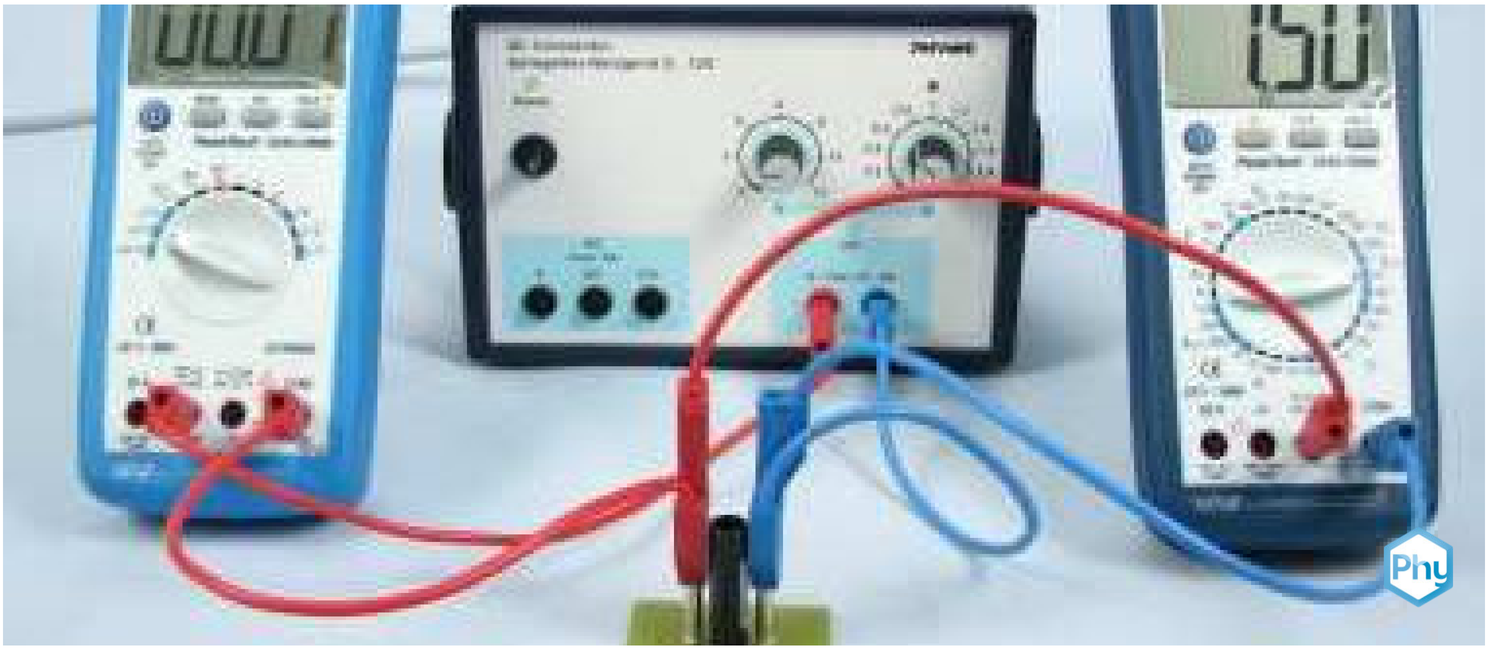
# How are the energy and colour of light related?



Physics › Modern Physics › Quantum physics

| Difficulty level | Group size | Preparation time | Execution time |
|---|---|---|---|
| easy | 1 | 10 minutes | 10 minutes |

This content can also be found online at:

http://localhost:1337/c/5f5067b937ffe20003f10029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# Teacher information

## Application

Experiment set-up

**How are the energy and colour of light related?**

The Planckian quantum of action $h$ is a fundamental natural constant in quantum physics. It occurs in the description of quantum phenomena in which physical properties cannot assume any continuous value, but only certain discrete values.

In this experiment, the Planckian quantum of action is determined by measurements on light-emitting diodes (LED).



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## Other teacher information (1/2)

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**Prior knowledge**

The LED is a semiconductor component and consists like a diode of an n- and a p-doped layer.

