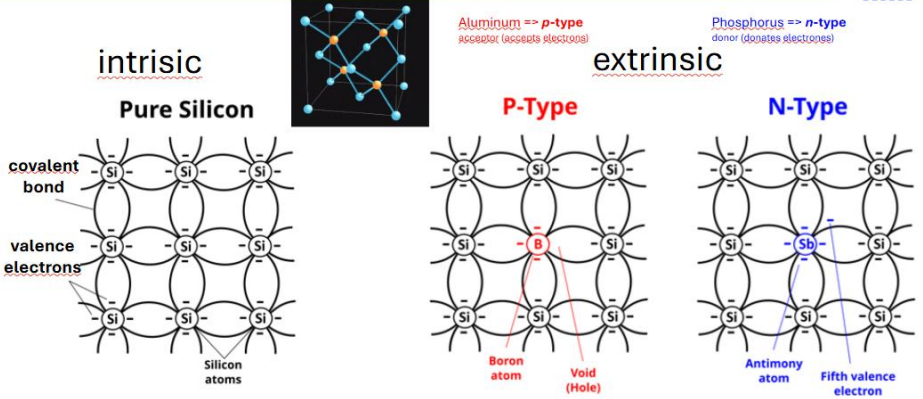
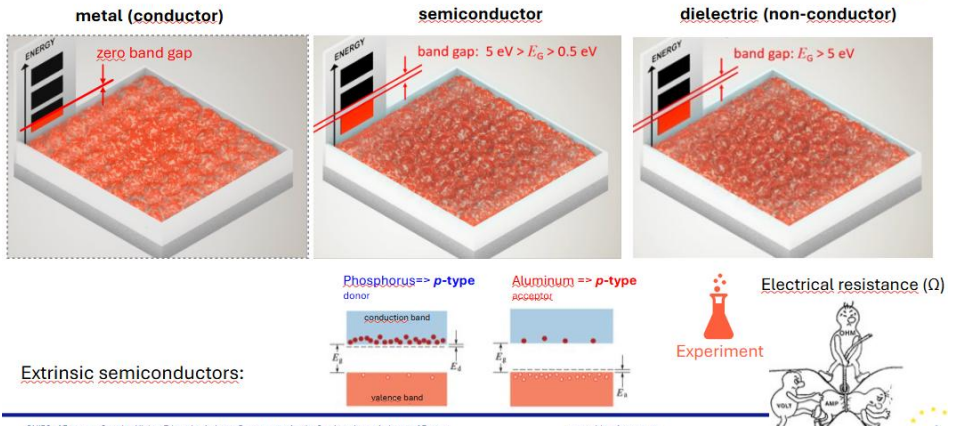
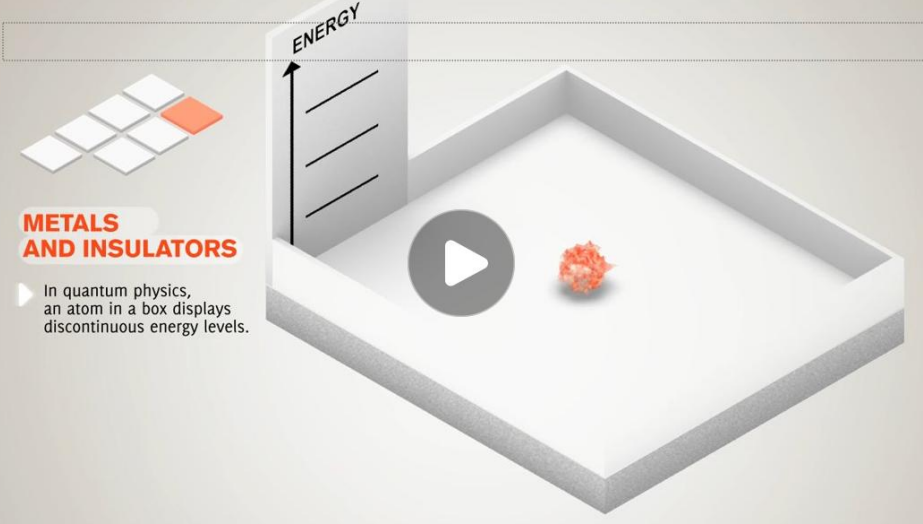
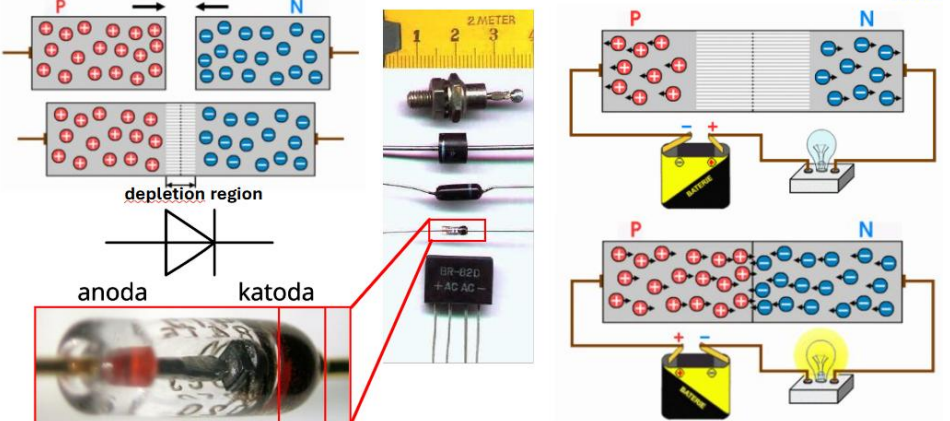
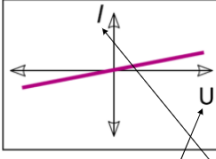
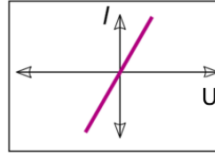
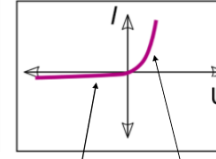
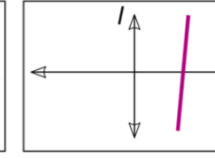
