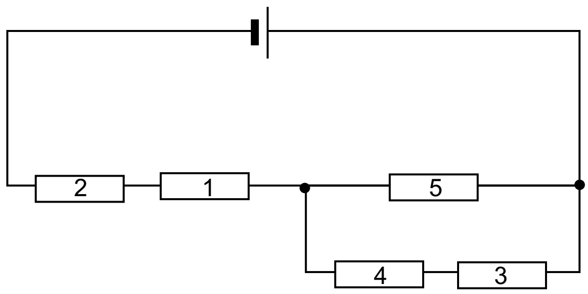
2026 Sec 4 Physics Chapter 15

D.C. Circuits (Sample Solutions)

Name: ____________________ ( ) Class: 4 / ___

1 Series and Parallel Circuits

Example 1



Example 2

(a) $1/R = 1/4.0\Omega + 1/12.0\Omega \Rightarrow R = 3.0\ \Omega$

total resistance = 3.0 Ω + 2.0 Ω = 5.0 Ω

(b) A_1 = emf / R_T = 10V /5.0Ω = 2.0 A;

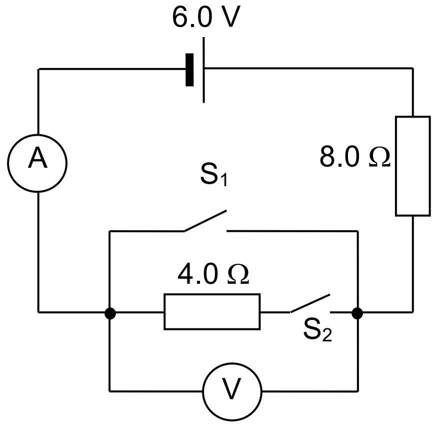
Method 1 to find A_2 and A_3:
p.d. in parallel portion = 10 V – (2.0 A) (2.0 Ω) = 10.0 V – 4.0 V = 6.0 V
A_2 = (6.0 V) / (4.0 Ω) = 1.5 A
A_3 = (6.0 V) / (8.0 Ω + 4.0 Ω) = 0.5 A

Method 2 to find A_2 and A_3:
Current is inversely proportional to resistance in a parallel circuit, hence
A_2 = ¾ × 2.0 = 1.5 A;
A_3 = ¼ × 2.0 = 0.5 A

Note: Redraw & simplify circuit for each part!

Example 3

The following diagram shows a 6.0 V cell of negligible internal resistance connected to two resistors with switches S_1 and S_2. The current taken by the voltmeter and the resistance of the ammeter can both be neglected.



Calculate and explain the readings of the ammeter and the voltmeter when:

(a) switch S_1 is opened and switch S_2 is closed.

$V = I\,R$

$6.0\text{ V} = I\,(12.0\ \Omega.)$

$I = \underline{0.50\text{ A}}$

$V = I\,R$

$V = 0.50\text{ A} \times 4.0\ \Omega$

$V = \underline{2.0\text{ V}}$

(b) Both the switches S_1 and S_2 are closed.

Closing S_1 creates a short-circuit across 4.0 Ω resistor. $V = \underline{0\text{ V}}$

$V = I\,R$

$6.0\text{ V} = \text{I}\,(8.0\ \boldsymbol{\Omega})$

$I = \underline{0.75\text{ A}}$

(c) Both the switches S_1 and S_2 are opened.

$I = \underline{0\text{ A}}$ (very small current due to infinite resistance of the voltmeter)

$V = \underline{6.0\text{ V}}$

Exercises 1

1 (a) 5.0 Ω (b) 2.0 Ω

(c) 0 Ω [short circuit] (d) 2.0 Ω

(e) 2.2 Ω [Hint: (2.0 Ω in parallel with 2.0 Ω) in series with 1.0 Ω]

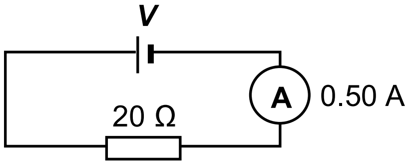
(f) 1.3 Ω [Hint: (1.0 Ω in series with 3.0 Ω) in parallel with 2.0 Ω]

(g) 3.8 Ω [Hint: 3.0 Ω in series with (1.0 Ω in parallel with 3.0 Ω)]

(h) 1.0 Ω [Hint: current will flow in the diagonal short circuit path instead of through the 3.0 Ω resistor]