In a semiconductor only certain energy bands can be occupied by the electrons.

By applying a voltage in the forward direction of the diode, the energy of the electrons is increased. This causes them to populate the conduction band on the n-side and then, after they have crossed the interface, fall back to the energetically lower valence band on the p-side.

There they recombine with the existing holes. The energy gained is released again and (partly) light is emitted.

## Other teacher information (2/2)

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**Scientific principle**

The band gap, i.e. the energy difference between the valence and conduction band, is varied in LEDs by the choice of materials.

The larger the band gap, the more energy the electrons must have to move from the valence band to the conduction band.

The threshold voltage is therefore different for different LEDs. At the same time, the size of the band gap influences the energy of the emitted photons and thus the frequency or color of the light.

From the threshold voltage $U_{Schwelle}$ the energy $E$ of the electrons. This energy corresponds to the photon energy. When applying the photon energy above the frequency $f$ of the light shows a linear relationship. The gradient or proportionality factor is the Planckian quantum of action $h$.



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## Notes on implementation

This test can be carried out in two different ways. For the second variant the ammeter is not necessary. Instead, the insertion of the glow of the LED is determined by the eye. Since the eye is not sensitive to IR light, this diode is not used here.

When testing with the eye as a light sensor, the threshold voltage and thus the electron or photon energy are measured at higher values than when testing with an ammeter. Although the threshold voltage has already been reached, the eye does not yet perceive light. Only from a certain light intensity does the eye react. The deviation is minimal and has only a minor influence on the result, as the slope of the straight line is approximately the same.

When connecting the LEDs, the correct polarity must be observed, as diodes only allow current to pass in one direction.

## Safety instructions

The general instructions for safe experimentation in science lessons apply to this experiment.



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# Student Information

## Motivation

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Experiment set-up

**How are the energy and colour of light related?**

The Planckian quantum of action $h$ is a fundamental natural constant in quantum physics. It occurs in the description of quantum phenomena in which physical properties cannot assume any continuous value, but only certain discrete values.

Determine the Planckian quantum of action $h$ by measurements and observations on light emitting diodes (LED).



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# Equipment

| Position | Material | Item No. | Quantity |
|---|---|---|---|
| 1 | LED - blue, with series resistor and 4 mm plugs | 09852-40 | 1 |
| 2 | LED - UV, with series resistor and 4 mm plugs | 09852-50 | 1 |
| 3 | LED - green, with series resistor and 4 mm plugs | 09852-30 | 1 |
| 4 | LED - red, with series resistor and 4 mm plugs | 09852-20 | 1 |
| 5 | LED - IR, with series resistor and 4 mm plugs | 09852-10 | 1 |
| 6 | Stray light tube for LED, Di = 8 mm, l = 40 mm | 09852-01 | 1 |
| 7 | Digital multimeter, 600V AC/DC, 10A AC/DC, 20 MΩ, 200 µF, 20 kHz, −20°C… 760°C | 07122-00 | 2 |
| 8 | PHYWE Power supply, 230 V, DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A | 13506-93 | 1 |
| 9 | Connecting cord, 32 A, 750 mm, red | 07362-01 | 3 |
| 10 | Connecting cord, 32 A, 750 mm, blue | 07362-04 | 2 |



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## Set-up (1/2)

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- This test can be carried out in two different ways. The difference is that a multimeter (voltage) is used in the second variant.
- Set up the experiment according to the illustrations.**Attention**: Pay attention to the correct polarity!

## Set-up (2/2)

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- Connect the two digital multimeters.**Attention**: Pay attention to the correct polarity!
- Measuring ranges: 2mA (current measurement), 20V (voltage measurement)





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# Implementation (1/2) - variant 1

Experiment procedure

- Select the LEDs with the colors UV, blue, red and IR.
- Plug the stray light tube onto the LED and close the opening with your thumb to prevent unwanted light from entering.
- The voltage is slowly increased until the ammeter shows a stable current (about 0.01 mA) that is as small as possible.

