- ***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 :*

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

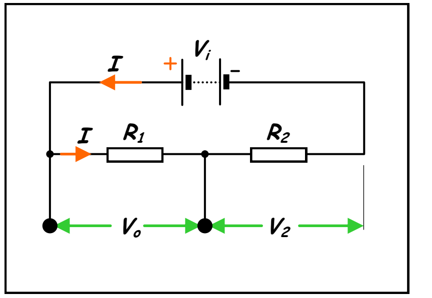
  - *Describe how the resistance of a* ***light-dependent resistor (LDR) depends on the intensity of light.***

  - *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 :*

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

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

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

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

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 :*

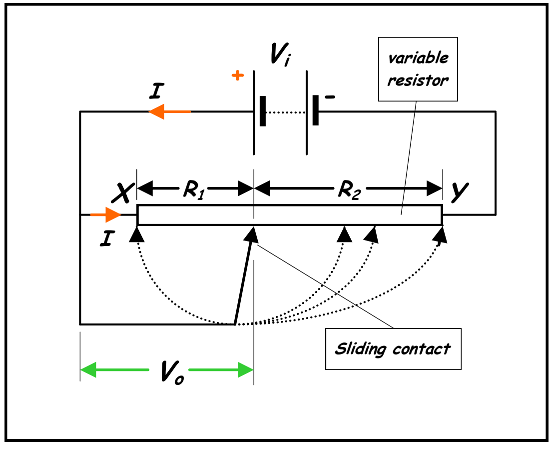
$$V_o = \frac{V_i R_1}{(R_1 + R_2)}$$

- *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 :*

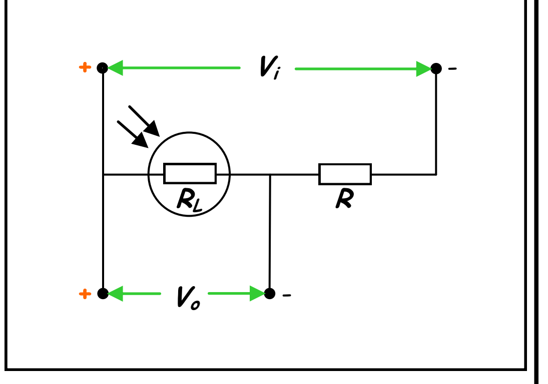
$$V_o = \frac{V_i R_1}{(R_1 + R_2)}$$

- *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 $V_o = \frac{V_i \times R}{(R + 0)} = \boxed{V_i}$

- ***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 total darkness, the only free electrons are those 'shaken' free by thermal vibrations of the atoms, so the LDR's RESISTANCE IS VERY HIGH.

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

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

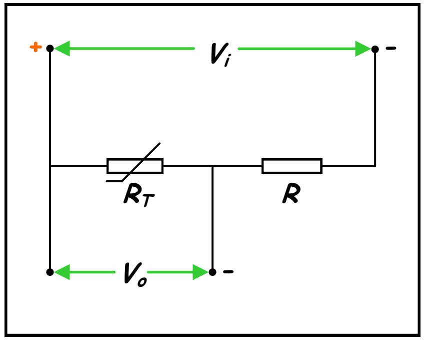
R_L is <u>VERY HIGH</u> (≈ 10 MΩ) **compared with R.**
So the **output pd (V_o) has its <u>MAXIMUM VALUE</u> (≈ V_i).**

- 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.

- 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>**.

- *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

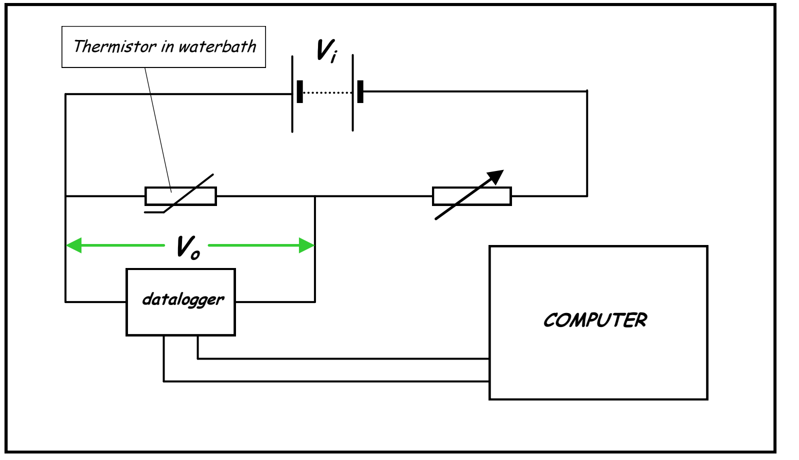
- *The design of commercial **light** or **temperature-sensing** potential - divider circuits requires a full knowledge of the relationship between the **output pd (V_o)** and either **light intensity** or **temperature.***