2 Determine the unknown (V or I) in the following circuits.

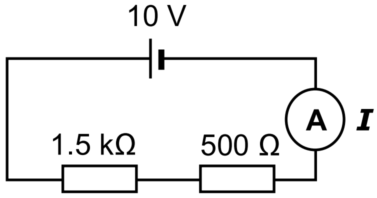
(a)



$V = I\ R = 0.50\ \text{A} \times 20\ \Omega = 10\ \text{V}$

$V = 10\ \text{V}$

(b)

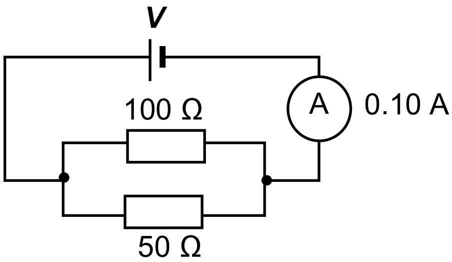


$I = V / R_T = 10 / (1500 + 500)$

$= 10 / 2000$

$I = 0.0050\ \text{A} = 5.0\ \text{mA}$

(c)

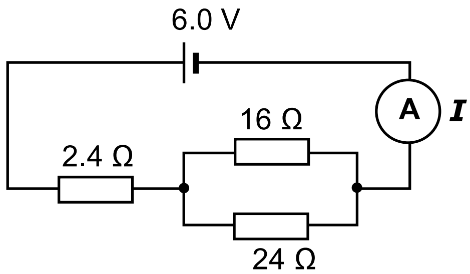


$R_T = [(1/100\Omega) + (1/3\Omega)]^{-1} = 100 / 3\ \Omega$

$V = I\ R = 0.10\ \text{A} \times (100/3\ \Omega)$

$V = 3.3\ \text{V}$

(d)



$R_T = 2.4\ \Omega + 9.6\ \Omega = 12.0\ \Omega$

$I = V / R_T = 6.0\ \text{A} / 12.0\ \Omega$

$I = 0.50\ \text{A}$

3 **(a)** $I = 1.0\ \text{A}$ Note: Redraw and simplify the circuits!

(b) $I = 0.50\ \text{A}$

4 **(a)** $1/R = 1/8.0\Omega + 1/24.0\Omega \rightarrow R = 6.0\ \Omega$,
total resistance = $6.0\Omega + 14.0\Omega$ = **$20.0\ \Omega$**

(b) $A_1 = \text{emf} / R_T = 10\ \text{V}/20\Omega = 0.50\ \text{A}$;

Method 1 to find A_1 & A_2:
p.d. in parallel portion = 10.0 V – (0.50 A) (14 Ω) = 10.0 V – 7.0 V = 3.0 V
$A_2 = (3.0\ \text{V}) / (8.0\ \Omega) = 0.375 = 0.38\ \text{A}$

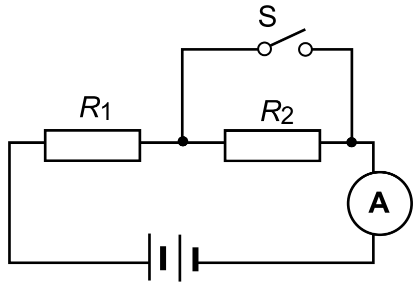
Method 2 to find A_1 & A_2:
Current is inversely proportional to resistance in a parallel circuit, hence
$A_2 = (24 / 32)\ 0.50\ \text{A} = 0.375\ \text{A} = 0.38\ \text{A}$

(c) the reading on the voltmeter.
$V = I\ R = 0.375\ \text{A} \times 8\ \Omega = 3.0\ \text{V}$

5 In the following circuit, when switch S is closed, the ammeter reads 3.0 A. When S is opened, the ammeter reads 2.0 A. What are the values of R_1 and R_2?

When switch is closed, it becomes a short circuit path, no current flows in R_2, hence

