The Measurement of Planck's Constant

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LNF

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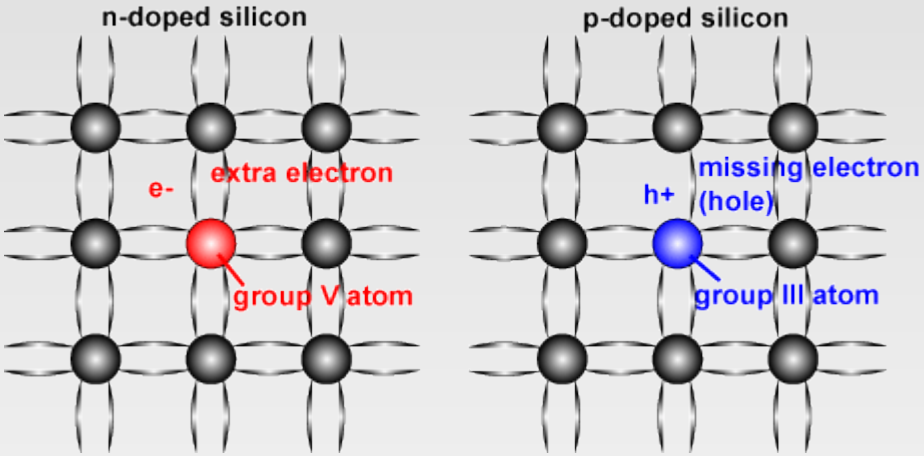
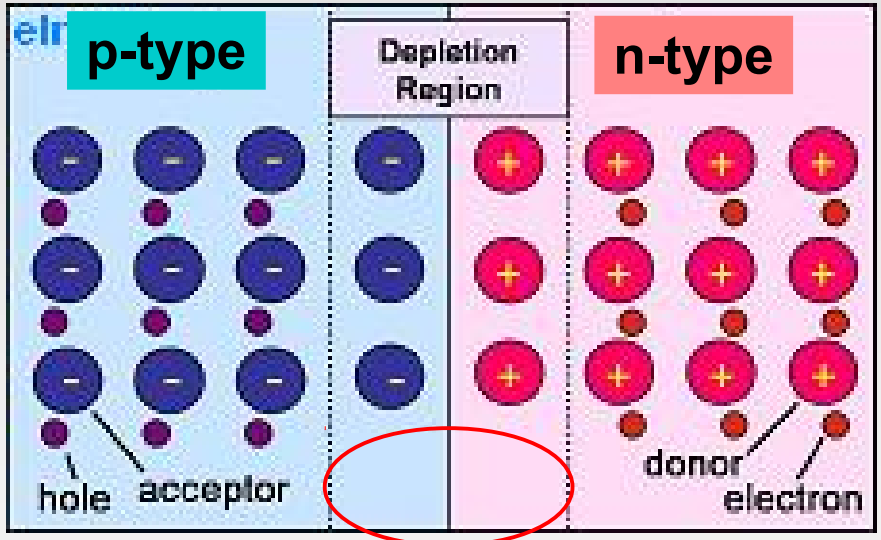
Our Experiment

- The goal of our measurement is to give an estimate of the Planck constant
- With our experimental setup what we can expect is to find at least the order of magnitude of the costant (~10^{-33} J s)
- We will measure *h* with an accuracy of about 10-20%

The diode

”A p–n diode is a type of two-terminal semiconductor diode based upon the p–n junction that conducts current in only one direction, made by joining a p-type semiconducting layer to an n-type semiconducting layer” (Wikipedia)