# Implementation (2/2) - variant 1

- Read the voltage $U_{Schwelle}$ at the voltmeter when the current flow begins and enter them in Table 1 in the log.


- Turn the voltage on the power supply back to zero and change the LED.
- Proceed accordingly with the following LEDs.



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## Implementation (1/3) - variant 2

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Experimental procedure - variant 2

The ammeter is not necessary for this variant.

This is where the eye determines the point at which the LED lights up. Since the eye is not sensitive to IR light, this diode is not used here.

In order to be able to lead the tube to the eye, the cables must be connected to the LED from behind during this test.

## Implementation (2/3) - variant 2

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- Move the stray light tube very close to the eye to minimize lateral light incidence.
- Select the LEDs with the colors UV, blue, green and red.
- Remove the ammeter.
- Plug the interference light tube onto the LED.



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## Implementation (3/3) - variant 2

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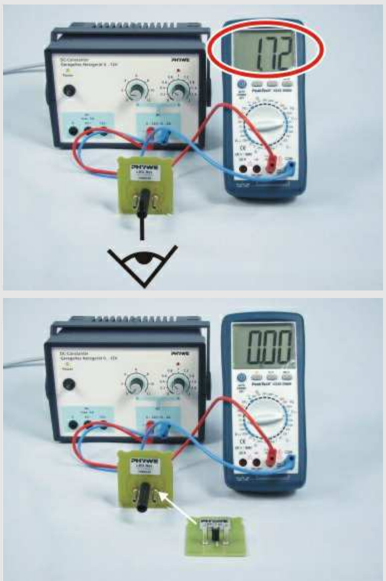

- Slowly increase the voltage at the power supply unit while observing the LED with your eye.
- As soon as the LED glows, note the corresponding voltage $U_{Schwelle}$ in Table 2.
- Turn the voltage at the power supply unit back to zero and change the LED.
- Proceed accordingly with the following LEDs.

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# Report



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# Task 1

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1. Note the voltage $U_{Schwelle}$ .
2. Calculate from the wavelength $\lambda_{max}$ of the LEDs with $c = 2.998 \cdot 10^8 m/s$ as the speed of light in a vacuum the frequency $f$ of light with the formula $c = \lambda \cdot f$.
3. Determine the maximum energy $E$ which an excited electron can have, about $E = e \cdot U_{Schwelle}$ whereat $e = 1,6 \cdot 10^{-19} C$ is the elementary charge.

**Result - Table 1**

| Colour LED | $U_{Schwelle}$ inV | $\lambda_{max}$ in nm | $f$ in $10^{14} Hz$ | $E$ in $10^{-19} J$ |
|---|---|---|---|---|
| UV | | | | |
| blue | | | | |
| red | | | | |
| IR | | | | |

# Task 2

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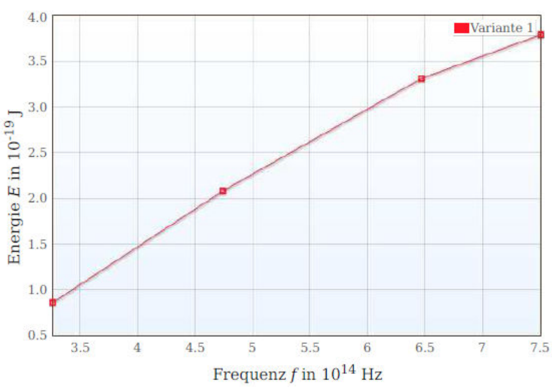
Calculate the slope to Table 1.




$m =$

Drag the words into the gaps!

The slope gives _____ between $E$ and $F$ so _____ $h$ via $E = h \cdot f$. The dimension of the gradient _____ (from $h$) results in: $[h] = [E]/[f] = J/s^{-1}$ = _____

the Planckian quantum of action

the proportionality factor

of the compensation line

$Js$

Check



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| Slide | Score / Total |
| --- | --- |
| Slide 19: Meaning of the quantum of action | **0/4** |

**Total amount** 0/4

Solutions Repeat Exporting text



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