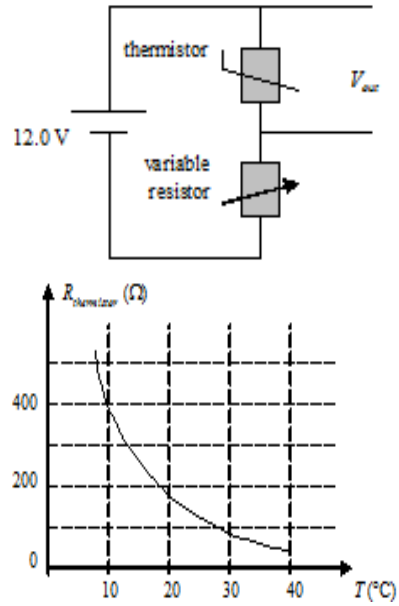
Application of voltage dividers

Example 1 A refrigerator is required to maintain its temperature below 10°C. The cooling unit is controlled by a thermistor. To turn the cooling unit on, a voltage of $V_{out} = 4.0\,\text{V}$ is required. What is the resistance of the variable resistor when the cooling unit is turned on?

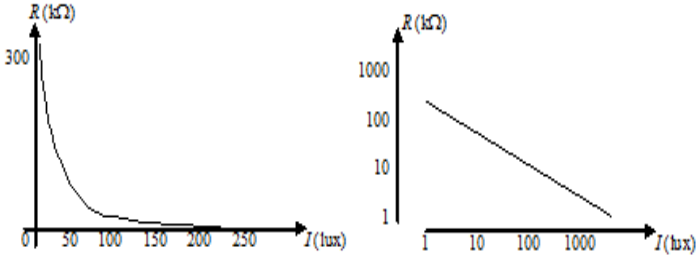


When $T = 10°\,\text{C}$, $R_{thermistor} = 400\,\Omega$, $V_{thermistor} = V_{out} = 4.0\,\text{V}$ and $V_{vr} = 12 - 4.0 = 8.0\,\text{V}$.

$$R_{vr} = \frac{V_{vr}}{V_{thermistor}} \times R_{thermistor} = \frac{8.0}{4.0} \times 400 = 800\,\Omega.$$

Transducers *are electronic devices that change electrical energy into other forms of energy and vice versa, e.g. thermistors (heat to electrical) and loudspeakers (electrical to sound) are transducers.* ***Photonic transducers*** *change electrical energy into light (which carries encoded information) and vice versa. The following devices are photonic transducers.*

A ***light dependent resistor*** *(LDR) is a photonic device whose resistance changes with intensity of light that it is exposed to. The following resistance versus light intensity (illumination) graph shows the characteristic of a typical LDR.*



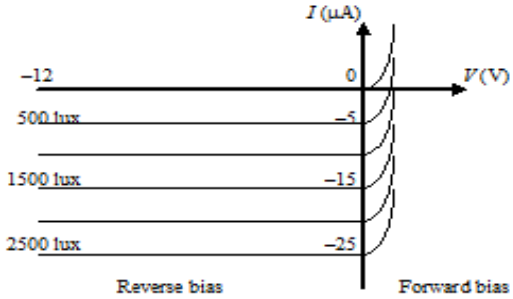
The data are usually plotted on axes with logarithmic scales (the right graph).

Condition	Light intensity (lux)	Resistance (kΩ)
Full moon	1	300
Dimly lit room	300	10
Winter outdoor	6000	2

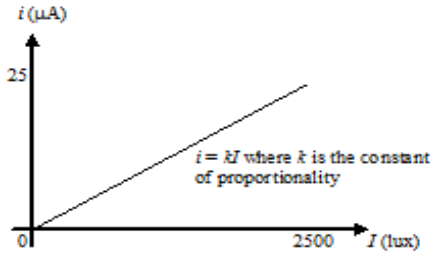
Note: 1 lux ≈ 0.0016 Wm^{-2} of yellow light.

A ***photodiode*** *is a diode whose conduction changes with illuminating light intensity when it is reverse biased. A reverse biased photodiode is said to be in photoconductive mode. Increasing the light intensity increases the reverse biased current (negative value) through a photodiode.*

The following I-V graph shows the characteristics of a typical photodiode at different illuminating light intensities.

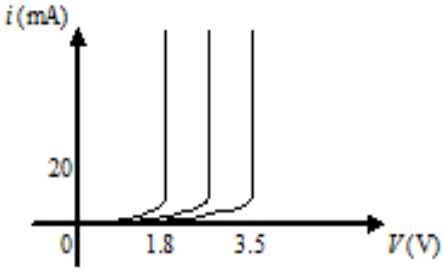


When a photodiode is reverse biased conducting current is directly proportional to light intensity.