$R_1 = V / I = 6.0\text{ V} / 3.0\text{ A} = 2.0\ \Omega$

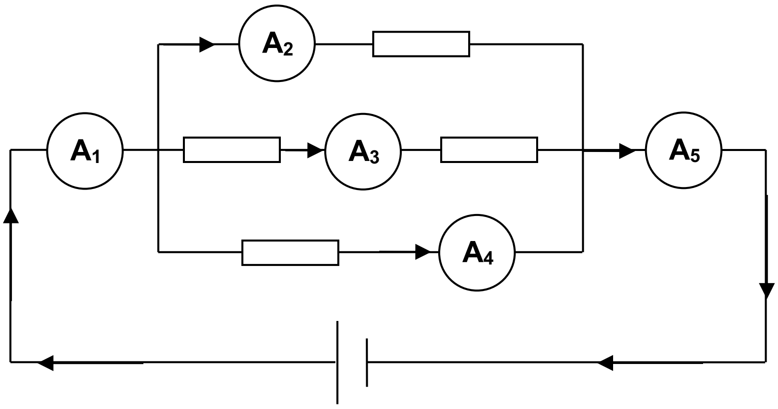


When switch is opened, current will flow through both resistors in series, hence

$R_1 + R_2 = V / I = 6.0\text{ V} / 2.0\text{ A} = 3.0\ \Omega$.

Therefore $R_2 = 3.0\ \Omega - 2.0\ \Omega = 1.0\ \Omega$

6 (a)



(b) A_1 and A_5 both show the same high reading. A_3 shows the lowest reading.

7 (a) Each wire = 1.5 m x 3.0 Ω/m = 4.5 Ω

Effective resistance of 3 wires in parallel, $R_E = (3/4.5)^{-1}$ = <u>1.5 Ω</u>

(b) $V = I R = 2.0\text{ A} \times 4.5$ = <u>9.0 V</u>

OR

$V = I_{\text{main}} R_E = (3 \times 2.0\text{ A}) \times (1.5\ \Omega) = 9.0\text{ V}$

2 Potential Divider Circuit

Example 4

(a) As the resistance R of the rheostat increases,
the p.d. across the rheostat V_{AS} also increases,
since $V_{AS} / V_{SB} = R / 1\text{ k}\Omega$ where $V_{SB} = 10\text{ V} - V_{AS}$

(b) As R increases,
the total <u>resistance</u> of the circuit increases, hence
the <u>current</u> in the circuit decreases, so the ammeter reading will decrease.

[Note: however, the ratio of the p.d. across AS and SB, V_{AS} / V_{SB} is independent of this current.]

Example 5

(a) When S is at A, voltmeter reading is zero.
As S moves from A towards B, the ratio of resistance of AS to SB increases.
Therefore, applying the potential divider concept, the voltmeter reading will increase.

(b) The effective resistance in the circuit remains the same.
Hence, the ammeter reading does *not* change.

(c) S at A, lamp will **not** light up as potential difference across the lamp is zero.

As S moves from A towards B, the ratio of resistance of AS to SB increases.
Therefore, applying the potential divider concept,
the p.d. across the lamp increases. Lamp gets brighter.

When S is at B, lamp is at brightness as p.d. across the lamp is the greatest.

Example 6 [B]

V_Y = (10/20) × 6.0 V = 3.0 V

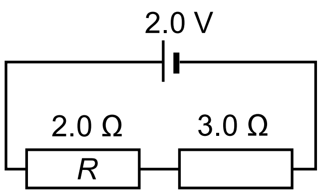
S at P: V_X = 6.0 V
➔ V_{XY} = 6.0 – 3.0 = 3.0 V

S at Q: $V_X = V_Y$
➔ V_{XY} = 0 V

Exercises 2

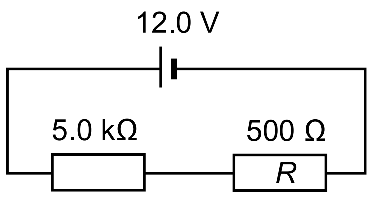
1 In each of the following circuit, find the potential difference across the resistor *R* using the potential divider concept.

(a)



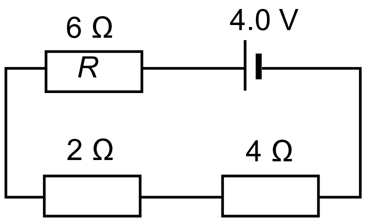
Show potential divider step:
V / 2.0 V = 2.0 Ω / (2.0 + 3.0) Ω
V = 2/5 × 2.0 V = 0.80 V

(b)



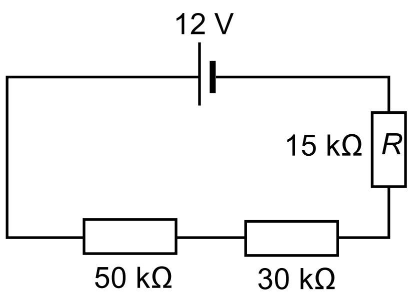
500 Ω /5500 Ω × 12.0 V = 1.09 V

(c)



