

Module 5 Unit 4

Radiation Sensors

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Types of Radiation

- **Ionizing**
Alpha, beta, gamma, X-rays, deep UV
- **Non-ionizing**
UV-A, visible, IR, microwaves, radio waves
- **Other**
 - Neutrons, cosmic rays, neutrinos, high magnetic field
 - particle/photon Energy $< 13 \text{ eV}^*$
- **Unit: sievert (Sv)** the effect of ionizing radiation that is equivalent to depositing radiation dose of 1 joule in 1 kg of biological mass (tissues)
- **(SAR – Specific Absorption rate is measured in W/kg)**



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Typical Dose Levels of Ionizing Radiation

Items	Radiation dose (μSv)
Stipulated limit per person	2/hr
Single fatal dose	10^7
Single dose causing cancer	10^6
CT scan	Max 40000 per run
Chest X-ray	70 per shot (0.1 sec)
Dental X-ray	20 per shot (0.1 sec)
Natural background radiation	0.1/hr
Chernobyl debris (today)	100
Fukushima (on the accident day)	400000
Hiroshima (back calculated)	10^8 single shot

*Over a prolonged exposure and averaged over 5 years



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Radiation Hazards

- Risks from ionizing radiation (non-fatal dose level)
- Nausea, general weakness, skin diseases, cancer, gastrointestinal issues, fertility, weakening of bones and muscles
- Risks from non-ionizing radiation
- Nausea, vomiting, eye irritation, restlessness, numbness, psychosomatic diseases



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Radiation Detectors

- Gas detectors
 - Ionization chamber
 - Proportional counter
 - **Geiger-Muller counter**
- **Scintillation detectors**
 - Solid phosphors
 - Inorganic
 - Plastics/Organic
 - Liquid
 - Gases
- Solid state detectors
 - Intrinsic semiconductors
 - **Photodiodes (p-i-n)**
 - SDD (FET)
- CCD



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Geiger-Muller Counter

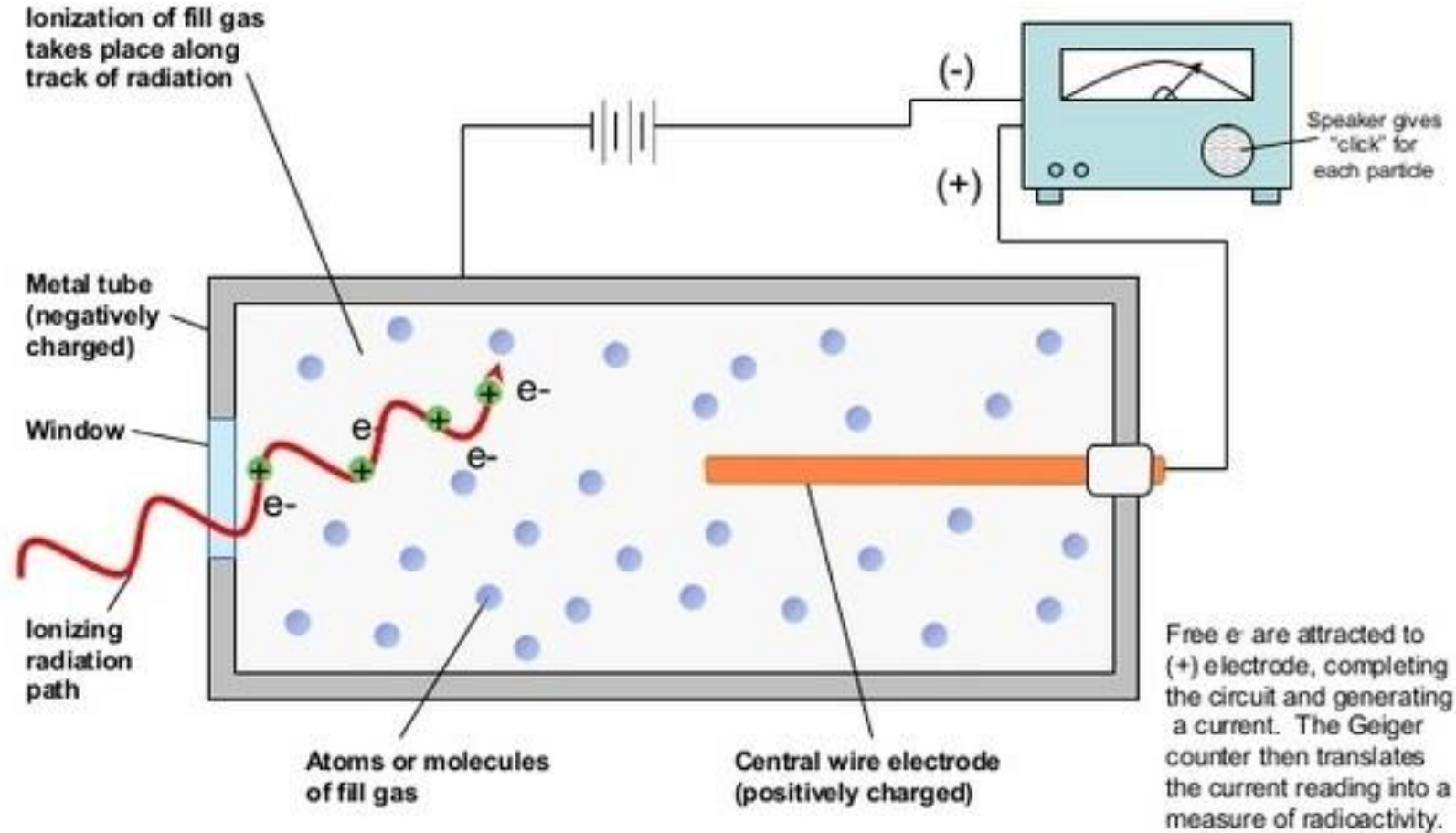
- Used for:
 - α , β and γ radiation
- Basic components:
 - quartz tube (sensor) with metallic lining inside
 - Counter (electronics)
- Working principle: electric discharge due to ionization of gas
 - Mixture of Argon and Ethyl alcohol (90:10) @ 0.01 atm pressure
 - Ethyl alcohol vapours is active component
- Main disadvantage:
 - Dead time
 - Background radiation