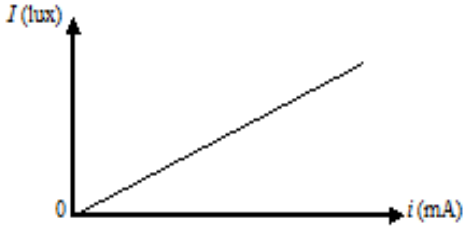


In comparison with a LDR (response time in the order of milliseconds), a reverse biased photodiode has a much faster response time and it is used to detect light signals with period less than a microsecond.

A ***light emitting diode*** *(LED) emits light when it is forward biased. The common LEDs have V_c ranging approximately from 1.8 to 3.5 V.*



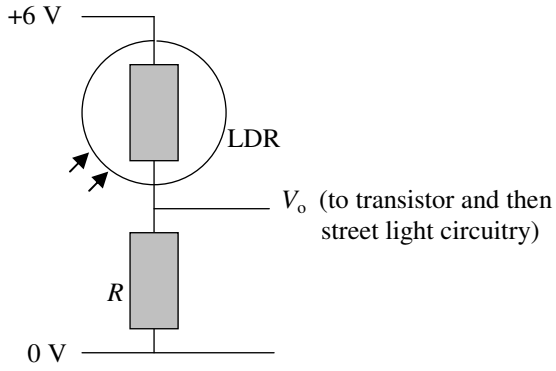
In fibre optic telecommunication LEDs emit light in the infrared region ($\lambda \approx 950 - 1550$nm). Other common LEDs used in electronics emit red (660nm), yellow (590nm) and green light (550nm).
The intensity of emitted light is directly proportional to the current.



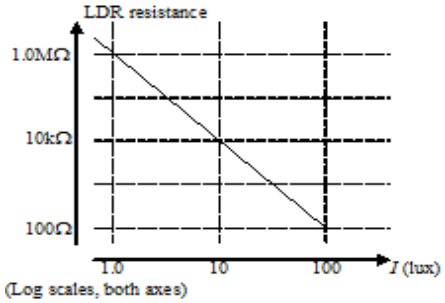
LEDs can respond to electrical signal with period < 1μs.

Design and analyse electronic circuits comprising ohmic resistors, electronic and photonic transducers

Non-contact switch *consisting of a LDR and an ohmic resistor, e.g. in street lighting:*



Example 2 Suppose the above LDR has the characteristic shown in the graph below, and street light turns on when $V_o \le 1.5$ V corresponding to light intensity ≤ 10 lux. Calculate the resistance of R to meet these requirements.



Street light turns on when outdoor light intensity (illumination) drops to 10 lux, $V_o = 1.5$ V, $\therefore V_R = 1.5$ V.

From graph, $R_{LDR} = 10$ kΩ.

$V_{LDR} = 6.0 - 1.5 = 4.5$ V.

$$\frac{R}{R_{LDR}} = \frac{V_R}{V_{LDR}},\ R = \frac{V_R}{V_{LDR}} \times R_{LDR} = \frac{1.5}{4.5} \times 10\ \text{k}\Omega \approx 3.3\ \text{k}\Omega.$$

Example 3 Refer to example 2. Should the resistance of R be higher or lower if the street light is set to turn on when outdoor light intensity drops to 8 lux?

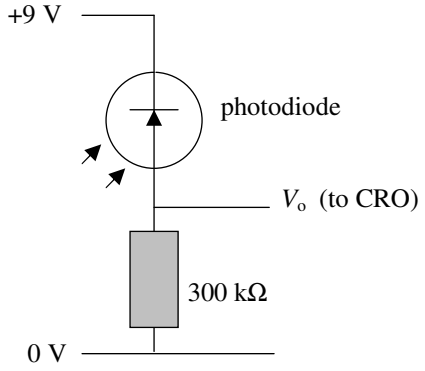
Street light is on when $V_o \le 1.5$ V, i.e. $V_R \le 1.5$ V and when the outdoor light intensity is 8 lux or lower.

From the given graph $R_{LDR} > 10$ kΩ.

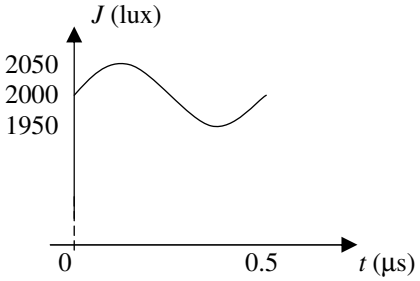
Since $R = \frac{V_R}{V_{LDR}} \times R_{LDR} = \frac{1.5}{4.5} \times R_{LDR}$, when $R_{LDR} > 10$ kΩ,

$R > 3.3$ kΩ, i.e. higher.