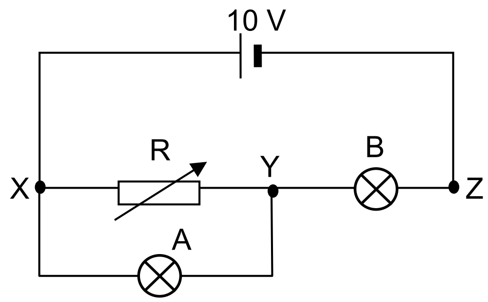
6.0 Ω / (6.0+2.0+4.0) Ω × 4.0 V = 2.0 V

(d)



15 kΩ / (15+50+30) kΩ × 12 = 1.9 V

2 In the circuit shown, A and B are two identical lamps, each with a rating of 10 V. State and explain the changes to the brightness of the two lamps as the resistance of the variable resistor R is gradually increased.



When the resistance of R is 0 Ω,

- A will not light up as R creates a short circuit (zero resistance) across A.
- **B will have normal brightness** as the p.d. across it is 10 V.

As the resistance of R gradually increases,

- the effective resistance across XY will increase.
- Applying the potential divider concept, p.d. across A will **increase** such that $0 < V_A <$ **5** V.
- Correspondingly, V_B = e.m.f. – V_A **decrease** too.
- This will cause the brightness of **lamp A to increase** and **lamp B to decrease**. However, both lamps are dim as each p.d. is smaller than their rating of 10 V.

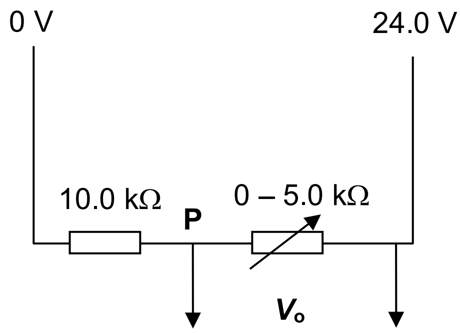
Why is the maximum possible value of $\boldsymbol{V_A}$ only 5 V?

Let assume that the resistance of rheostat is increased to an infinitely large value, it is as though as the circuit is opened there. When this happens, all the current will flow through lamps A and B like a series circuit.

Since lamps A and B are identical, each will share the e.m.f. of 10 V equally.

3. In the circuit shown,

(a) use the potential divider concept to calculate the range of the output voltage, $\boldsymbol{V_o}$.



When R = 0 Ω, V_o = 0 V

When R = 5.0 kΩ,

V_o = 5.0 kΩ /15 kΩ × 24.0 V = 8.0 V

Hence, range of V_o = 0 to 8.0 V

(b) determine the potential at point **P** of the circuit when the variable resistor is set at 2.0 kΩ.

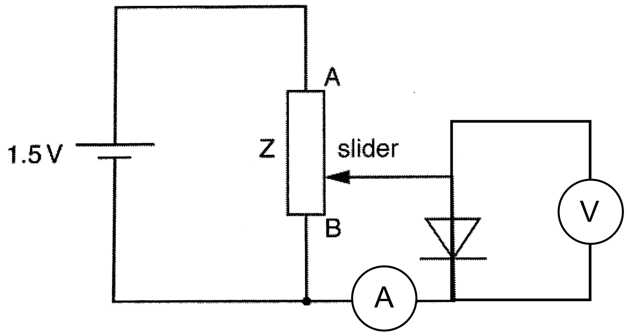
(10.0) / (10.0 + 2.0) × 24.0 V

potential at **P** = 20.0 V

[*Note*: take reference from the point of zero potential, which is the left side in this circuit diagram.]

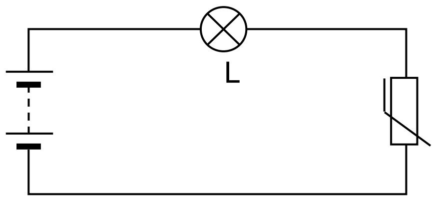
4 (a) variable potential divider or potentiometer

(b)



3 Thermistor

Example 7



The circuit shows a lamp L and a thermistor connected in series. This thermistor has a negative coefficient.

Does the lamp L get brighter or dimmer if the thermistor is heated? Explain.

