- ***Candidates should be able to :***

  - *Draw a simple **potential divider circuit.***

  - ***Explain** how a potential divider circuit can be used to produce a variable pd.*

  - ***Recall** and **use** the potential divider equation :*

$$V_{out} = V_{in} \times \frac{R_2}{(R_1 + R_2)}$$

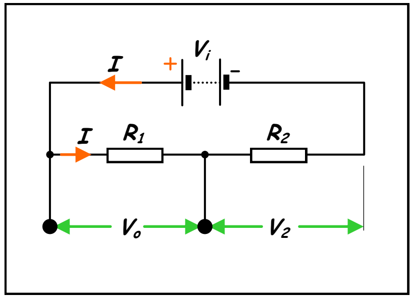
  - *Describe how the resistance of a **light-dependent resistor (LDR) depends on the intensity of light.***

  - *Describe and explain the use of **thermistors and LDRs in potential divider circuits.***

  - *Describe the **advantages of using data-loggers** to monitor physical changes.*

- ***SUPPLYING A FIXED PD***

The simplest potential divider circuit (shown opposite) is one which uses two resistors in series to give a smaller, fixed pd from a larger pd.



*For the circuit shown, the **current (I)** through R_1 and R_2 is given by :*

$$I = \frac{\text{pd across the resistors}}{\text{total resistance}} = \frac{V_i}{R_1 + R_2}$$

pd across resistor $R_1 = V_o = IR_1 = \dfrac{V_i R_1}{R_1 + R_2}$

pd across resistor $R_2 = V_2 = IR_2 = \dfrac{V_i R_2}{R_1 + R_2}$

So, $\dfrac{V_o}{V_2} = \dfrac{V_i R_1 / (R_1 + R_2)}{V_i R_2 / (R_1 + R_2)} = \dfrac{R_1}{R_2}$

Therefore, the ratio of the pds across each resistor is equal to the ratio of the resistances.

*The **OUTPUT VOLTAGE or PD (V_o)** across R_1 is given by :*

$$V_o = \frac{V_i R_1}{(R_1 + R_2)}$$

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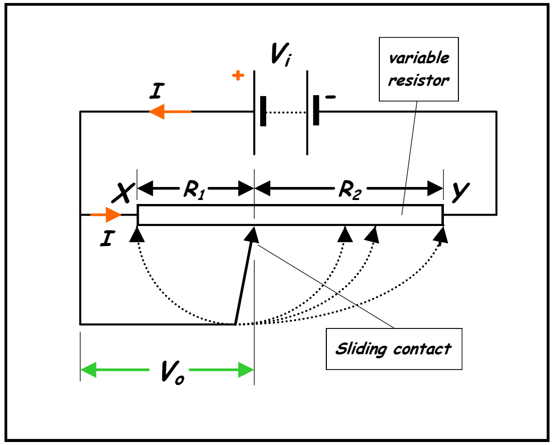
- *For example, a pd of **12 V** can be obtained from a **100 V** supply by setting **R_1 at 1500 Ω** and **R_2 at 11000 Ω**.*

$$V_o = \frac{V_i R_1}{(R_1 + R_2)} = \frac{100 \times 1500}{(1500 + 11000)} = \boxed{12\ V}$$

- ***SUPPLYING A VARIABLE PD***

The potential divider circuit shown opposite uses a variable resistor to give a continuously variable output pd from a fixed input pd.



*By moving the sliding contact on the variable resistor, the value of the **OUTPUT PD (V_o)** can be adjusted :*

- *From a minimum of **0 V (sliding contact at position X).***
- *To the **maximum value when it is equal to the INPUT PD (V_i) (sliding contact at position Y).***

*The **OUTPUT VOLTAGE or PD (V_o)** across R_1 is given by :*

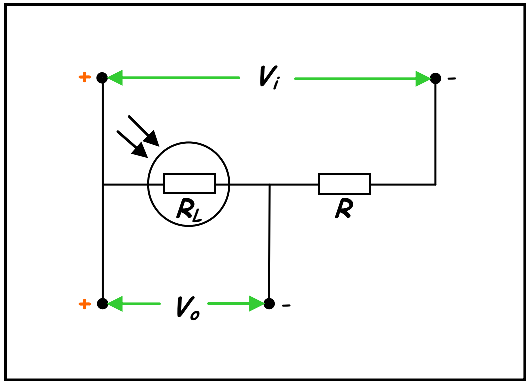
$$V_o = \frac{V_i R_1}{(R_1 + R_2)}$$

- *With the sliding contact at **position X**, $R_1 = 0\ \Omega$, so $V_o = \boxed{0\ V}$*
- *With the sliding contact at **position Y**, $R_1 = R$ (max. resistance of the variable resistor)*

$R_2 = 0\ \Omega$, so $V_o = \dfrac{V_i \times R}{(R + 0)} = \boxed{V_i}$

- ***LIGHT-DEPENDENT POTENTIAL DIVIDER***

*The diagram opposite shows a **light-dependent resistor (LDR)** may be used In a potential divider to provide an **output pd (V_o)** which varies with **light intensity**.*



An LDR is a resistor made from semiconducting material in which electrons are liberated when light shines on the surface of the material.