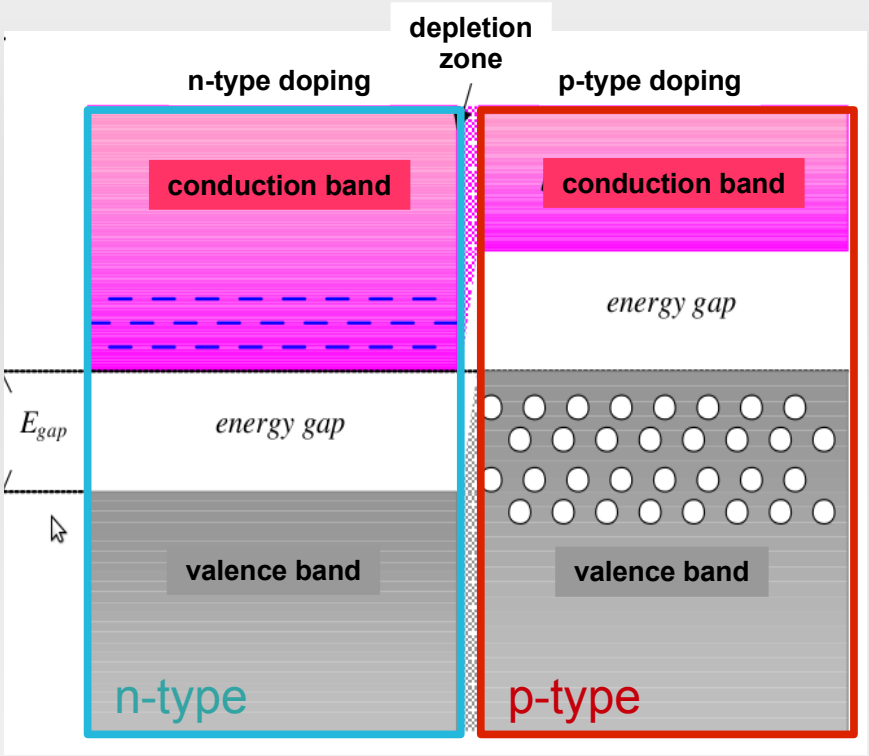


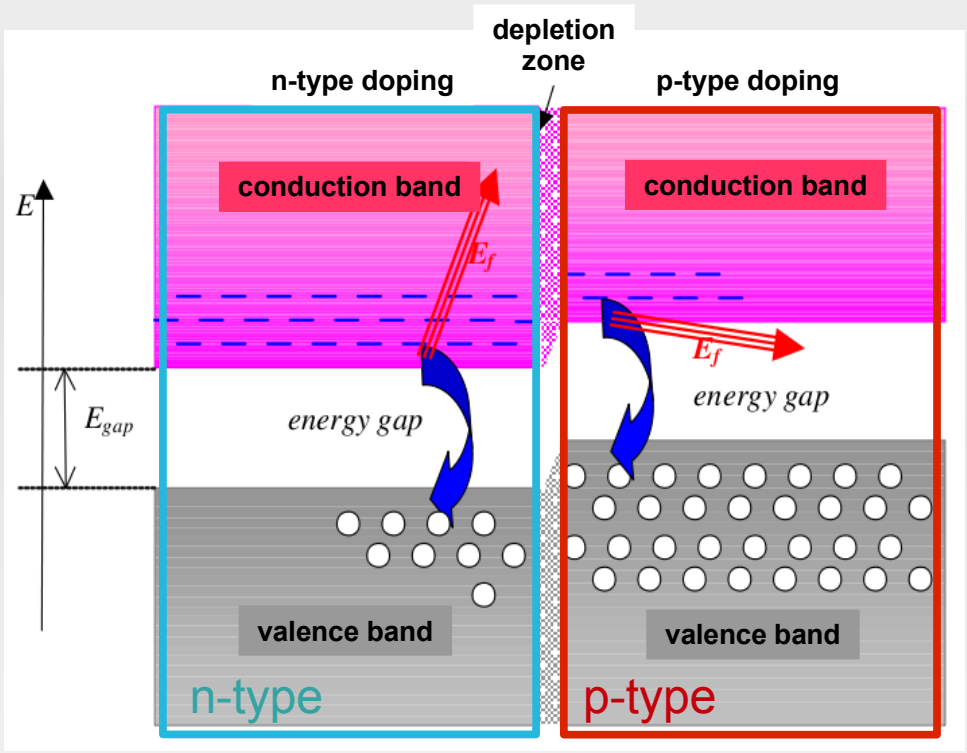
- A hole is like an e^- with positive charge
- Semiconductor has n valence e-
  - A **donor** has n+1 valence e-
  - An **acceptor** has n-1 valence e-
- Free e- are available in n-type zone
- Free e+ are available in p-type zone

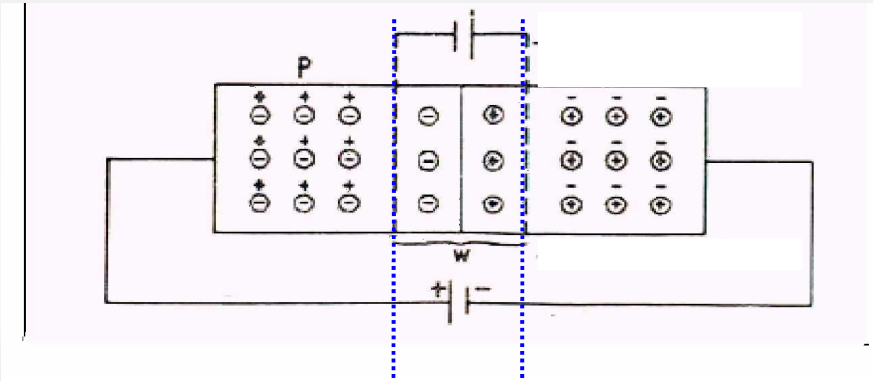
hole + electron = annihilate
NO free charges here!