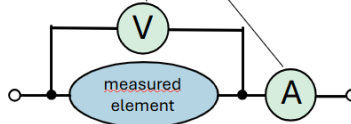
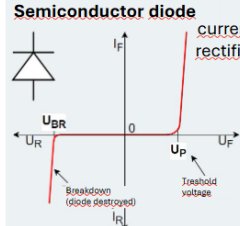
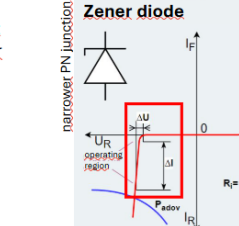
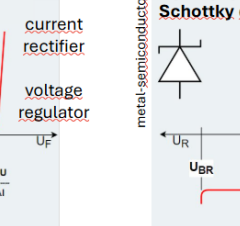
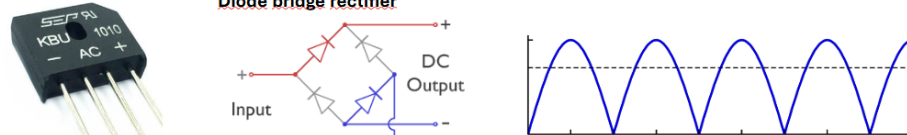
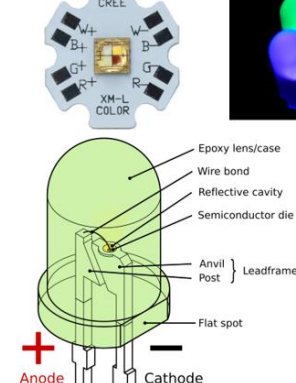
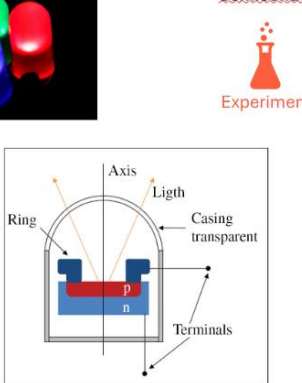


