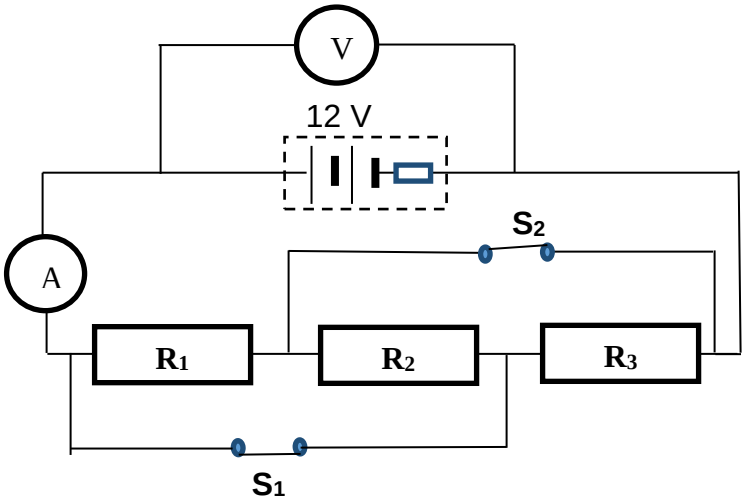
6.3 equivalent resistance of the parallel connection (combination). (3)

6.4 internal resistance of the battery. (4)

[12]

QUESTION 7

In the circuit diagram below the *emf* of the battery is 12 V and the internal resistance is 0,4 Ω. Switches **S_1** and **S_2** are closed.The ammeter reading is 3 A. The resistance of the three resistors is the same. Ignore the resistance of the wires.



7.1 Write down TWO differences between electromotive force (emf) and terminal potential difference. (2)

7.2 State *Ohm's law* in words. (2)

7.3 Calculate the current passing through resistor **R_2**. (4)

7.4 Determine the reading of the voltmeter. (4)

7.5 The switches **S_1** and **S_2** are now open.

7.5.1 How will the reading on the ammeter be affected? Write down only INCREASEs, DECREASEs or REMAINs THE SAME. (1)

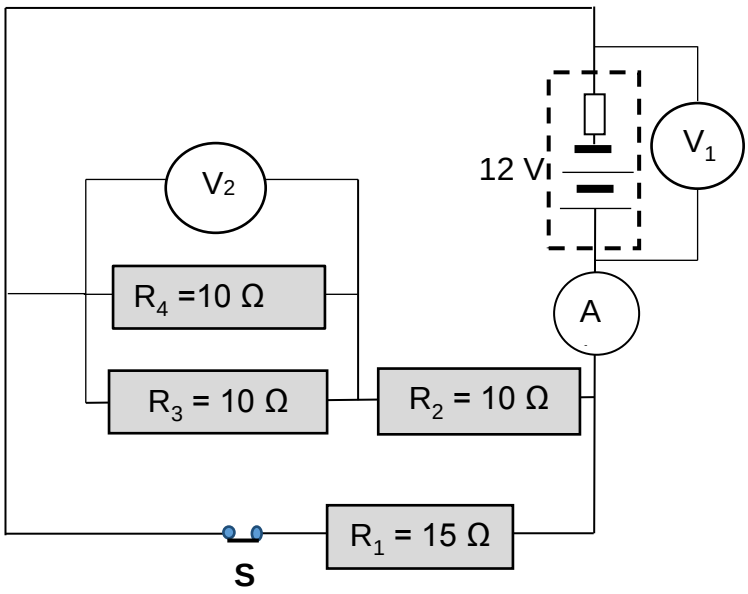
7.5.2 How will the reading on the voltmeter be affected? Write down only INCREASES, DECREASES or REMAINS THE SAME.
Explain the answer.

(4)

[17]

QUESTION 8 (Start on a new page.)

In the circuit diagram below the resistance of the conductors and the ammeter are negligible. The *emf* of the battery is 12 V and the internal resistance is 0,5 Ω. The switch **S** is closed.