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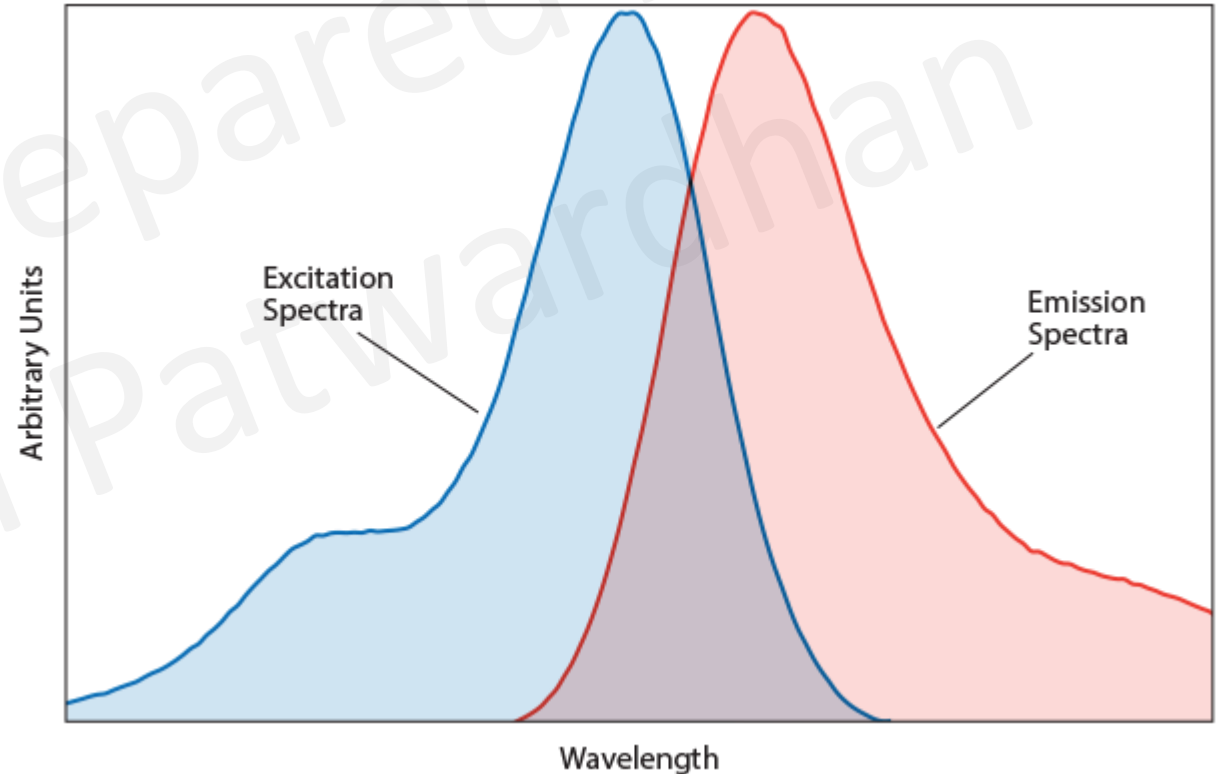
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Geiger-Muller Counter