Light sensor *comprising a photodiode and an ohmic resistor for detection of time-varying light signals of very short periods (i.e. very high frequency):*



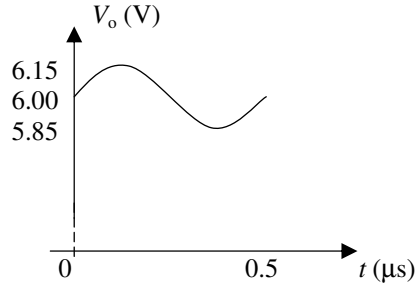
Example 4 Refer to the characteristics of the photodiode discussed earlier. The photodiode is exposed to a time-varying light signal as shown below:



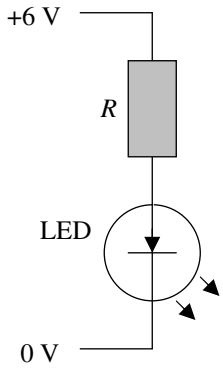
Sketch a graph showing V_o as a function of t.

From the characteristics of the photodiode, the photodiode current is centred at 20 μA, and varies between 19.5 and 20.5 μA.

$\therefore V_o$ is centred at $(20\times10^{-6})(300\times10^{3}) = 6$ V, and varies between 5.85 and 6.15 V.



Light source *circuit comprising a LED and an ohmic resistor:*



The emitted light intensity is directly proportional to the forward bias current through the LED.

Example 5 In the above circuit the voltage across the LED is 2.0 V when it is forward biased and R = 200 Ω.

(a) Calculate the forward bias current.

(b) What value of R will double the intensity of light emitted?

(a) $V_R = 6.0 - 2.0 = 4.0$ V.

$$\therefore I_{LED} = I_R = \frac{V_R}{R} = \frac{4.0}{200} = 0.020\ \text{A} = 20\ \text{mA}.$$

(b) Since emitted light intensity is directly proportional to forward bias current through the LED, $\therefore I_{LED}$ needs to be doubled and hence R needs to be halved, i.e. 100 Ω.

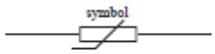
Exercise: Next page

2011 VCAA Exam 1

The following information relates to Questions 5 and 6.

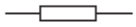
Two students have built a model house and wish to install a fan that will turn on when the temperature is greater than 20°C.
The students used the following.

- a thermistor – The characteristics are shown in Figure 3 below.

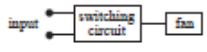


- a 6.0 V battery

- one only of the following resistors: 500 ohm, 1500 ohm or 4500 ohm



- a switching circuit that turns on the fan when the voltage across the input of the switching circuit is greater than 4.5 V



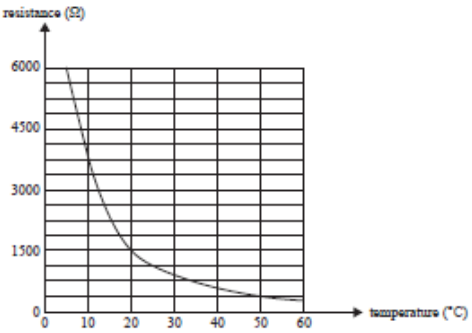


Figure 3

Question 5
What is the resistance of the thermistor when the temperature is 20°C?

Question 6
Using the thermistor, the 6 V battery and one resistor from the listed resistors, draw a circuit to produce a voltage greater than 4.5 V at the input of the switching circuit, and so turn the fan on, when the temperature is greater than 20°C. You must include the value of the resistor you have used on your diagram.

The following information relates to Questions 7 and 8.

A security system uses a light-emitting diode (LED) that emits ultraviolet light, and a photodiode that responds to this ultraviolet light.
The circuits are shown in Figure 4.

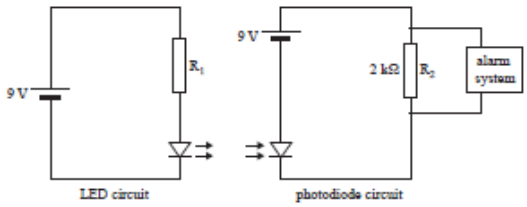


Figure 4

The current–voltage characteristics of the LED and photodiode are in Figures 5 and 6 respectively.

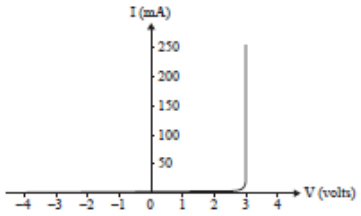


Figure 5

The LED operates at full brightness with a forward current of 150 mA.