8.1 State *Ohm's law* in words. (2)

8.2 Calculate the:

8.21 Reading on ammeter **A_1** (6)

8.2.2 Power dissipated in the 15 Ω resistor (4)

8.2.3 Reading on voltmeter **V_2** (3)

8.3 Switch **S** is now opened.

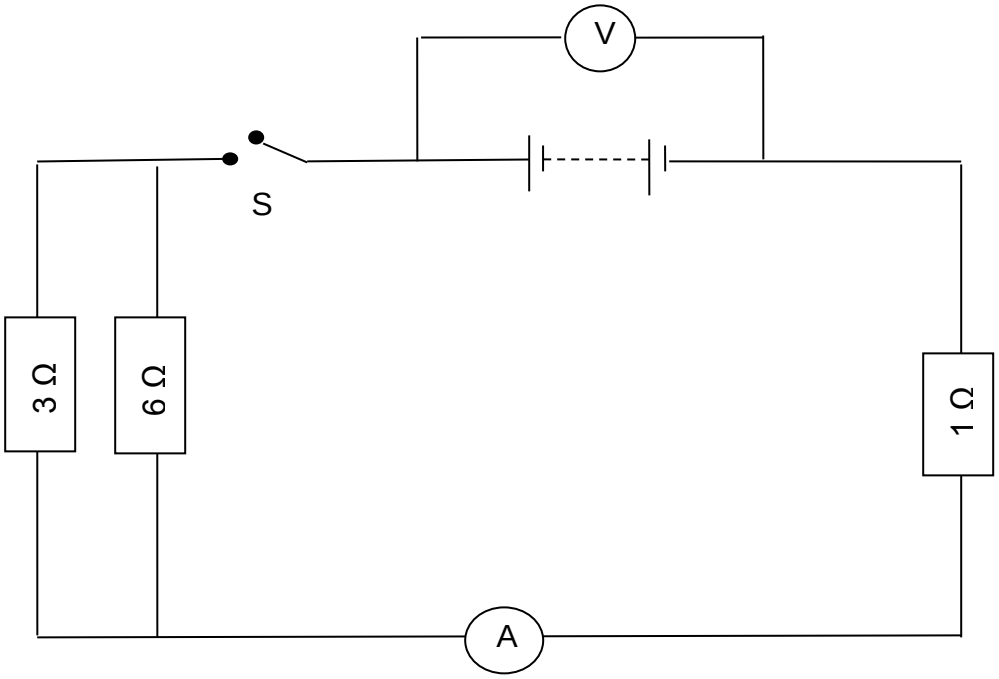
8.3.1 How will the reading on the ammeter **A_1** be affected? Write down INCREASES, DECREASES or REMAINS THE SAME. Explain the answer. (3)

8.3.2 How will the reading on voltmeter **V_1** be affected? Write down INCREASES, DECREASES or REMAINS THE SAME. Explain the answer. (3)

[21]

QUESTION 9

The battery in the circuit diagram below has an emf (ε) of 12 V and an unknown internal resistance **r**. The resistance of the connecting wires and the ammeter is negligible.



9.1 Write down the reading on voltmeter **V** when switch **S** is open. (2)

Switch **S** is now closed. The reading on voltmeter **V** changes to 9 V.

9.2 Calculate the total external resistance of the circuit. (5)

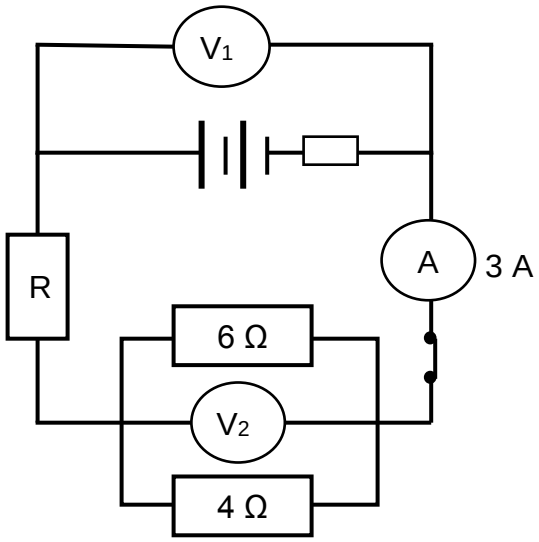
9.3 Calculate the internal resistance, **r** , of the battery. (6)

9.4 Calculate the power for 1 Ω resistor. (4)

9.5 Calculate the energy dissipated in 1 Ω resistor in 20 s (4)
[21]

QUESTION 10

When the switch in the circuit is opened the voltmeter 1 reads 12.V. When the switch is closed the reading drops to 10 V and the ammeter reading is 3 A.