Scintillation Counter

- Used for:
 - α , β , γ radiation and X-rays
- Basic components:
 - Phosphor (Scintillator)
 - solid, liquid or gaseous state
 - Photomultiplier tube
 - Counter (electronics)
- Working principles:
 - Luminescence
 - Photoelectric effect
 - Photon multiplication

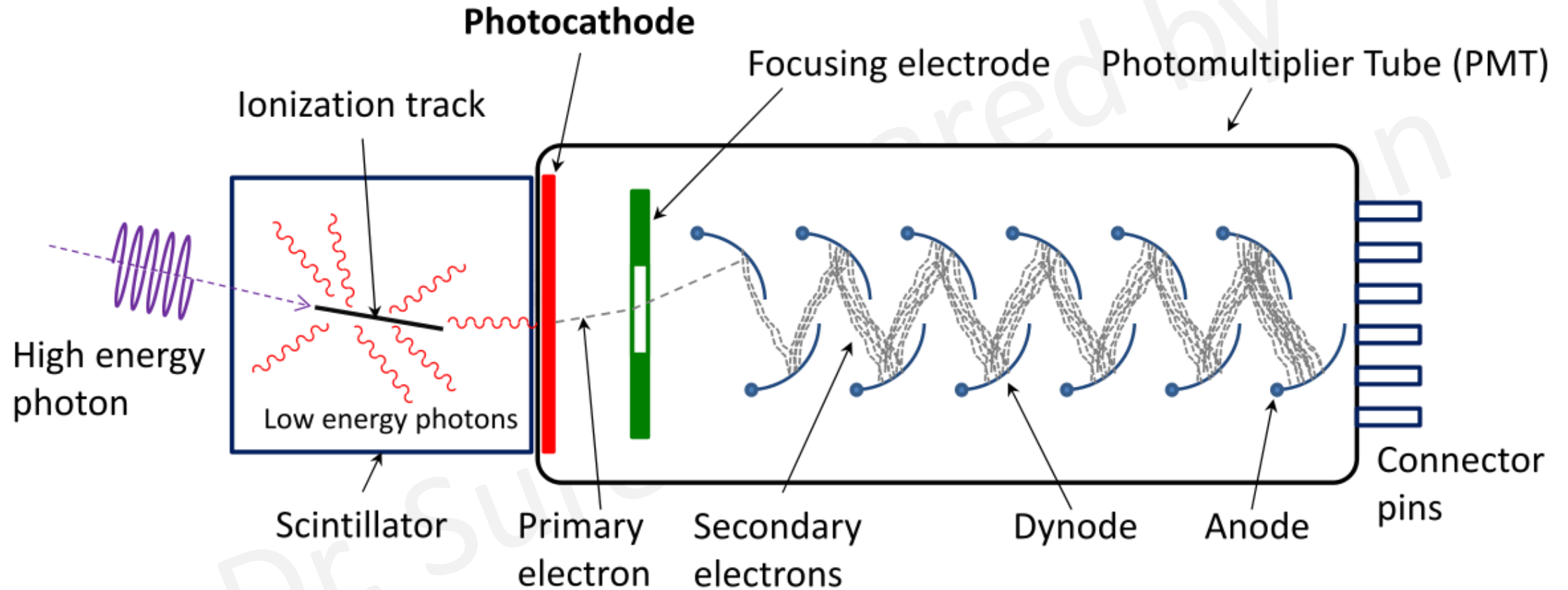


Common Scintillators Used

State	Examples	Application
Solid	ZnS	α particles
	Anthracene ($C_{14}H_{10}$), Stilbene ($C_{14}H_{12}$)	β particles
	NaI, CsI	γ radiation, X-rays
Liquid	Butyl PBD*, Naphthalene, p-Terphenyl (solvent: toluene)	β particles
Gas	Xenon	γ radiation