Question 7
Use the information above to determine the maximum value of resistor R_1 for the LED to operate at full brightness.

Figure 6 shows the current through the photodiode (in mA) for different values of the power (in mW) of the light falling on it.

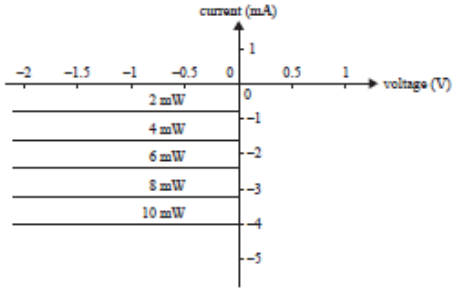


Figure 6

Question 8
Use the information in Figure 6 to determine the voltage across the 2 kΩ resistor in Figure 4, when the power of the light falling on the photodiode is 10 mW.

2010 VCAA Exam 1

The following information relates to Questions 6–8.

Ryan wants to install some garden lights that will come on at sunset.
A circuit will be used to control the lights.
The circuit consists of

- a 12 V DC power source
- a Light Dependent Resistor (LDR)
- a resistor R
- a switching circuit.

The characteristics of the LDR are shown in Figure 5, and the circuit in Figure 6.

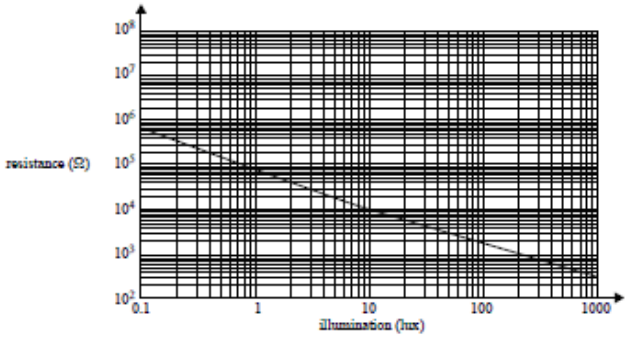


Figure 5

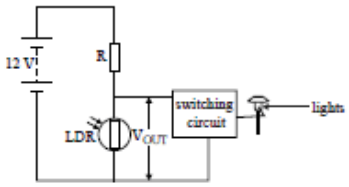


Figure 6

The switching circuit turns the lights ON when V_{OUT} is 4.0 volts.

Ryan wants the lights to come on when the illumination has fallen to 10 lux.

Question 6
What must be the value of the resistor R in Figure 6, to ensure the lights come on at 10 lux?

Question 7
As sunset approaches, and the daylight gets less bright, does the value of V_{OUT} increase or decrease as it approaches 4 V?
Explain your reasoning.

Question 8
Ryan decides that he wants the lights to come on earlier. Should he increase or decrease the resistance R to achieve this? Explain your answer.

2008 VCAA Exam 1

Use the following information to answer Questions 9–11.

A thermistor is a device the resistance of which varies with temperature. The resistance-temperature characteristic for a thermistor is shown in Figure 7.

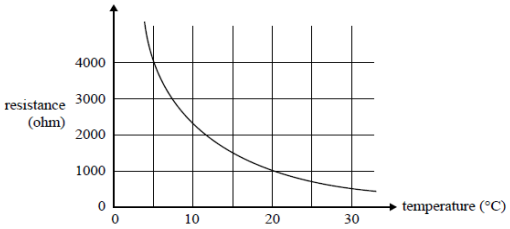


Figure 7

Question 9
What is the value of the resistance of the thermistor at 20°C?

The thermistor is incorporated into the control circuit for the refrigeration unit of a coolroom. The circuit is shown in Figure 8 below.

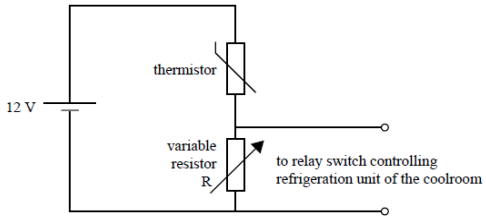


Figure 8

The relay switches the refrigeration unit ON when voltage, V, across variable resistor R ≥ 4V and switches OFF when V < 4V.
The refrigeration unit must turn on when the temperature of the coolroom rises to, or exceeds, 5°C.

Question 10
At what value should the resistor R be set so that the refrigeration unit turns on at this temperature?
You must show your working.

Question 11
The coolroom is not cold enough.
To set the temperature lower, should R be increased or decreased? Explain your answer.