Level 3 Physics: Demonstrate understanding of electrical systems – Batteries and Kirchoff's Laws - Answers

In 2013, **AS 91526** replaced **AS 90523.**

The Mess that is NCEA Assessment Schedules….

In AS 90523 there was an Evidence column with the correct answer and Achieved, Merit and Excellence columns explaining the required level of performance to get that grade. Each part of the question (row in the Assessment Schedule) contributed a single grade in either Criteria 1 (Explain stuff) or Criteria 2 (Solve stuff).

From 2003 to 2008, the NCEA shaded columns that were not relevant to that question.

In 91526, from **2013 onwards**, each part of a question contributes to the overall Grade Score Marking of the question and there are no longer separate criteria. There is no shading anymore. There is no spoon. At least their equation editor has stopped displaying random characters over the units.

In **2018**, the Assessment Schedule states that the Marking convention is "a = 1, m = 2, e = 3 and for E at least one e is required and for M at least one m is required"

In **2019**, the Assessment Schedule states that the Marking convention is "a = 1, m = 2, e = 3 and for E at least one e is required"

Question	Evidence	Achievement	Merit	Excellence
2019(1) (a)	$V_{\text{terminal}} = emf - IR$ $8.60\text{ V} = 9.00\text{ V} - 0.333\text{ A} \times R$ $R = \frac{0.400}{0.333} = 1.20\ \Omega$	• $R = 1.20\ \Omega$ (Must show understanding of r, V & EMF) **SHOW QUESTION**		
(b)	Outside Voltage Loop: +9.00 V – 1.20 Ω x 0.333 A – 25.0 Ω x I_3 – 18.0 Ω x I_3 = 0 I_3 = 0.200 A Equation at Junction A: $I_1 = I_2 + I_3$ 0.333 A = I_2 + 0.200 A I_2 = 0.133A Left Hand Loop: +9.00 V – 1.20 Ω x 0.333 A – 9.80 Ω x 0.133 A – *EMF* = 0 *EMF* = 7.30 V	• $I_1 = I_2 + I_3$ • Correct loop equation with 2 unknowns • I_3 = 0.20 A **SHOW QUESTION for I_3**	• $I_1 = I_2 + I_3$ AND I_3 = 0.20 A • I_2 = 0.133A AND I_3 = 0.20 A Correct Voltage loops shown using incorrect/values.	• *emf* = 7.30 V AND • I_3 = 0.20 A AND • I_2 = 0.133A OR $I_1 = I_2 + I_3$

2018(1) (a)	The battery has an internal resistance. Current flow creates a voltage across the resistance, lowering the voltage available to the circuit.	Internal resistance linked to voltage drop when current flows (accept resistance inside the battery).		
(b)	EMF = 6.02 V $V_{terminal} = EMF - I \times R_{internal}$ 5.85 V = 6.02 V - 1.89 A x R_i R_i = 0.089947 Ω =0.09 Ω OR $EMF = I(R + r)$ 6.02 = 1.89 (3 + r) r = 0.18 Ω	EMF = 6.02 V Int Resistance = 0.0899 Ω Int Resistance = 0.18 Ω Int Resistance = 0.095 Ω (if stated that EMF = 5.85) (**SHOW question**)	EMF = 6.02 V AND r = 0.0899 **or** 0.18 Ω (**SHOW question**)	
2014(2) (a)	$11.0 - 10.0 - 2.5I - 20I - 5.0I - 2.7I = 0$ $1.0 - 30.2I = 0$ I = 0.03311 = 0.033 A	Kirchhoff equation attempted. Total resistance is 30.2 Ω. Total PD is 1.0 V.	Complete correct working (ignore negative value).	
(b)	The current will flow right to left (anticlockwise), because the +ve terminal of the 11 V battery is at a higher potential than the +ve terminal of the 10V battery, and current flows from high potential to lower potential. OR The current will flow right to left (anticlockwise), because, when a Kirchhoff equation is constructed with the current flowing in this direction, the value of the current is positive.	Right to left / anticlockwise because the top battery has a higher potential difference. Right to left/ anticlockwise because positive calculated value is produced when clockwise current is used.		