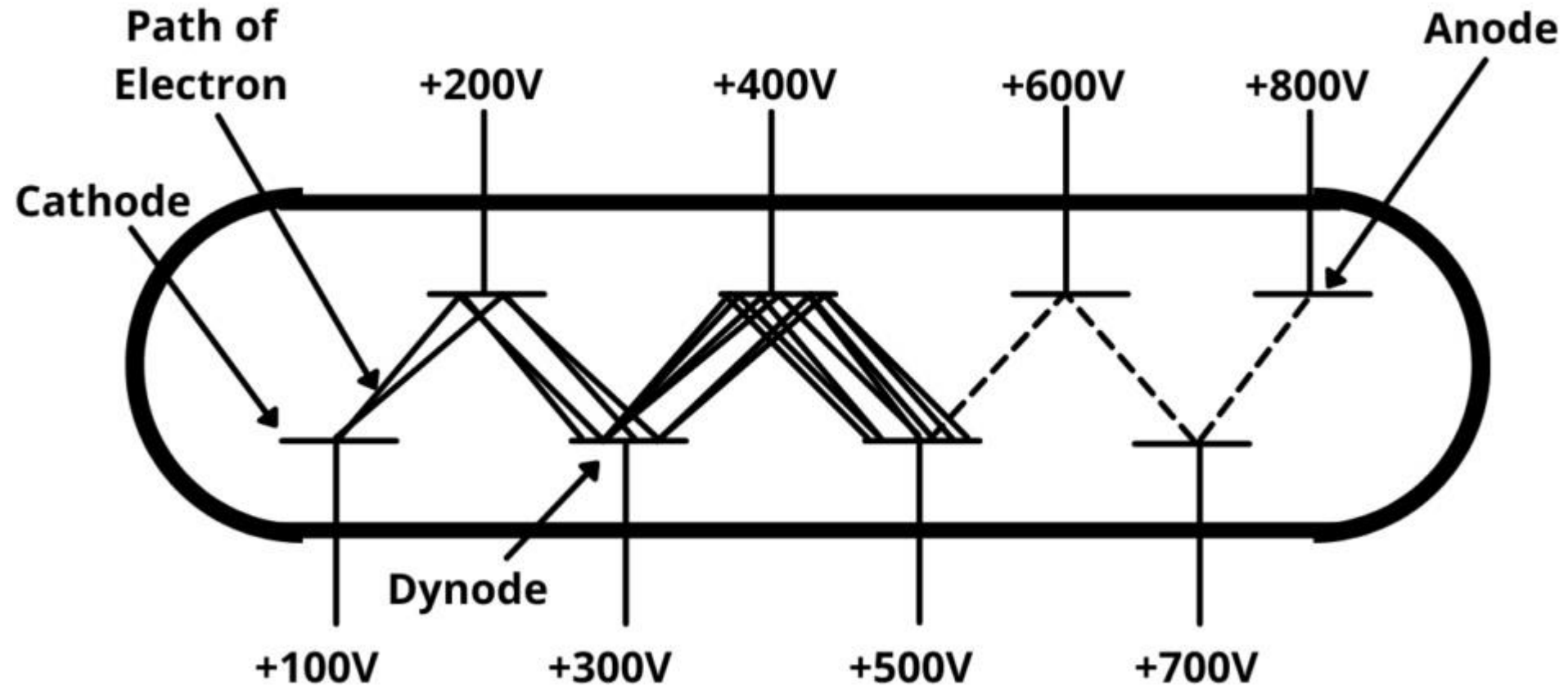
*2-[4-biphenyl]-5-[4-tert-butylphenyl]-1,3,4-oxadiazole