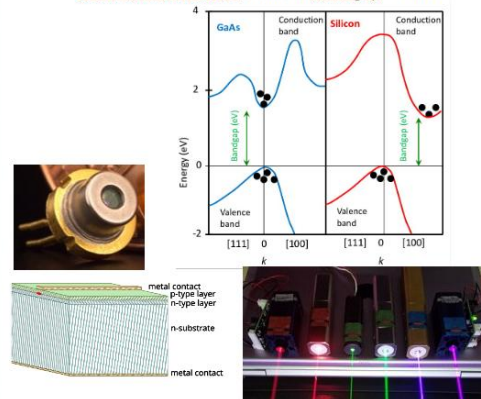
9.	What is a semiconductor?
Target group	Pupils, optional teachers
Age pupils	16–18
Duration	1.5-2 hours
What is a semiconductor	
Summary of the introduction	
Video Metals and Insulators	

Applications: PN junction → Diode	 Diode structure showing P and N regions, depletion region, anode, and cathode. Includes a circuit diagram with a battery and a light bulb, and a photograph of a diode component.
VA characteristic (Linear vs. Non-linear elements)	Resistor  Resistor (lower resistance)  Diode  Battery  Volt-Ampère characteristic  Experiment
VA characteristic (advanced)	Semiconductor diode  Zener diode  Schottky diode  Diode bridge rectifier 
Diode → LED (Light-Emitting Diode)	 Semiconductor with a direct bandgap => LED  Experiment 

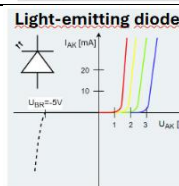
Diode → LED → Semiconductor Laser

Color	Wavelength (nm)	Voltage (V)	Semiconductor material
Infrared	$\lambda > 700$	$0.5V < 1.9$	Gallium arsenide (GaAs) Aluminum gallium arsenide (AlGaAs)
Red	$610 < \lambda < 700$	$1.63 < \Delta V < 2.05$	Aluminum gallium arsenide (AlGaAs) Gallium arsenide phosphide (GaAsP) Aluminum gallium indium phosphide (AlGaInP) Gallium(III) phosphide (GaP)
Orange	$590 < \lambda < 610$	$2.05 < \Delta V < 2.10$	Gallium arsenide phosphide (GaAsP)
Yellow	$570 < \lambda < 590$	$2.10 < \Delta V < 2.18$	Aluminum gallium indium phosphide (AlGaInP) Gallium(III) phosphide (GaP)
Green	$500 < \lambda < 570$	$1.9^{III} < \Delta V < 4.0$	Indium gallium nitride (InGaN) / Gallium(III) nitride (GaN) Gallium(III) phosphide (GaP) Aluminum gallium indium phosphide (AlGaInP) Aluminum gallium phosphide (AlGaP)
Blue	$450 < \lambda < 500$	$2.48 < \Delta V < 3.7$	Zinc selenide (ZnSe) Indium gallium nitride (InGaN) Silicon carbide (SiC) as substrate Silicon (Si) as substrate — (under development)
Violet	$400 < \lambda < 450$	$2.75 < \Delta V < 4.0$	Indium gallium nitride (InGaN)
Purple	multiple types	$2.48 < \Delta V < 3.7$	Dual binned LEDs, blue with red phosphor, or white with purple plastic
Ultraviolet	$\lambda < 400$	$3.1 < \Delta V < 4.4$	Diamond (225 nm) ^[22] Boron nitride (215 nm) ^{[23][24]} Aluminum nitride (AlN) (210 nm) ^[25] Aluminum gallium nitride (AlGaInN) Aluminum gallium indium nitride (AlGaInN) — (down to 210 nm) ^[26]
White	Broad spectrum	$2.7 < \Delta V < 3.5$	Blue diode with yellow phosphor or violet/UV diode with multi color phosphor

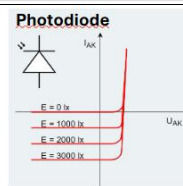
Semiconductor with a direct bandgap => LED



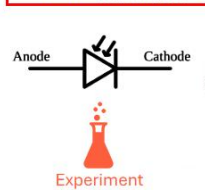
Diode → LED → Photodiode



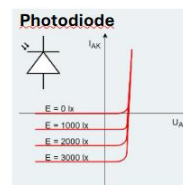
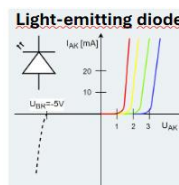
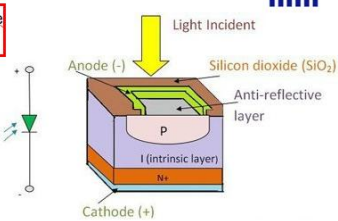
Experiment



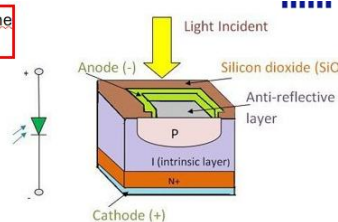
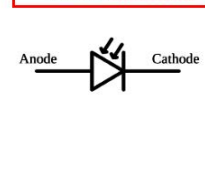
speaker vs. microphone LED vs. photodiode



Experiment



speaker vs. microphone LED vs. photodiode



Digital camera chip



ams OSRAM SFH 2400...



Vishay BPW21R Photodiode



ams OSRAM SFH 2700 FA...



ams OSRAM BPW 21...



ams OSRAM SFH 3710...