In <u>total darkness</u>, the only free electrons are those 'shaken' free by thermal vibrations of the atoms, so the LDR's <u>RESISTANCE IS VERY HIGH</u>.

As the <u>light energy incident on the LDR is increased</u>, more and more electrons are liberated and this means that the LDR's resistance becomes increasingly <u>LOWER</u>.

The **OUTPUT PD (V_o)** is given by :

$$V_o = \frac{V_i R_L}{(R_L + R)}$$

In BRIGHT LIGHT

R_L is <u>LOW</u> (≈ 50 to 100 Ω) **compared with R.**
So the **output pd (V_o) is <u>VERY SMALL</u>**.

As the **light intensity <u>DECREASES</u>, R_L <u>INCREASES</u>.**

In TOTAL DARKNESS

R_L is <u>VERY HIGH</u> (≈ 10 MΩ) **compared with R.**
So the **output pd (V_o) has its <u>MAXIMUM VALUE</u> (≈ V_i).**

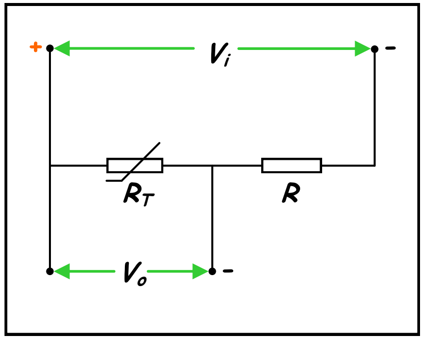
- Since the output pd depends on light intensity, this potential divider could be used to control any process which is **light-level** dependent.

  At the simplest level, this could mean **automatically switching on street lights when darkness falls.** A switching circuit could be set to operate when V_o reaches a pre-determined value, corresponding to a particular light intensity level. If **R** were replaced by a **variable resistor**, it would allow some manual adjustment of the value of **Vo** at a particular light intensity. So, if for example, the street lights were set to switch on at $V_o = \frac{1}{2} V_i$, **R** could be adjusted so that this occurred at any desired level of illumination.

- If **R** and **R_L** were interchanged, V_o will **increase** as the **light intensity increases.** This could be used in a circuit to set off an alarm when a light is switched on or a safe is opened with the lights on.

- ## TEMPERATURE-DEPENDENT POTENTIAL DIVIDER

- A **THERMISTOR** is a device whose resistance varies markedly with temperature.



With ***<u>increasing</u>*** temperature :

The resistance of a **negative temperature coefficient (NTC)** thermistor ***<u>decreases</u>***.

The resistance of a **positive temperature coefficient (PTC)** thermistor ***<u>increases</u>***.

- The **OUTPUT PD (V_o)** is given by :

$$V_o = \frac{V_i R_T}{(R_T + R)}$$

For a **NTC** thermistor :

- When the temperature is ***<u>HIGH</u>***, **R_T** is ***<u>SMALL</u>*** compared with **R** and so V_o will be ***<u>SMALL</u>***.

- When the temperature is ***<u>LOW</u>***, **R_T** is ***<u>LARGE</u>*** compared with **R** and so V_o will be ***<u>LARGE</u>***.

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- *This **temperature-dependent** potential divider could form part of a circuit used to trigger a frost alarm or to switch on a heating system in order to keep the temperature above a certain value.*

  *Replacing the fixed resistor **R** with a **variable resistor** allows manual adjustment of the 'trigger' temperature.*

- *If R_T and **R** are interchanged, V_o will then **increase** with **increasing** temperature. Such a potential divider could form part of a circuit used to switch on an air-conditioning system when the temperature exceeds a certain value.*