Scintillators Tube



Photocathode: bialkali e.g. CsKSb

Photomultiplier Tube - Electrodes



Dynode: Beryllium copper oxide

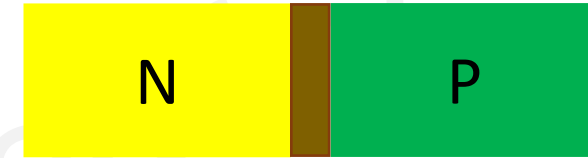


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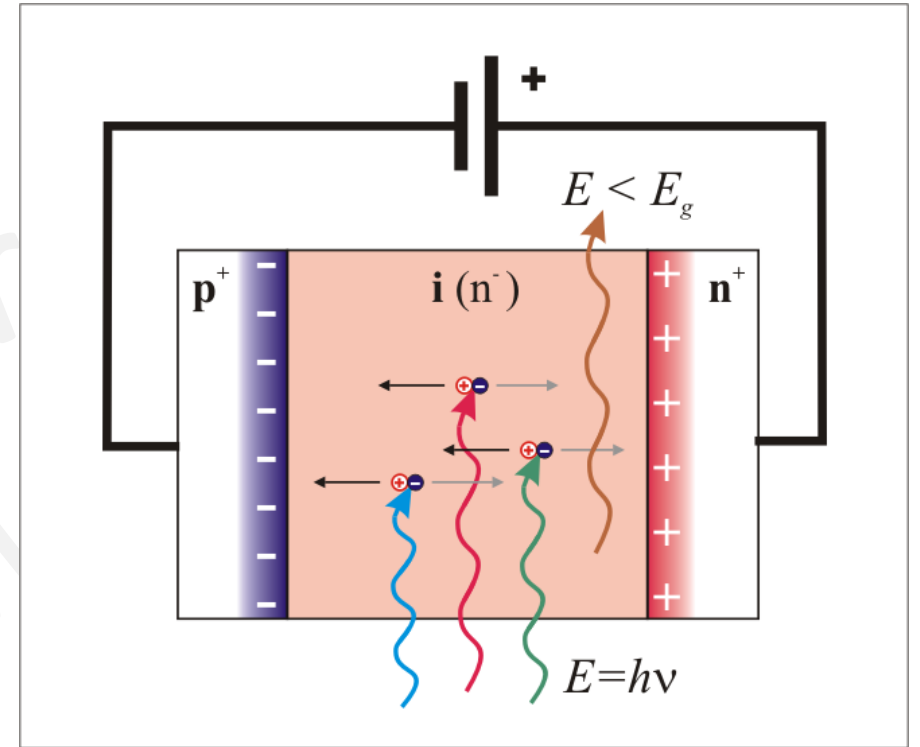
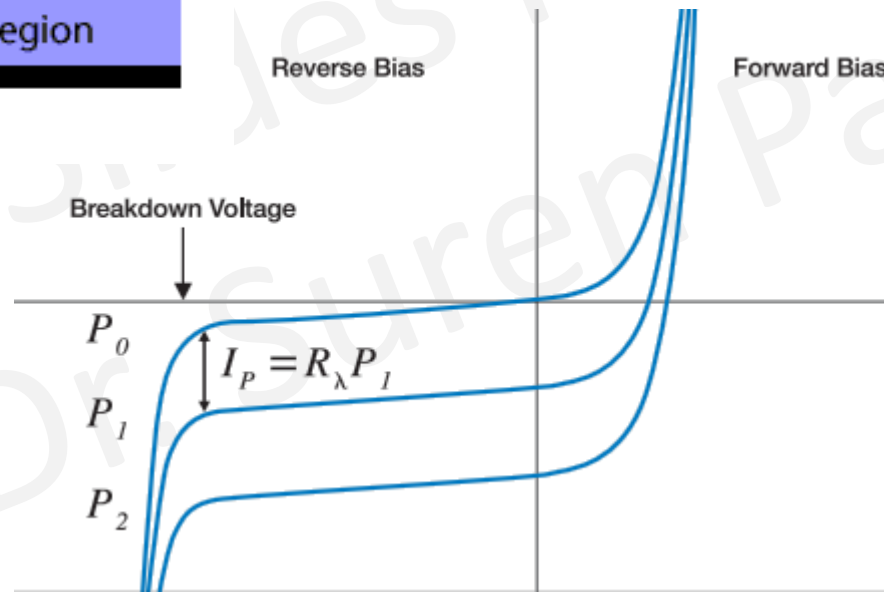
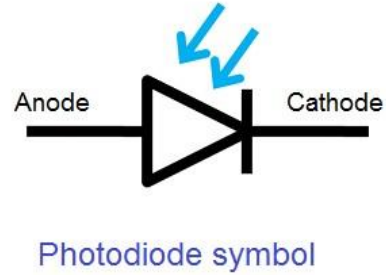
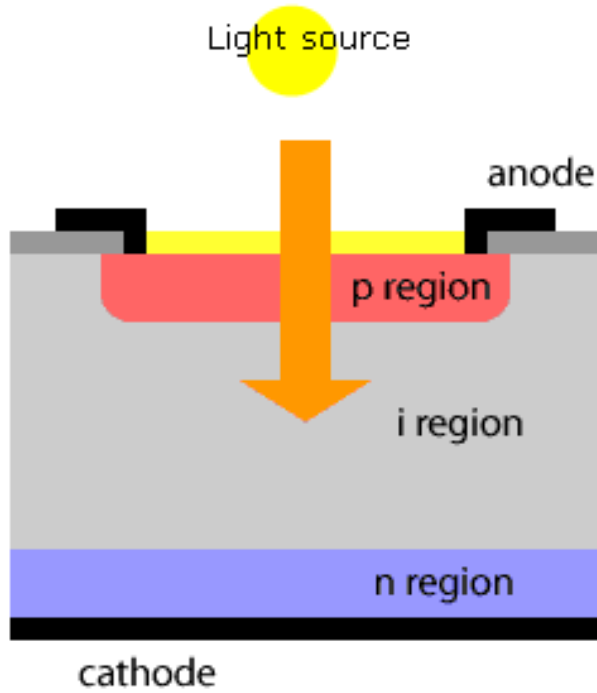
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Photodiodes