Method 1:

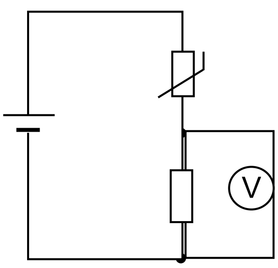
- As the thermistor is heated, the resistance of thermistor decreases.
- This will cause the effective resistance in the circuit to decrease.
- The current increases, hence, the lamp gets brighter.

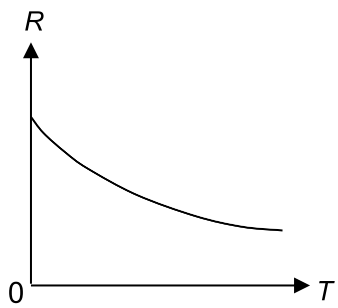
Method 2:

- As the thermistor is heated, the resistance of thermistor decreases.
- Applying the potential divider concept, p.d. across the thermistor will decrease.
- Since sum of p.d. of thermistor and p.d. across lamp is the e.m.f. of source, p.d. across lamp will increase, so lamp will become brighter.

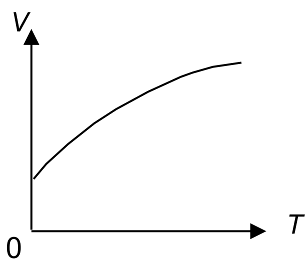
Example 8

A thermistor is connected in the circuit shown. The graph below shows how its resistance R varies with temperature T.





(a) Sketch another graph to show how the potential difference V measured by the voltmeter varies with temperature T.

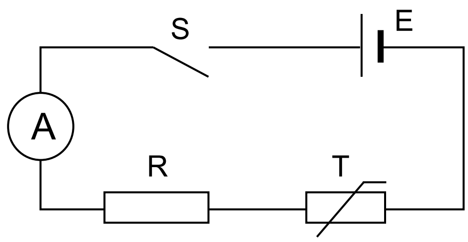


(b) Explain briefly how the graph is derived.

From the graph, the resistance of the thermistor **decreases** with temperature at a decreasing rate.
Hence, based on potential divider concept, the p.d. across the thermistor, $V_{thermistor}$ will **decrease** with temperature at a decreasing rate too.
Since output V = e.m.f. – $V_{thermistor}$, the output V will **increase** with temperature at a decreasing rate.

Exercises 3

1 In the circuit shown below, E is a battery of e.m.f. 3.00 V, R is a resistor of resistance 2.40 kΩ and T is a thermistor.



When the switch S is closed, the current in the circuit is 0.500 mA.
Calculate

(a) the resistance of the whole circuit,

3.00 V ÷ (0.5 × 10^{-3} A) = 6000 Ω

(b) the resistance of the thermistor,

Resistor of thermistor = 6000 – 2400 = 3600 Ω

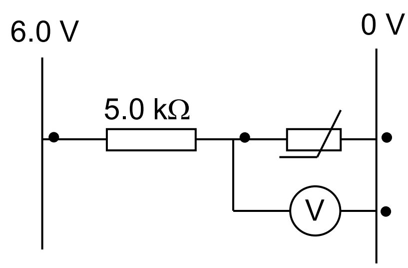
(c) the potential difference across the thermistor,

$V = I\ R$ = 0.000500 × 3600 = 1.80 V

(d) the power developed in the thermistor. [Given: $P = I\ V$]

$P = I\ V$ = 0.000500 × 1.80 = 0.000900 W = 0.900 mW

2 In the circuit shown, a thermistor is connected in series with a 5.0 kΩ fixed resistor.
When the temperature is high, the resistance of the thermistor is 1.0 kΩ and when the temperature is low, the resistance of the thermistor increases to 8.0 kΩ.



(a) When the temperature is high, determine:

(i) the potential difference across the thermistor measured by the voltmeter,

V = (1.0 / (1.0 + 5.0)) x 6.0 = 1.0 V

(ii) the power dissipated by the thermistor. [Given: $P = V^2/R$]