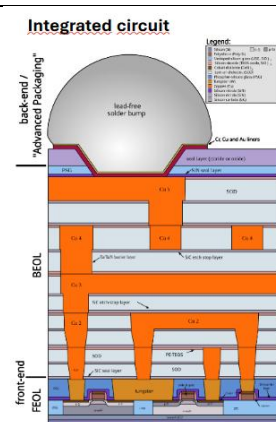


ams OSRAM SFH 2706...

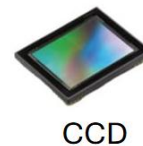


AMS OSRAM Photodiode...

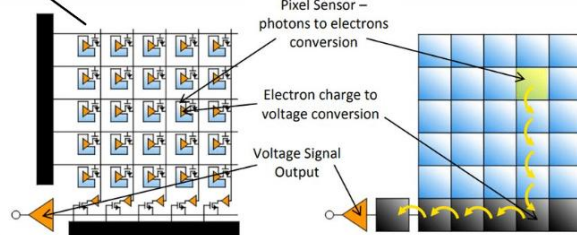
Diode → LED → Photodiode (CCD, CMOS)



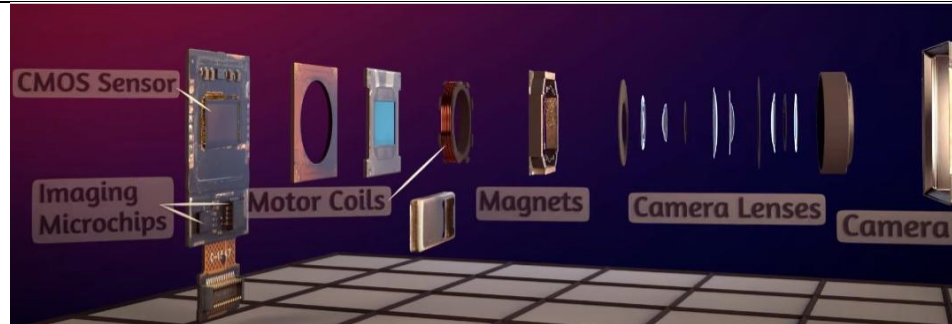
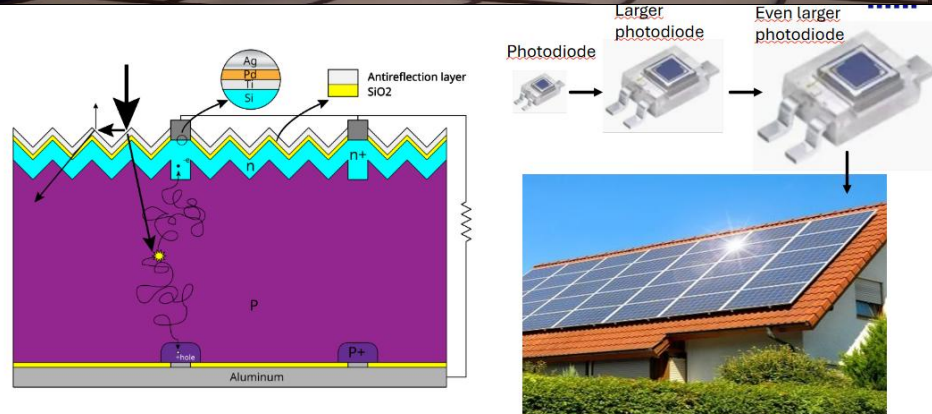
CMOS