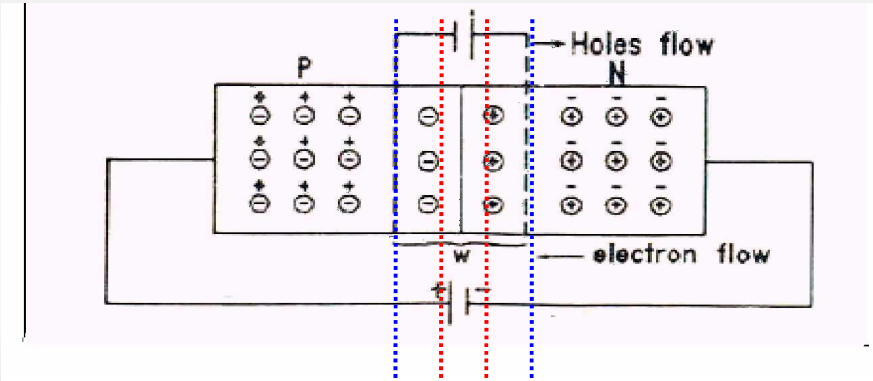
the depletion zone generate an opposing **E** which prevents the drift of other charges!

The LED diode









$\Delta V = 0$

$\Delta V = V_p - V_n > 0$

h measurement with a LED: ”theory”

- When we apply a large enough potential difference across a light-emitting diode (LED), it emits photons that all have the same frequency
- When the LED **just begins to glow**, the energy E lost by each electron as it passes through the LED is converted into the energy of a single photon
- The energy lost by **each** electron is **E = eV**, where e is the elementary charge (1.6×10^{-19} C) and V is the potential threshold across the LED.
- The energy E of **a photon** of frequency f is **E = hf** , where h is Planck’s constant ($h = 6.63 \times 10^{-34}$ Js).

...energy is (always) conserved!! So: **eV = hf**

h measurement : what to do...

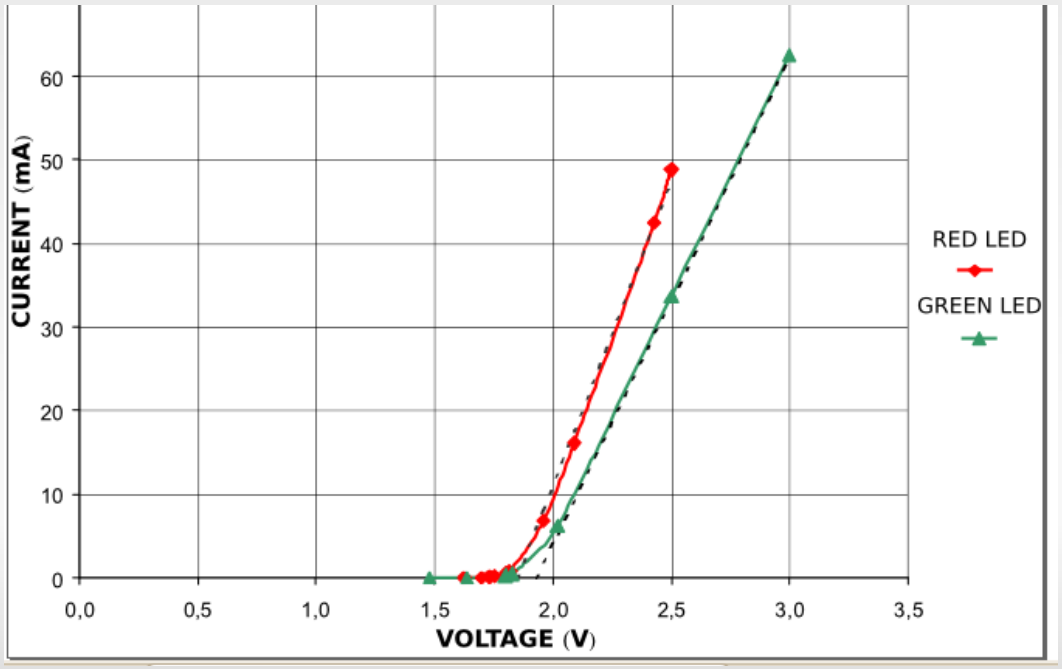
We need to identify the beginning point of the LED glowing

1) Vary the current supply up to the lighting point (use the viewing tube)