(c)	If I_1 is the current through switch 1, I_2 the current through switch 2, and I_3 the current through switch 3: $I_3 = I_1 + I_2$ $11.0 - 5.0I_1 - 2.7I_1 = 0 \Rightarrow I_1 = 1.4286$ $10.0 - 20I_2 - 2.5I_2 = 0 \Rightarrow I_2 = 0.4444$ $\Rightarrow I_3 = 1.873 = 1.87$ A	$I_1 = 1.4286$ A $I_2 = 0.4444$ A $I_1+I_2=I_3$ ($S_1+S_2=S_3$)	I_1 and I_2 correctly calculated and added.	
(d)	The emf of the battery will stay the same, but the internal resistance will increase. The resistance of branch 2 will increase, so the current will decrease. As the current through the 20.0 Ω resistor decreases, the voltage through the resistor will decrease. The power delivered to the resistor will drop because of the drop in voltage and current.	The emf of the battery will stay the same. The current will decrease. Lost volts increases. Output Voltage decreases. Power decreases. Attempt at calculating change in P/ Vo/ I	Power will decrease, because current **and** output voltage will decrease. Power decreases because output voltage/ current decreases but emf constant. Power decreases because lost volts increases. Calculation using $P = I^2R$, no mention about emf or V_0 Output P decreases because more power is used by internal resistance.	A decrease in power will occur because **current and voltage** will decrease, because the resistance of branch 2 has increased, while the **emf has stayed the same**. Correct calculations comparing before and after.
2012(1) (a)	$\frac{6.2}{0.500} = 12.4\,\Omega$ Accept 12.3 – 12.5	[2]Correct answer 12.4 Ω		
(b)	7.4 V A best fit line drawn through the points crosses the *y*-axis at 7.4 V. This shows that when there is no current the terminal potential would be 7.4 V. When there is no current through the internal resistance, the terminal potential will equal the EMF of the cell.	[1]7.4 V.	[1]Correct answer referring to the graph trend line and linking EMF to no current or no-load voltage.	

(c)	Gradient: $\frac{6.0-7.2}{600\text{ mA}-100\text{ mA}}=-2.4\,\Omega$ Kirchoff's law says $IR = \varepsilon - Ir$ so the gradient is the negative of the internal resistance. Accept 2.3 - 2.5	[2]–2.4 Ω.	[2]2.4 Ω AND Statement that gradient is the internal resistance.	
(d)	New line drawn so that the *y*-intercept is the same, but the gradient is steeper. The EMF of the cell will remain the same over time but the internal resistance of the cell will increase (as the products of the reaction in the cells build up).	[1]Correct intercept. OR Steeper gradient. OR Wrong line, but statement that internal resistance has increased.	[1]Correct line.	[1]**Correct line** and complete reasoning. **Internal resistance has increased and the EMF remains same**
2011(1) (a)	$I=\frac{V}{R}=\frac{12}{4+2}=2.00\text{ A}$ Note: No working required.	[2]Correct answer.		
(b)(i)	$I_B + I_N = I_C$ OR $I_B + I_N - I_C = 0$	Correct answer.		

(ii)	For out side loop $I_B \times 4 = 5.58 \times 0.1$ $I_B = 0.1395$ A $I_C = \left(\frac{5.58 \times 0.1}{4}\right) + 5.58$ $= 5.72$ A OR for RHS loop: $12 - (5.58 \times 0.1) - 2I_C = 0$ $11.442 = 2I_C$ $I_C = 5.72$ A	[1]Demonstrates concept knowledge of voltage law. Any loop equation correctly written	[2]Correct I_B or correct application of the voltage law but wrong answer	[2]Correct answer.
2008(1) (a)	EMF/ Electro motive force / Open circuit voltage	[1]Correct		
(b)	$R = \frac{V}{I} = \frac{5.87}{0.743}$	[2]Correct working.		
(c)	$r = \frac{(\varepsilon - V)}{I} = \frac{(6.12 - 5.87)}{0.743} = 0.336\ \Omega$ or $R_{tot} = \frac{V}{I} = \frac{6.12}{0.743} = 8.24$ $8.24 - 7.90 = 0.337\ \Omega$	[2]Correct R_{tot}.	[2]Correct working showing all steps (formula not required).	