- ***USE OF DATALOGGERS TO MONITOR PHYSICAL CHANGES***

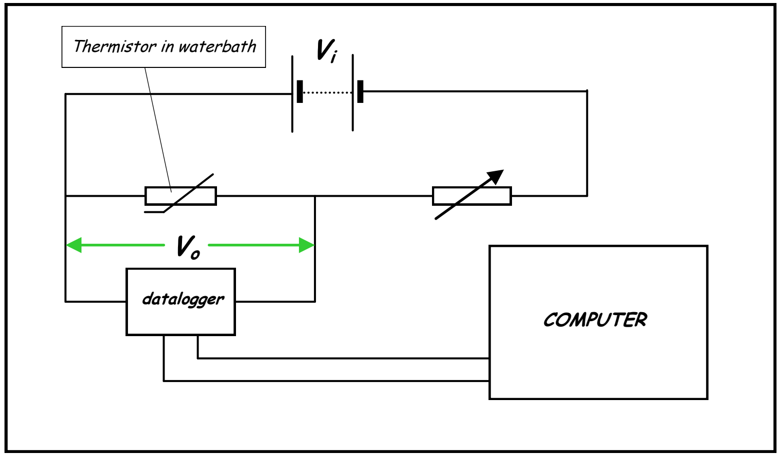
- *The design of commercial **light** or **temperature-sensing** potential - divider circuits requires a full knowledge of the relationship between the **output pd (V_o)** and either **light intensity** or **temperature.***

  *A **<u>DATALOGGER</u>** is a small, portable electronic device which enables data from an external sensor to be recorded over a given time period. it can be interfaced with a computer which analyses the data and displays the information graphically.*

  The advantages of a datalogger for monitoring physical changes are :

  - *The data is recorded automatically over any desired period.*
  - *The collected data is continuously processed and displayed in a clear, graphical form.*

USE OF DATALOGGER TO INVESTIGATE THE RELATIONSHIP BETWEEN OUTPUT PD (Vo) AND TEMPERATURE



*The circuit shown above may be used to investigate the variation of **output pd (V_o)** with **temperature** for a **temperature-dependent potential divider.***

The datalogger's temperature sensor (i.e. the thermistor) is placed in a water bath whose temperature is gradually increased by heating it electrically.

One of the datalogger inputs records the changing water temperature and the second input records the output pd (V_o) of the circuit. The two sets of continuously varying, corresponding readings are fed to a computer, which then analyses the data and displays the information as a graph.

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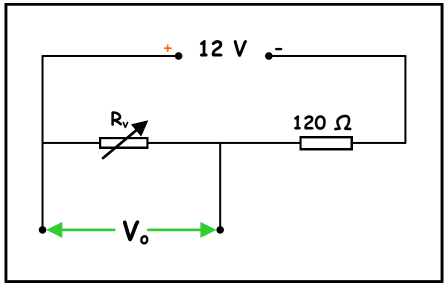
- **PRACTICE QUESTIONS**

1 For the potential divider shown opposite, calculate the **range** over which the **output pd (V_o)** will vary when the variable resistor **(R_v)** is adjusted from **0 Ω to 720 Ω**.



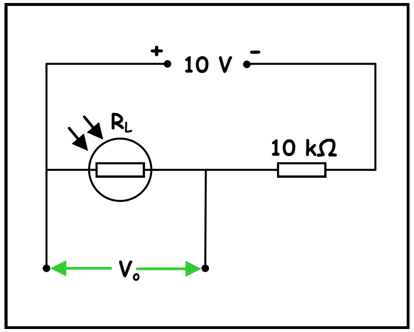
2 A potential divider consists of a **2.5 kΩ** resistor connected in series with a **10 kΩ** resistor and a battery of emf **6.0 V** and negligible internal resistance.

(a) Draw the **circuit diagram** and calculate the **pd across each resistor**.

(b) If a **5 kΩ** resistor is then connected **in parallel** with the **10 kΩ** resistor, what will be the **pd values** across each resistor in this new circuit ?

3 For the **light-dependent potential divider** circuit shown opposite, calculate :

(a) The **output pd (V_o)** when the LDR : (i) is in **the dark** and has a resistance of **8.0 MΩ**.
(ii) is in **bright light** and has a resistance of **200 Ω**.



(b) The **value of R_L** in lighting conditions for which **V_o = 4.0 V**.

4 A light sensor consists of an **LDR** connected **in series** with a **6 kΩ** resistor and a **6.0 V** battery. A high resistance voltmeter connected in parallel with the resistor, gives a reading of **3.4 V** when the LDR is **in darkness**.

(a) Calculate the **pd across the LDR** and **its resistance** when the voltmeter reading is **3.4 V**.

(b) A bright light is now shone on the LDR. **Describe** and **explain** the change observed in the voltmeter reading.

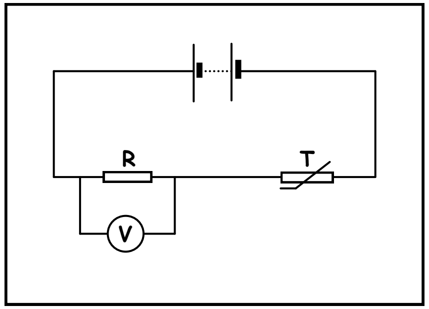
5 A potential divider consists of a **1.5 kΩ** resistor connected in series with a **thermistor** and a **15 V** supply of negligible internal resistance.