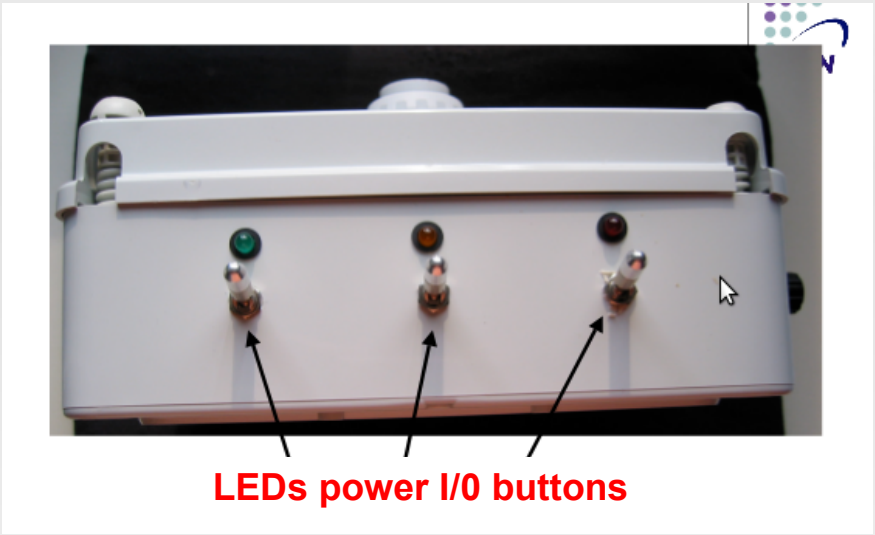
2) Measure the voltage for increasing values of supply current (put each couple of values on a ”I vs V” graph)

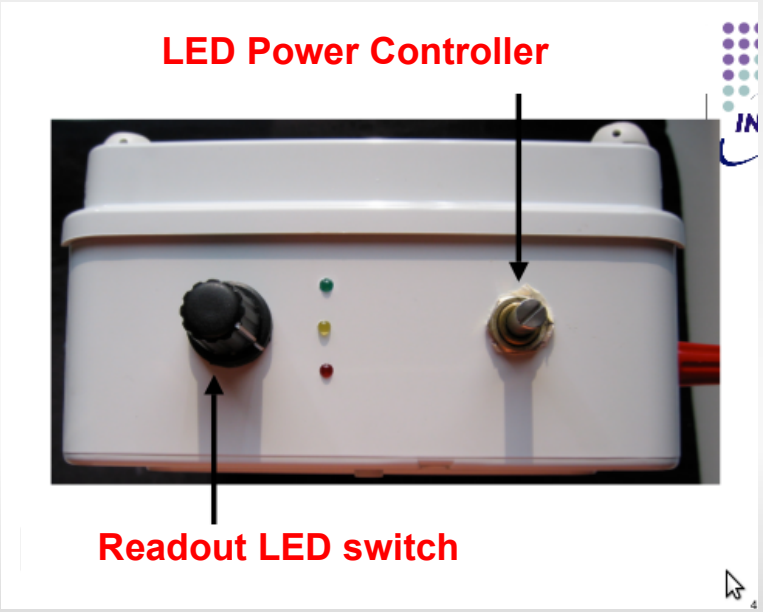
3) Measure the "threshold voltage" from the extrapolation at I = 0 of the linear portion of the characteristic curve of the diode

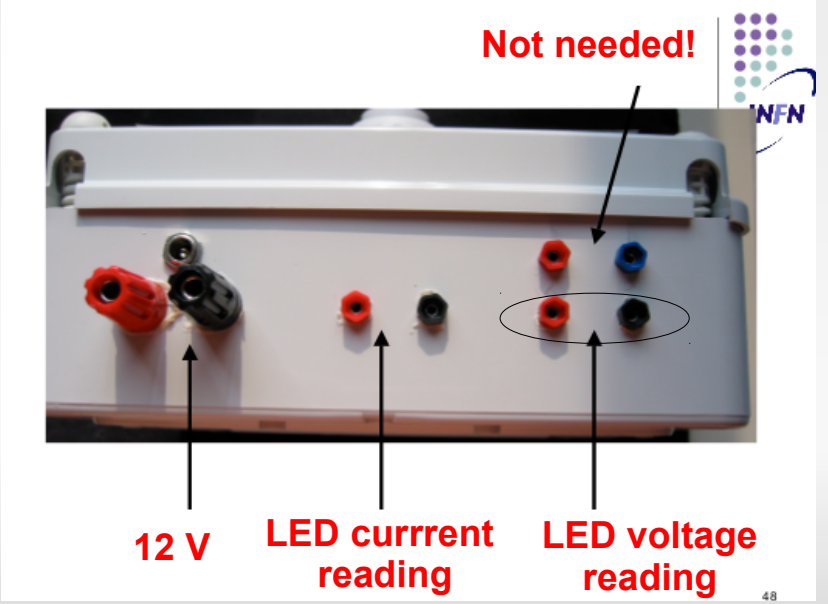
4) Extract h from V, f and e (formula: eV = hf)