- Used for:
 - UV, visible and IR radiation
- Basic components:
 - P-N junction diode
 - Biasing and amplifier circuits
- Working principles:
 - Zero bias (photovoltaic mode)
 - Solar cell
 - Reverse bias (photoconductive mode)
 - PN Photodiode
 - PIN Photodiode
 - Avalanche Photodiode
 - Schottky Photodiode



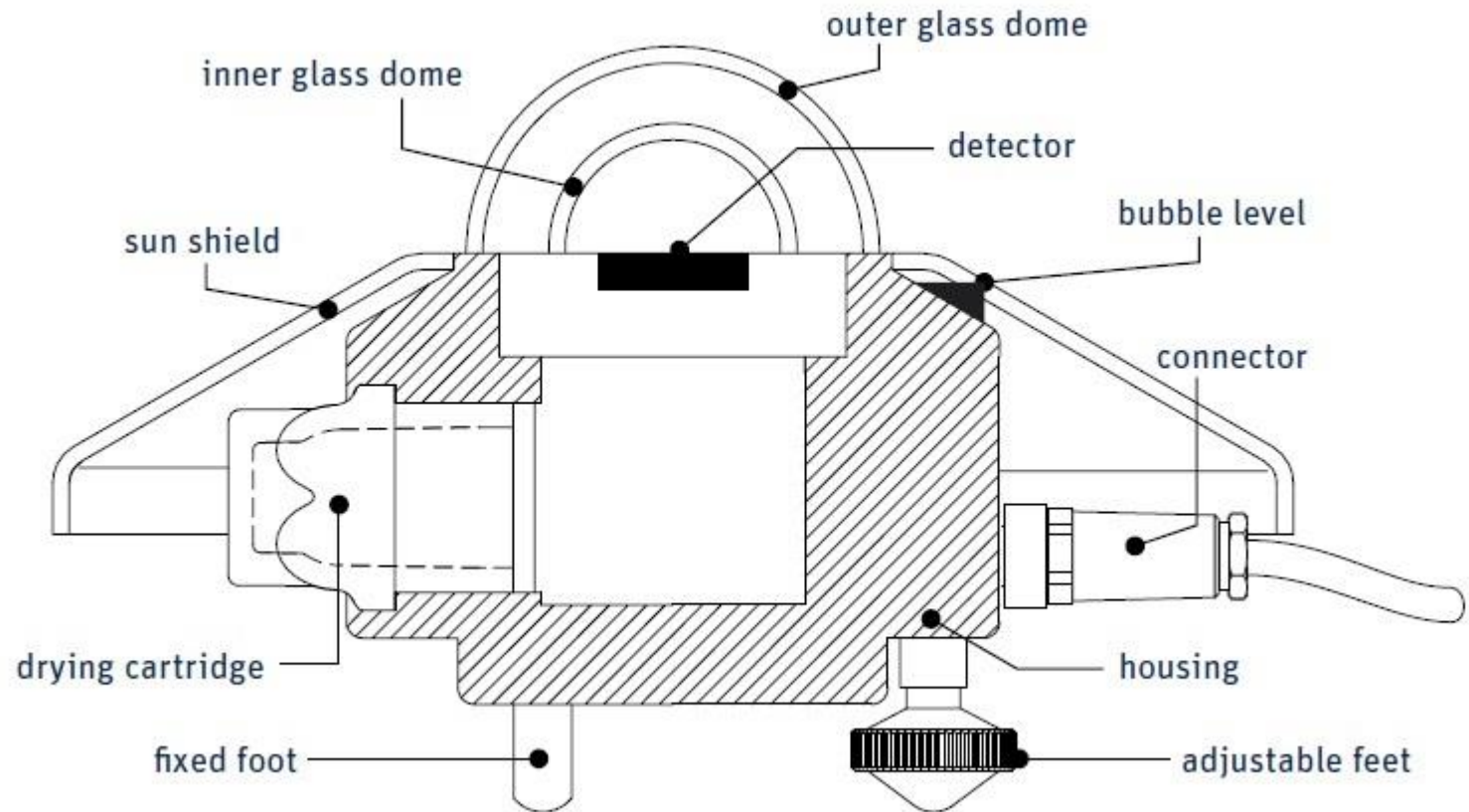
P-I-N Photodiodes



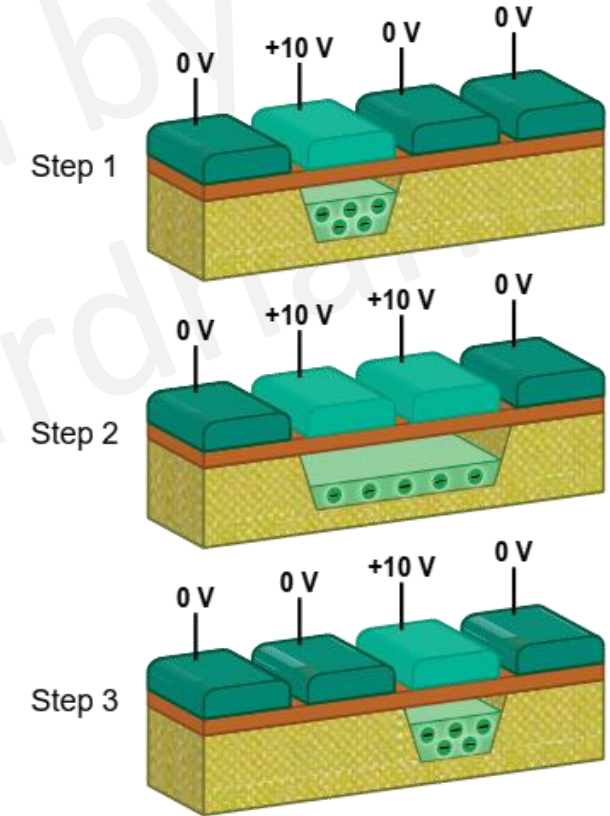
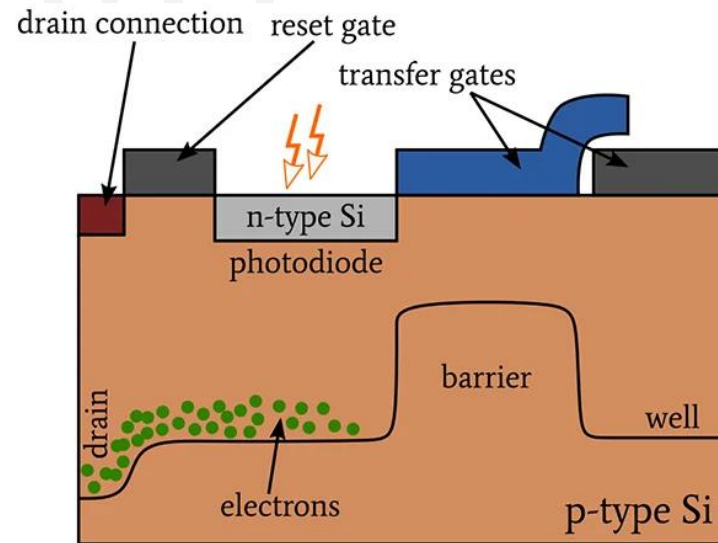
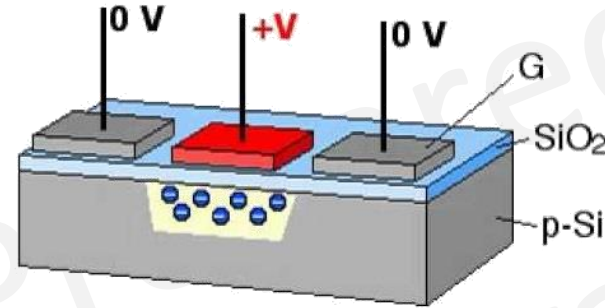
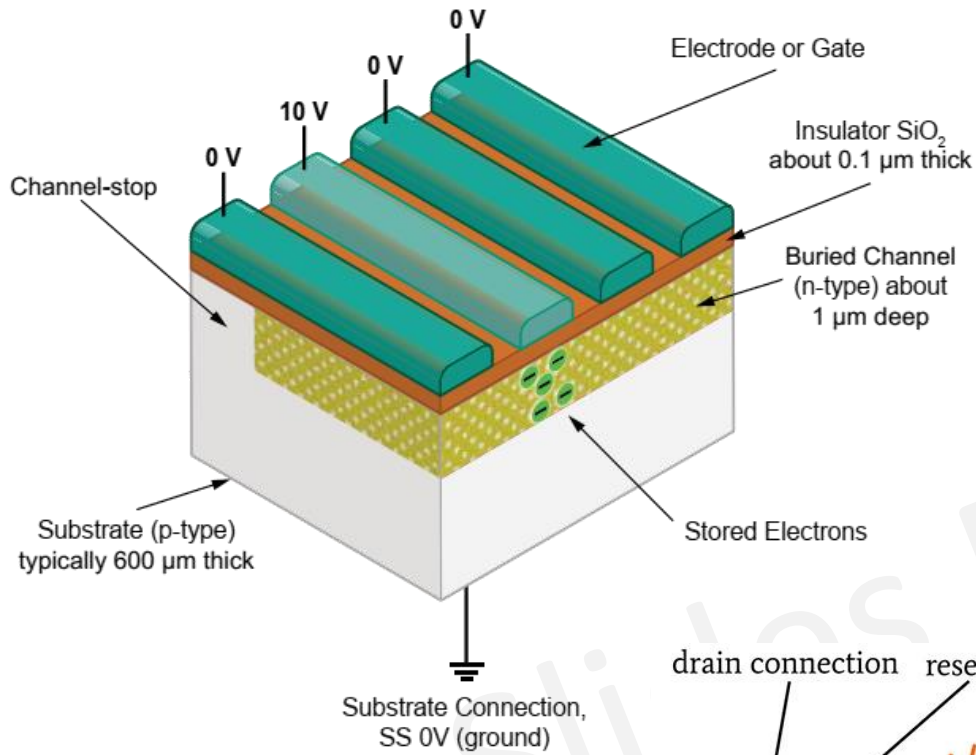
$$I_{\text{total}} = I_0 \left(e^{qV_A/nkT} - 1 \right) - I_{\text{photo}}$$

Pyranometer

- Used for:
 - Solar radiation
- Basic components:
 - Thermopile
 - Environmental shield
 - electronics
- Working principles:
 - Thermo-emf
 - Cr-Al



CCD



Reference: Teledyne Imaging



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CCD Readout Sequence