The **output pd (V_o)** is taken across the thermistor, whose resistance varies between **120 Ω at 100 °C** and **6.0 kΩ at 0 °C**.

Calculate the output pd : **(a) at 100 °C** **(b) at 0 °C**

- **HOMEWORK QUESTIONS**

1 The diagram shows a potential divider circuit used to monitor the temperature of a greenhouse.
The thermistor **T** is a **negative temperature coefficient** type. the voltmeter is placed across the resistor **R**.



Describe and **explain** how the voltmeter reading changes as the temperature of the greenhouse **increases**.
(OCR AS Physics - Module 2822 - January 2006)

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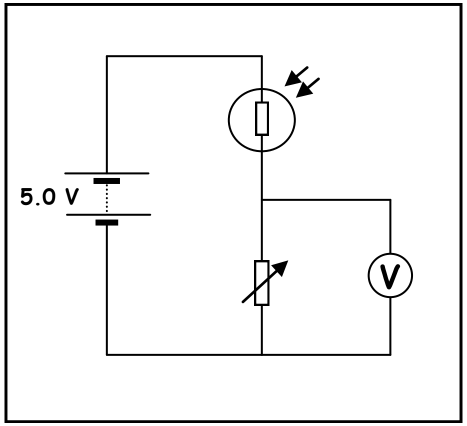
2 The diagram shows a potential divider circuit. The voltmeter has a very large resistance and the battery may be assumed to have negligible internal resistance.
For a particular intensity of light, the resistance of the LDR is **2.4 kΩ.** The variable resistor is set on its maximum resistance of **4.7 kΩ.**

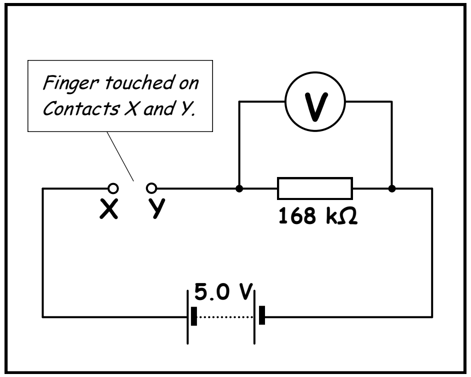


(a) Calculate the **reading on the voltmeter.**

(b) State how the answer to (a) changes when the light intensity is **decreased.**

(OCR AS Physics part question - Module 2822 - May 2002)

3 The diagram shows a potential divider circuit designed as a touch sensor. The battery has **negligible** internal resistance and the voltmeter has **infinite** resistance.



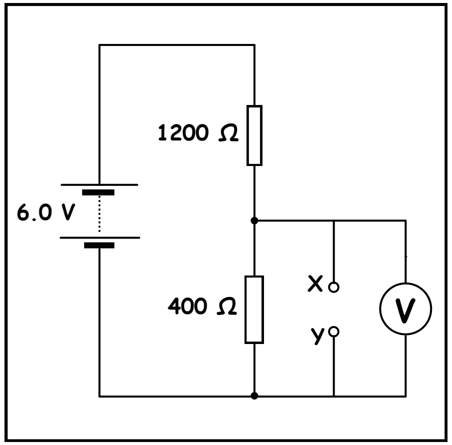
(a) Explain why the voltmeter reading is **zero** when there is nothing connected between contacts **X** and **Y.**

(b) When the finger makes contact between **X** and **Y,** the voltmeter reading changes from **0 V** to **3.4 V** because of the electrical resistance of the skin. Use this information to calculate the **electrical resistance of the skin** between the two contacts.

(OCR AS Physics - Module 2822 - June 2005)

4 (a) **Kirchhoff's** first lawis based on the conservation of an electrical quantity. **State the law** and **the quantity conserved.**

(b) The diagram opposite shows a potential divider circuit. The battery has **negligible** internal resistance and the voltmeter has **very high** resistance.



(i) Show that the voltmeter reading is **1.5 V.**

(ii) An electric device rated at 1.5 V, 0.1 A is connected between the terminals **X** and **Y.** The voltmeter reading drops to a very **low** value and the device fails to operate, even though the device itself is not faulty.

1. Calculate the **total resistance of the device and the 400 Ω resistor in parallel.**

2. Calculate the **pd across the device** when it is connected between **X** and **Y.**

3. **Why** does the device fail to operate ?

(OCR AS Physics - Module 2822 - January 2001)

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