The experimental setup

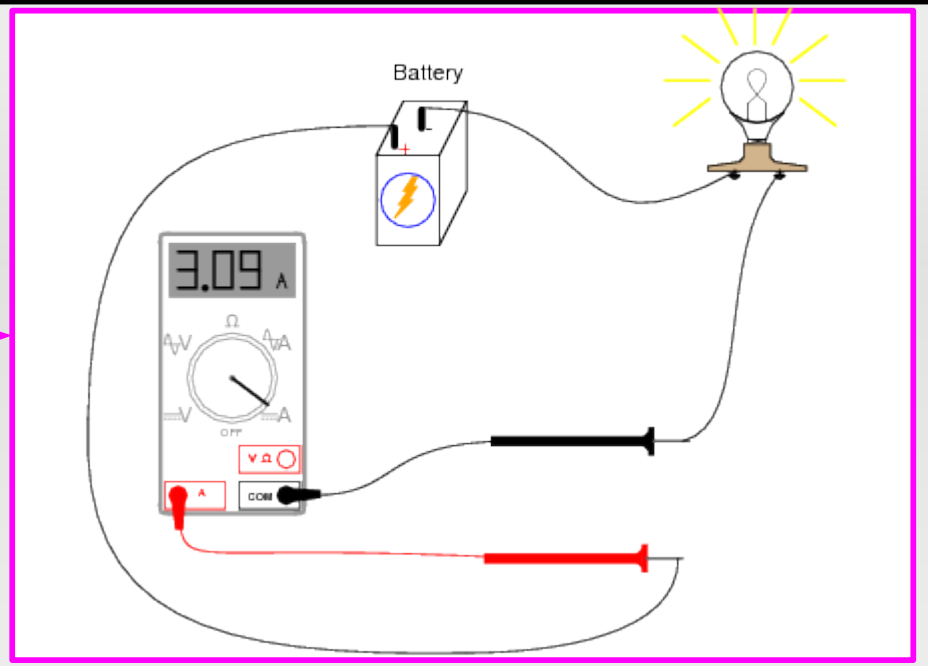


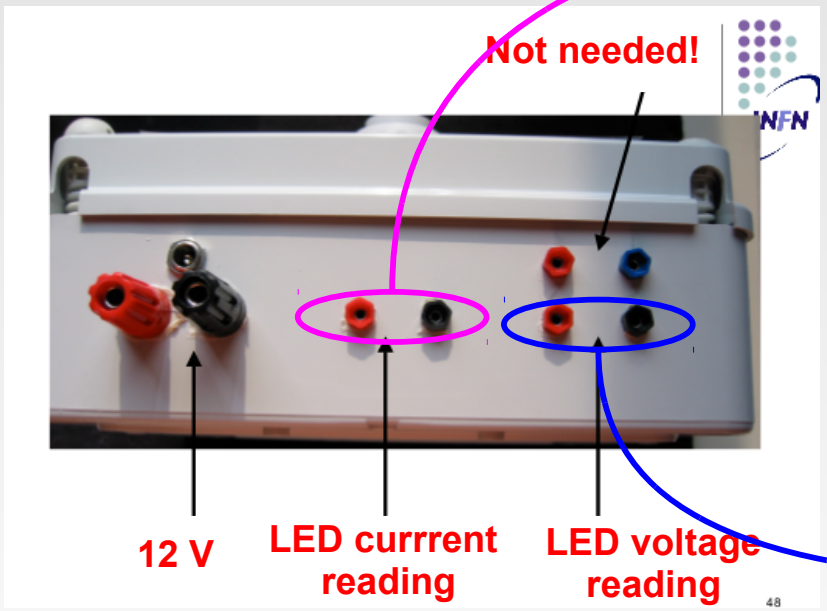




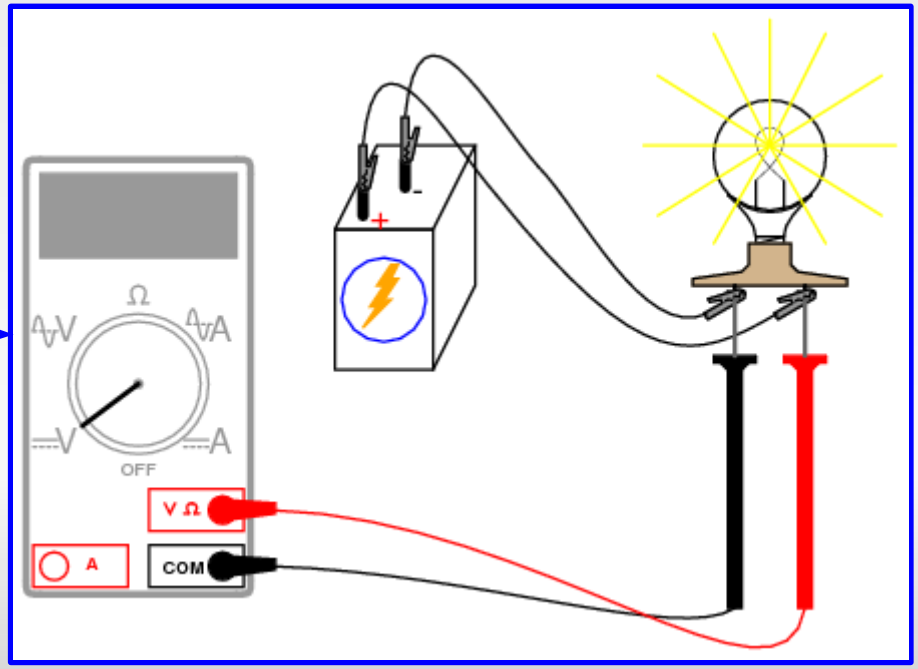
The instruments (be careful !)