$P = V^2 / R = (1.0)^2 /1000$ = 0.0010 W = 1.0 mW

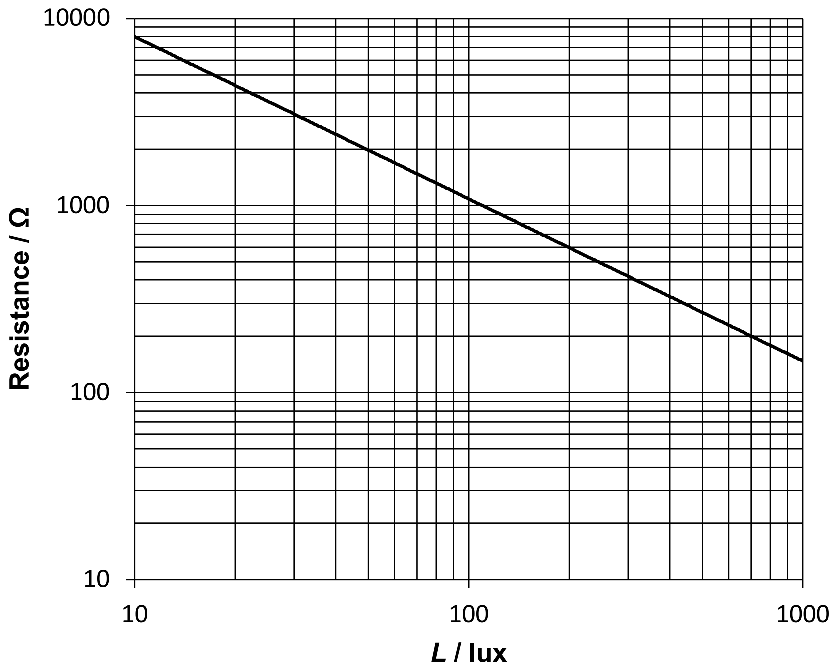
(b) Describe and explain the changes in the voltmeter reading when the temperature decreases.

Voltmeter reading increases to a maximum value of 8.0/(8.0+5.0) x 6.0 = 3.7 V (2 sf). This is because as the temperature decreases the <u>resistance</u> of the thermistor <u>increases</u>; hence, based on <u>potential divider concept</u>, a greater potential difference is observed across the thermistor.

4 Light-Dependent Resistor

Exercises 4

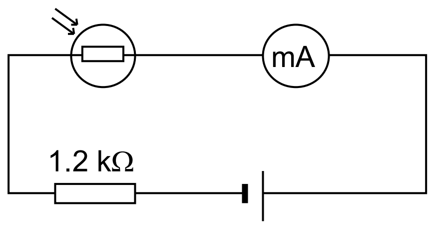
1 The graph shows how the resistance of an LDR varies with brightness, *L* that is measured in lux.



(a) Complete the table:

L / lux	*R* / Ω
700 (bright light)	200
200	600
10 (poor light)	8000

(b) The LDR above is connected in series with a 1.2 kΩ resistor in the circuit shown.



(i) Using the values from the table above, determine the resistance of the above circuit under bright light.

1200 + 200
R = 1400 Ω

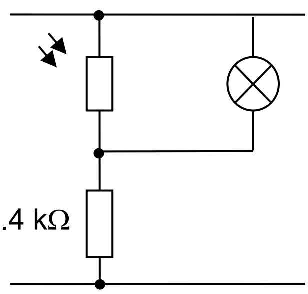
(ii) Hence, determine the reading on the milliammeter.

$I = V / R$ = 10 / 1400 = 0.0071 A = 7.1 mA

2 The diagram shows how a LDR may be used in a circuit to automatically turn on a light bulb in the dark.

The LDR has a resistance of 5.0 kΩ in the dark but a resistance of 25 Ω when exposed to light.

(Assume the lamp to have very high internal resistance)



(a) Calculate the potential difference across the light bulb when

(i) the LDR is in the dark.

In the dark,
p.d. across bulb
= 5000 / (5000 + 2400) × 12.0
= 8.108 = 8.1 V (2 s.f.)

(ii) The LDR is exposed to light.

When exposed to light,
p.d. across blub
= 25 / (25 + 2400) × 12.0
= 0.12 V (2s.f.)

(b) Hence, explain why the light bulb automatically lights up in the dark.

- When it is dark, the <u>resistance</u> of the LDR <u>increases</u> to 5.0 kΩ.
- Hence, applying the <u>potential divider concept</u>, the <u>p.d.</u> across the LDR <u>increases</u> to 8.1 V,
- and the <u>p.d. across the bulb also increases accordingly</u>, as it is connected in <u>parallel</u> to the LDR.
- This p.d. is high enough for the bulb to light up.

(c) Sketch and explain how the circuit may be modified so that the light bulb lights up when the LDR is exposed to light.

Connect the bulb in parallel to the 2.4 kΩ resistor instead.

Hence, p.d. across the bulb will be

12.0 V – 0.12 V = 11.9 V

which is high enough for the bulb to light up.