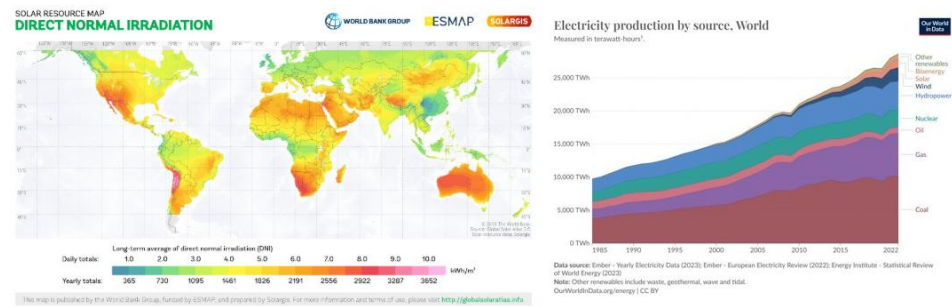
CCD



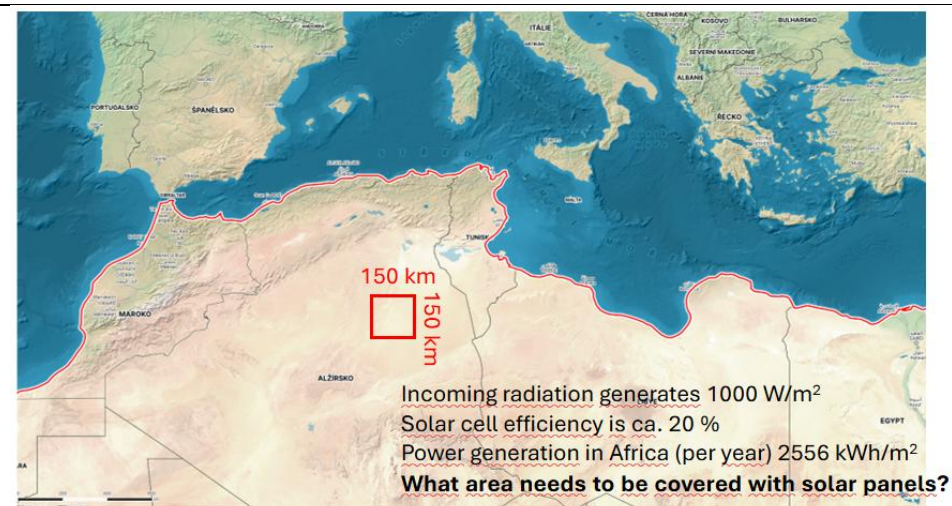
Phone camera


 Diode → LED
→ Photodiode
→ Solar Cell


Solar irradiation vs. energy consumption



Solar cells (why, how many, how..?)

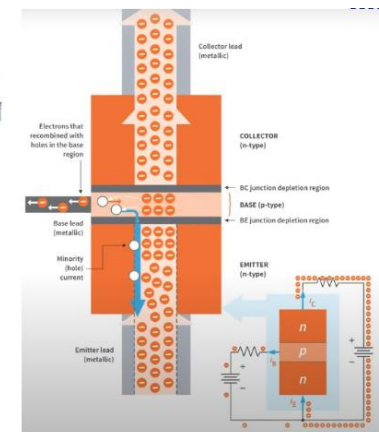
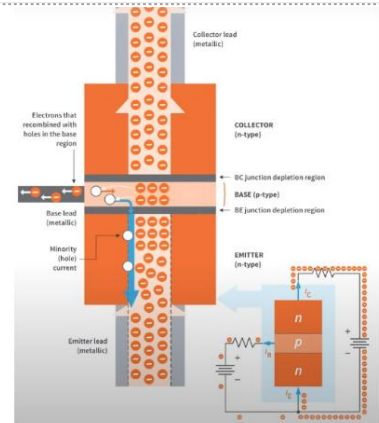
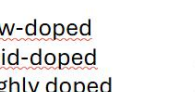


[illegible]

The top row shows the physical structures of NPN and PNP transistors. The NPN transistor (left) has a central p-type base region between two n-type regions (emitter and collector). The PNP transistor (right) has a central n-type base region between two p-type regions (emitter and collector). Labels indicate the Collector (C), Base (B), and Emitter (E) terminals and junctions.

The bottom row shows the electrical characteristics in forward and reverse bias. For the NPN transistor (left), the base-emitter junction is forward-biased (BE forward-biased) and the base-collector junction is reverse-biased (BC reverse-biased). For the PNP transistor (right), the base-emitter junction is forward-biased (BE forward-biased) and the base-collector junction is reverse-biased (BC reverse-biased). The diagrams show the connection of the base, emitter, and collector to a circuit with a resistor and a DC voltage source.

B low-doped
C mid-doped
E highly doped



A AND B

Inputs	Output	
A	B	C
0	0	0
0	1	0
1	0	0
1	1	1

A OR B

Inputs	Output	
A	B	C
0	0	0
0	1	1
1	0	1
1	1	1

A NOT B

Inputs	Output	
A	B	C
0	0	0
0	1	0
1	0	1
1	1	0

George Boole
(1815 – 1864)

FALSE

A NOR B

A XOR B

A XNOR B

A AND B

A AND B

B NOT A

NOT A

A NOT B

A NOT B

NOT B

A - B

A XNOR B

A XNOR B

A XOR B

A XOR B

TRUE

TRUE

**Metal-oxide-
semiconductor
field-effect
transistor
(MOSFET)**