  *A **DATALOGGER** 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.***

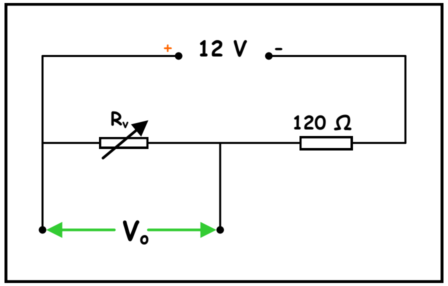
The datalogger's temperature sensor (i.e. the thermistor) is placed in a water bath whose temperature is gradually increased by heating it electrically.

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.

UNIT G482	Module 3	2.3.2	Practical Circuits

- **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**.



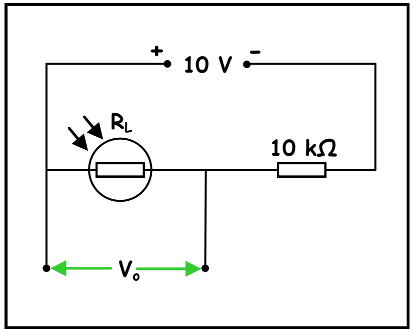
2 A potential divider consists of a **2.5 kΩ** resistor connected in series with a **10 kΩ** resistor and a battery of emf **6.0 V** and negligible internal resistance.

(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.

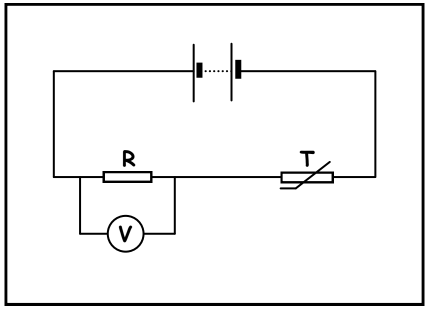
5 A potential divider consists of a **1.5 kΩ** resistor connected in series with a **thermistor** and a **15 V** supply of negligible internal resistance.

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**

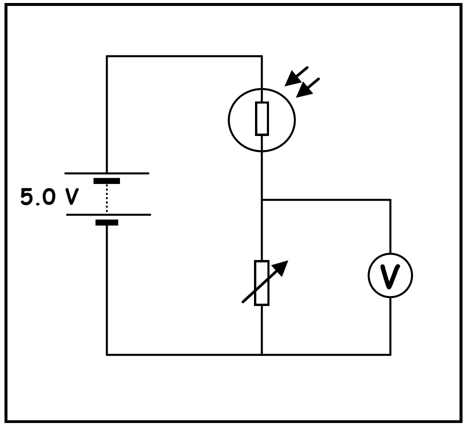
1 The diagram shows a potential divider circuit used to monitor the temperature of a greenhouse.
The thermistor **T** is a **negative temperature coefficient** type. the voltmeter is placed across the resistor **R**.



Describe and **explain** how the voltmeter reading changes as the temperature of the greenhouse **increases**.

(OCR AS Physics - Module 2822 - January 2006)

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.**

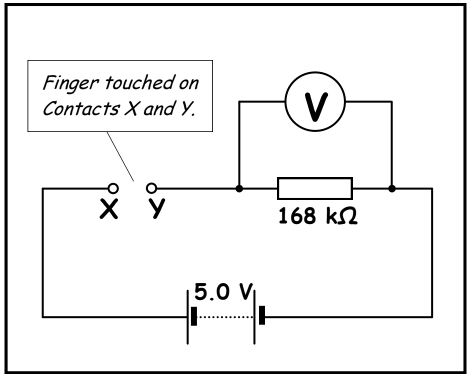


(a) Calculate the **reading on the voltmeter.**

(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.



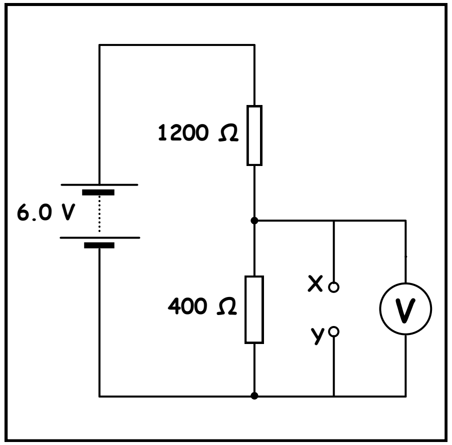
(a) Explain why the voltmeter reading is **zero** when there is nothing connected between contacts **X** and **Y.**

(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)