AMMETER

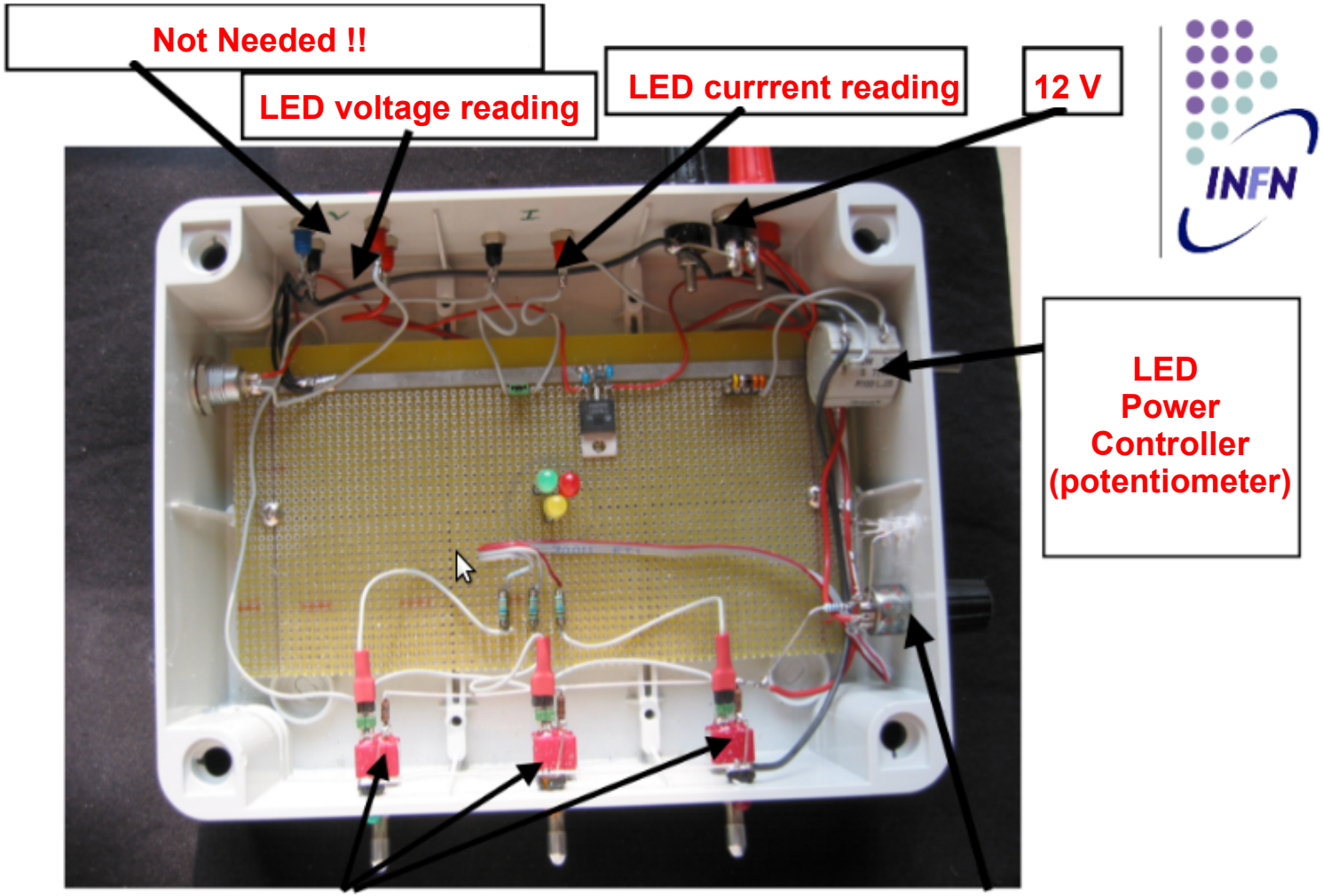




VOLTMETER



The experimental setup



Last remarks...

