Photo-emissive Detectors

Photo-emissive Detectors

- Photo-emission: absorption of a photon by a material causes ejection of an electron
- Capture of photo-electrons can be used to measure light
- Magnetic/electric field accelerates e- to an amplifier
- Photon stream detected as electric current at amplifier output
- Underlying physics is the photoelectric effect

Photoelectric effect

- Light can make metals emit electrons
- Not all photons can do it – need minimum energy
- But higher-energy light does not produce more electrons
- Instead, they produce faster electrons

$$E_{photon} = h\nu$$

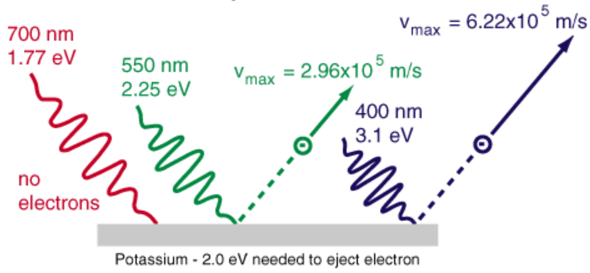
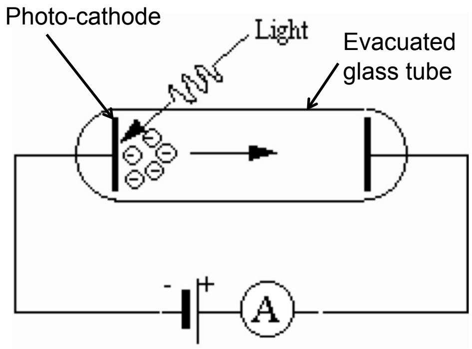
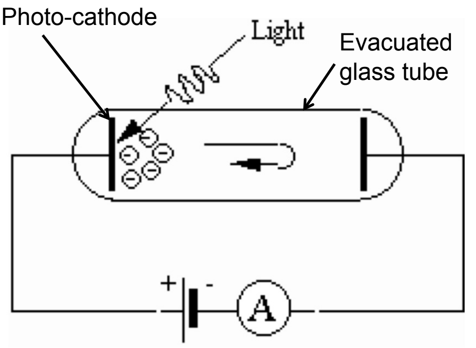


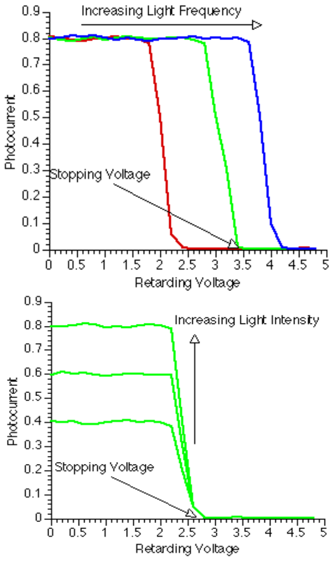
Photo-cell



- Current measured by Ammeter (photo-current) is proportional to intensity of incident light
- No matter how feeble the intensity of light the photo-current starts immediately
- Below a certain frequency of light the photo-current is zero regardless of intensity

Reverse Polarity Photo-cell





- Electric field does work (eV) on electrons in direction opposite to direction of travel
- As retarding voltage increases sufficient work is done to reduce photo-current to zero
- Stopping voltage depends on frequency of light and NOT on intensity of light

Measuring ϕ and h

- e- energy = photon energy – work done to remove e- from photo-cathode
- Maximum e- energy = photon energy – minimum work done to remove e-
- $m_e v_{max}^2/2 = hv - \phi$
- ϕ is called the work function of the metal from which the photo-cathode is made
- Maximum e- energy is measured by measuring the stopping potential
- $eV_{stop} = hv - \phi$
- Measure V_{stop} as a function of light frequency to measure h and ϕ

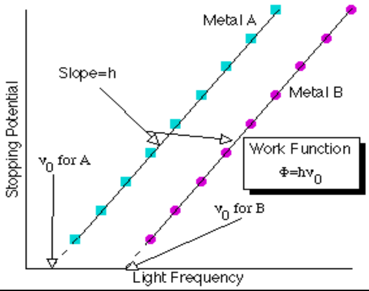
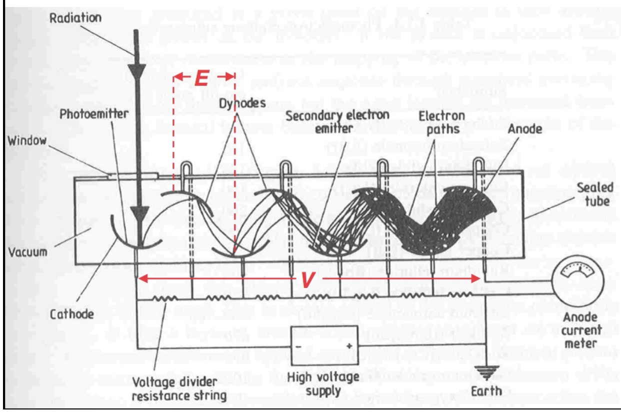