(d)	If a battery with a higher internal resistance was used: There is a greater drop in pd across the internal resistance, so the pd is reduced across the lamp, so less current flows, so bulb is less bright / has less power. OR The circuit has a greater total resistance, so less current flows, so bulb is less bright / has less power.	[1]Dimmer lamp/lower voltmeter reading/lower terminal voltage/greater total resistance/lower current.	[1]Dimmer lamp due to less current / lower terminal pd.	[1]Complete explanation with voltage or current argument.
(e)	Two identical lamps in parallel have half the resistance $R = \frac{7.90}{2} = 3.95\ \Omega$ $I = \frac{\varepsilon}{(R+r)}$ $= \frac{6.12}{(3.95+0.336)} = 1.43\ \text{A}$	[2]Correct calc of R for 2 bulbs.	[2]Correct answer (consistent with answer to 1(c)).	
2007(1) (b)	$2.50 - 1.20I - 0 - 215I = 0$ $\Rightarrow I = \frac{2.50}{216.2}$ = 0.011563 = **0.0116 A** **Note 1.20Ω resistor needed**		[2]Correct answer	
(f)	$I_1 = I_2 + I_3$	[1]Correct equation		

(g)	**This is a SHOW question** $V = \varepsilon - Ir$ I_2 is zero $\Rightarrow I_1 = I_3 = I$ $\Rightarrow 2.50 - (112 + 215 + 1.20) \times I = 0$ $\Rightarrow I = \mathbf{7.6173 \times 10^{-3}}$ $\Rightarrow V = 2.50 - 7.6173 \times 10^{-3} \times 1.20$ $= 2.50 - 9.14076 \times 10^{-3}$ **OR** $V = 7.6173 \times 10^{-3} \times (112 + 215)$ = 2.4909 V before rounding	Watch for **2.48608V** (if used I=.0116A) or current calculated in 1b (N) $V_T = 2.50 - \frac{1.64}{215} \times 1.20$ $= 2.490846$ V (N)		[2]Correct working. $V = 2.50 - 7.6173 \times 10^{-3} \times 1.20$ (= 2.4909V) **OR** $V = 7.6173 \times 10^{-3} \times (112+215)$ ($I = 7.6173 \times 10^{-3}$)
(h)	$V_{terminal} - 1.64 - V_C = 0$ $2.4909 - 1.64 = V_C = 0.85$ V $I = 7.6279 \times 10^{-3}$ $(= \frac{1.64}{215})$ gives $V_{bulb} = 7.6279 \times 10^{-3} \times 112 = 0.854$ V	[2]Correct answer. Care with 0.86V (N)		

2005(1) (a)	**This is a show question** $r = \frac{8.06 - 1.18}{0.107}$ $= \frac{6.88}{0.107}$ $(= 64.299 \quad = 64.3\ \Omega)$		Bottom and top lines correct **OR** Equivalent statement	
(b)	The battery has a much lower internal resistance than the solar cell and so a much higher current can be drawn. The terminal voltage of both the battery and the cell are the same so the battery can deliver far more power than the cell.	ONE correct and relevant statement: Typical responses might be: Lower internal resistance Total resistance (in circuit) is reduced Higher current (drawn from battery). **Watch for contradictory statements.** Voltage across (supplied to) motor will be greater Battery will deliver more power Terminal voltages (of solar cell and battery) the same From data given terminal voltage is 7.41V.	Link made between the lower internal resistance or total resistance and the higher current **OR** lower internal resistance, higher voltage across motor or terminal or circuit or similar **OR** lower internal resistance and greater power (to drive the motor).	Link made between the lower internal resistance and the higher current. **AND** higher voltage (across motor). Terminal voltages the same **AND** current increased.
(c)	Around any **closed loop or circuit,** the sum of or total or adding the voltages are equal to zero or equivalent statement.	Correct statement.		

(d)	$8.06 - (0.029 \times r_s) +$ $(0.645 \times 0.14) - 7.50 = 0$ $\Rightarrow r_s = 22.4241$ (= **22 Ω**) Or $T_{terminal} = E - Ir = 7.50 - 0.14 \times 0.645$ $= 7.4097V$ Therefore $V_r = 0.6503V$ So internal resistance = $\frac{0.6503}{0.029} = 22.4241\,\Omega$ From the outside loop:		Correct answer.	