- Be careful: LEDs can be destroyed if the current flowing through them is too large!!
- Typical frequency values for LEDs (you will use the ones on the datasheet):

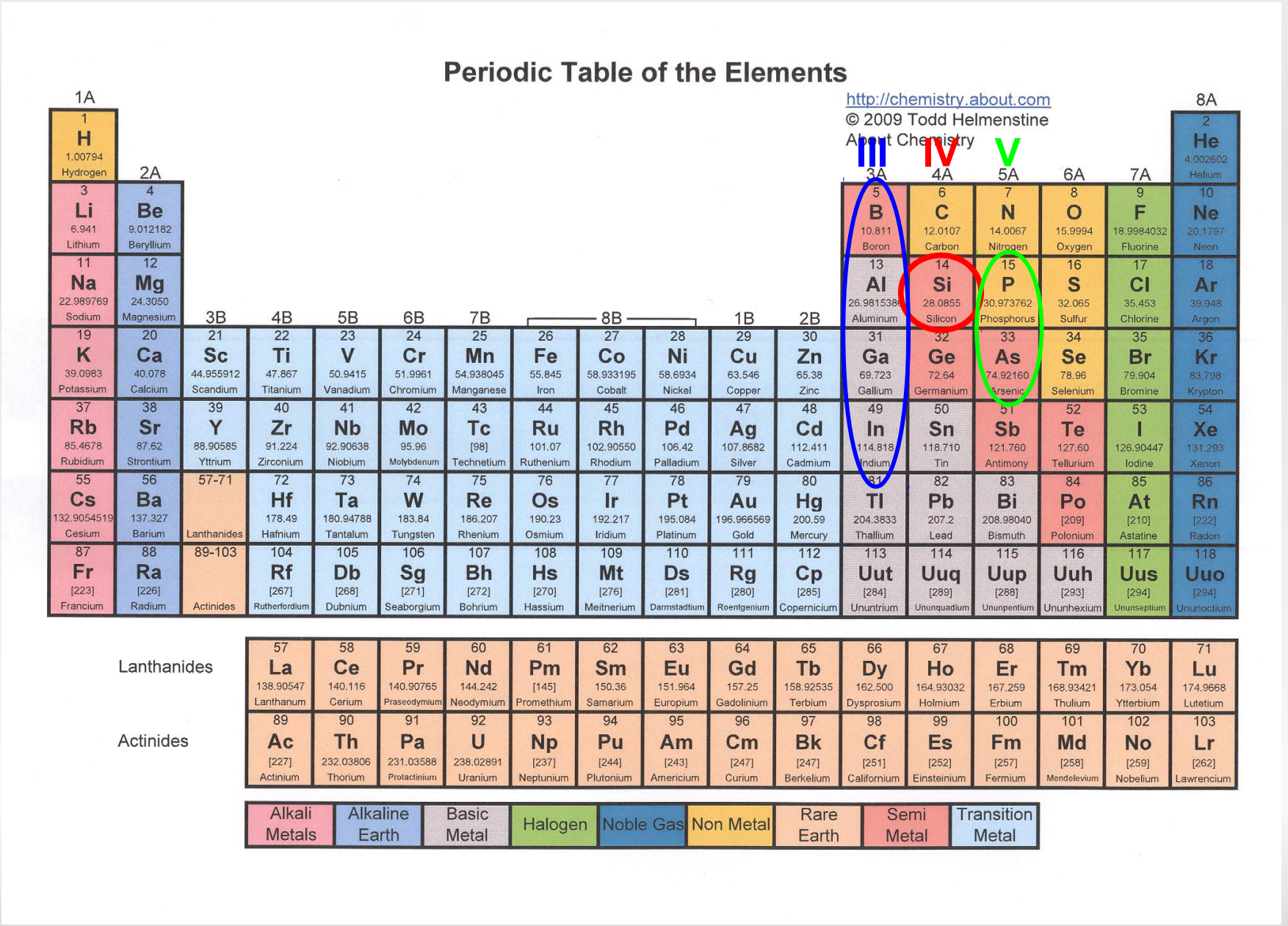
Colour of LED	Red (KSB-1372)	Amber (KSB-1393)	Yellow (KSB-1356)	Green (KSB-1337)	Blue (KLL-5058A)
Frequency (x 10^{14} Hz)	4.54	5.00	5.08	5.31	6.38
Potential Difference (V)	1.43	1.58	1.62	1.69	2.29

- Useful constants (needed to extract h from **eV = hf**):

$e = 1.602\ 10^{-19}$ C
$h = 6.626\ 10^{-34}$ J s
$f = c/\lambda$
$c = 2.9979\ 10^{8}$ ms^{-1}

let's get started with the measure...good luck with your work!