10.1 What is the reading of the ammeter when the switch is open? (1)

10.2 What is the emf (ε) of the battery? (1)

10.3 Calculate the equivalent resistance of the resistors connected in parallel. (3)

10.4 What is the reading of voltmeter V_2? (3)

10.5 Determine the internal resistance of the battery. (3)

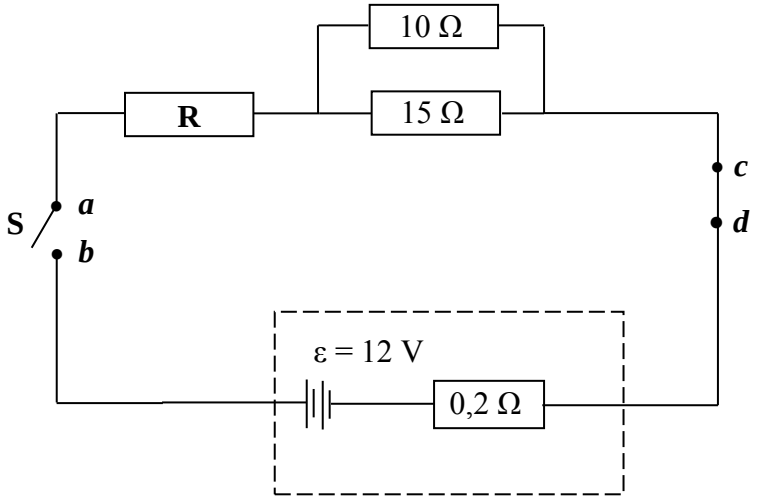
10.6 What is the total external resista **V_2** of the circuit? (3)

10.7 If the resistor of 6 Ω burns out. How does this affect the reading of the ammeter and the reading of voltmeter **1**? Explain the answer. (4)

[18]

QUESTION 11 (DBE/November 2016)

11.1 In the circuit below the battery has an emf (ε) of 12 V and an internal resistance of 0,2 Ω. The resistances of the connecting wires are negligible.



11.1.1 Define the term *emf of a battery.* (2)

11.1.2 Switch **S** is open. A high-resistance voltmeter is connected across points ***a*** and ***b***.
What will the reading on the voltmeter be? (1)

11.1.3 Switch **S** is now closed. The same voltmeter is now connected across points ***c*** and ***d***.
What will the reading on the voltmeter be? (1)

When switch **S** is closed, the potential difference across the terminals of the battery is 11,7 V.

Calculate the:

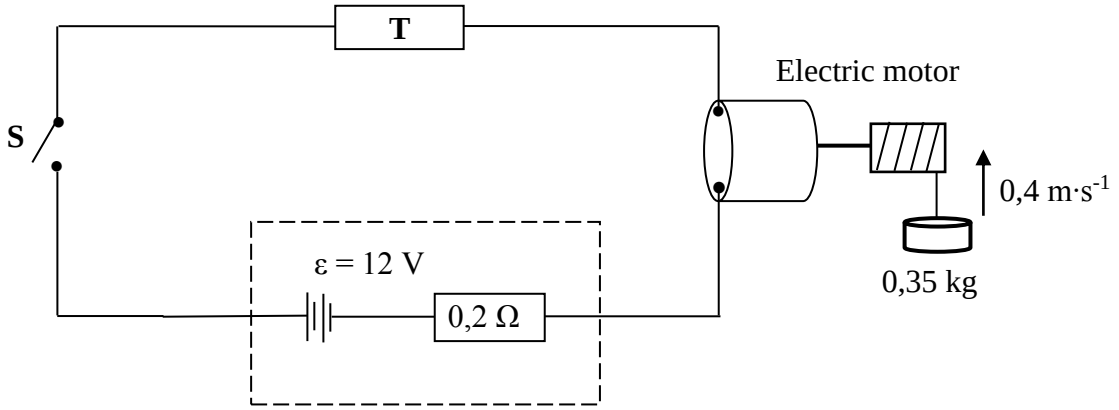
11.1.4 Current in the battery (3)

11.1.5 Effective resistance of the **parallel** branch (2)

11.1.6 Resistance of resistor **R** (4)

11.2 A battery with an emf of 12 V and an internal resistance of 0,2 Ω are connected in series to a very small electric motor and a resistor, **T**, of unknown resistance, as shown in the circuit below.

The motor is rated **X** watts, 3 volts, and operates at optimal conditions.



When switch **S** is closed, the motor lifts a 0,35 kg mass vertically upwards at a constant speed of 0,4 $m \cdot s^{-1}$. Assume that there is no energy conversion into heat and sound.

Calculate the value of:

11.2.1 **X** (3)

11.2.2 The resistance of resistor **T** (5)

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