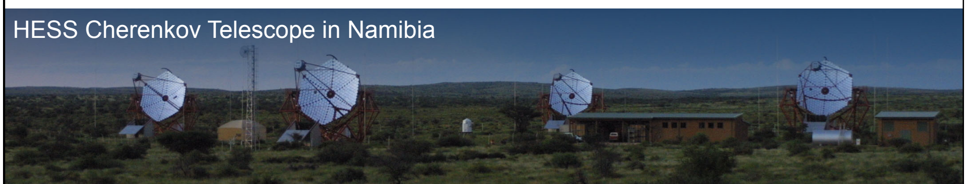
Photo-multiplier Tubes (PMTs)

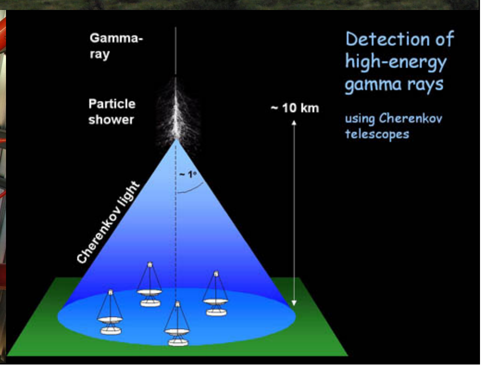
- PMTs amplify the signal measured from low levels of incident light using n electrodes at increasing +ve voltage
- Primary electrons are photo-emitted; emission of secondary electrons caused by collisions
- Gain at each electrode = g



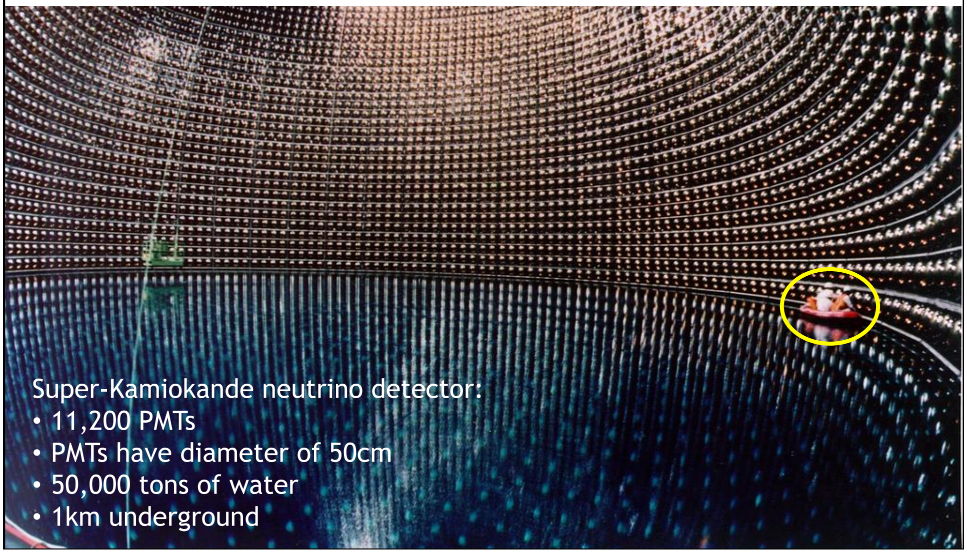
- $g = 3 - 5$; $n = 10 - 12$, typically
- Total gain of tube $G = g^n$
- $G = 10^5$ to 10^8
- $g \propto E^{\alpha}$, where $\alpha = 0.7 - 0.8$ (E is the dynode Δvoltage)
- Total cathode-anode voltage V
  - $\Rightarrow E = V / (n+1)$
  - $\Rightarrow g \propto V^{\alpha}$
  - $\Rightarrow G \propto V^{\alpha n}$
- $\alpha n = 7 - 10$
  - $\Rightarrow$ gain highly dependent on V
  - $\Rightarrow$ need to have very stable V
- V typically 10kV

PMTs and TeV gamma-rays





PMTs and Neutrinos



PMT Performance

- Advantages:
  - Unrivalled sensitivity at room temperature
  - Good linearity
  - Better quantum efficiency than photography
- Disadvantages:
  - Moderate quantum efficiency (10-40%)
  - Limited multiplexing capability for astronomy