Spares


Periodic Table of the Elements
http://chemistry.about.com
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About Chemistry
III
IV
V
1A
2A
3B
4B
5B
6B
7B
8B
1B
2B
3A
4A
5A
6A
7A
8A
1 H 1.00794 Hydrogen
2 He 4.002602 Helium
3 Li 6.941 Lithium
4 Be 9.012182 Beryllium
5 B 10.811 Boron
6 C 12.0107 Carbon
7 N 14.0067 Nitrogen
8 O 15.9994 Oxygen
9 F 18.9984032 Fluorine
10 Ne 20.1797 Neon
11 Na 22.989769 Sodium
12 Mg 24.3050 Magnesium
13 Al 26.981538 Aluminum
14 Si 28.0855 Silicon
15 P 30.973762 Phosphorus
16 S 32.065 Sulfur
17 Cl 35.453 Chlorine
18 Ar 39.948 Argon
19 K 39.0983 Potassium
20 Ca 40.078 Calcium
21 Sc 44.955912 Scandium
22 Ti 47.867 Titanium
23 V 50.9415 Vanadium
24 Cr 51.9961 Chromium
25 Mn 54.938045 Manganese
26 Fe 55.845 Iron
27 Co 58.933195 Cobalt
28 Ni 58.6934 Nickel
29 Cu 63.546 Copper
30 Zn 65.38 Zinc
31 Ga 69.723 Gallium
32 Ge 72.64 Germanium
33 As 74.92160 Arsenic
34 Se 78.96 Selenium
35 Br 79.904 Bromine
36 Kr 83.798 Krypton
37 Rb 85.4678 Rubidium
38 Sr 87.62 Strontium
39 Y 88.90585 Yttrium
40 Zr 91.224 Zirconium
41 Nb 92.90638 Niobium
42 Mo 95.96 Molybdenum
43 Tc [98] Technetium
44 Ru 101.07 Ruthenium
45 Rh 102.90550 Rhodium
46 Pd 106.42 Palladium
47 Ag 107.8682 Silver
48 Cd 112.411 Cadmium
49 In 114.818 Indium
50 Sn 118.710 Tin
51 Sb 121.760 Antimony
52 Te 127.60 Tellurium
53 I 126.90447 Iodine
54 Xe 131.293 Xenon
55 Cs 132.9054519 Cesium
56 Ba 137.327 Barium
57-71 Lanthanides
72 Hf 178.49 Hafnium
73 Ta 180.94788 Tantalum
74 W 183.84 Tungsten
75 Re 186.207 Rhenium
76 Os 190.23 Osmium
77 Ir 192.217 Iridium
78 Pt 195.084 Platinum
79 Au 196.966569 Gold
80 Hg 200.59 Mercury
81 Tl 204.3833 Thallium
82 Pb 207.2 Lead
83 Bi 208.98040 Bismuth
84 Po [209] Polonium
85 At [210] Astatine
86 Rn [222] Radon
87 Fr [223] Francium
88 Ra [226] Radium
89-103 Actinides
104 Rf [267] Rutherfordium
105 Db [268] Dubnium
106 Sg [271] Seaborgium
107 Bh [272] Bohrium
108 Hs [270] Hassium
109 Mt [276] Meitnerium
110 Ds [281] Darmstadtium
111 Rg [280] Roentgenium
112 Cp [285] Copernicium
113 Uut [284] Ununtrium
114 Uuq [289] Ununquadium
115 Uup [288] Ununpentium
116 Uuh [293] Ununhexium
117 Uus [294] Ununseptium
118 Uuo [294] Ununoctium
Lanthanides
57 La 138.90547 Lanthanum
58 Ce 140.116 Cerium
59 Pr 140.90765 Praseodymium
60 Nd 144.242 Neodymium
61 Pm [145] Promethium
62 Sm 150.36 Samarium
63 Eu 151.964 Europium
64 Gd 157.25 Gadolinium
65 Tb 158.92535 Terbium
66 Dy 162.500 Dysprosium
67 Ho 164.93032 Holmium
68 Er 167.259 Erbium
69 Tm 168.93421 Thulium
70 Yb 173.054 Ytterbium
71 Lu 174.9668 Lutetium
Actinides
89 Ac [227] Actinium
90 Th 232.03806 Thorium
91 Pa 231.03588 Protactinium
92 U 238.02891 Uranium
93 Np [237] Neptunium
94 Pu [244] Plutonium
95 Am [243] Americium
96 Cm [247] Curium
97 Bk [247] Berkelium
98 Cf [251] Californium
99 Es [252] Einsteinium
100 Fm [257] Fermium
101 Md [258] Mendelevium
102 No [259] Nobelium
103 Lr [262] Lawrencium
Alkali Metals
Alkaline Earth
Basic Metal
Halogen
Noble Gas
Non Metal
Rare Earth
Semi Metal
Transition Metal