Radiation Protection & Radiation Therapy

For Medical Students

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بسم الله الرحمن الرحيم

Radiation Units

- **Activity**
- Number disintegrations per second (Curie, Becquerel)

- **Exposure**
- (Roentgen, C/kg)

- **Absorbed dose**
- Energy deposited in any medium by any type of ionising radiation (rad, Gray)

- **Dose equivalent**
- Dose allowing for type of radiation and biological damage (rem, Sievert)

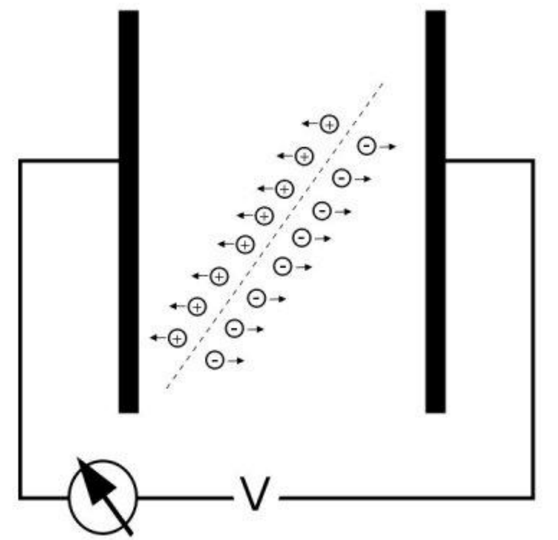


Table 1. Measurement of Radiation

QUANTITY	METRIC (SI)	CONVENTIONAL	CONVERSION	COMMENT
Exposure	Coulomb per kilogram (C/kg)	Roentgen (R)	1 R = 2.58 × 10^{-4} C/kg	Directly measured
Absorbed dose	Gray (Gy)	Radiation absorbed dose (rad)	10 mGy = 1 rad	Deterministic effects
Effective dose	Sievert (Sv)	Roentgen equivalent man (rem)	1 Sv = 100 rem	Stochastic effects

Old/US Units

- Rad — 100 Rads = 1 Gray
- Rem — 100 Rem = 1 Sievert
- Ci (dps) — 1 Curie = 3.7×10^{10} Bq

1 mCi = 3.7×10^{7}

(to avoid confusion, steer clear of CGS units if possible)

Equivalent Dose

- Equivalent dose (H_T) is the absorbed dose in tissue or organ T weighted for the type and quality of radiation R.
- $H_T = QF \times D$
- $H_{T,R} = W_R D_{T,R}$
- Where $D_{T,R}$ is the absorbed dose averaged over organ
- or tissue T, due to radiation R
- W_R is the radiation weighting factor

Unit of equivalent dose

The SI unit: sievert (Sv)

$$H_T\ (\text{Sv}) = \text{QF or } W_R \times D\ (\text{Gy})$$

Traditional (old) unit:

rem (roentgen equivalent man)

$$H_T\ (\text{rem}) = \text{QF or } W_R \times D\ (\text{rad})$$

1 Sv = 100 rem

Radiation weighting factors (W_R)

Radiation type and energy range		W_R
Photons (X-rays and gamma-rays) all energies		1
Electrons, all energies		1
Neutrons		
	<10 keV	5
	10-100 keV	10
	>100 kev to 2 MeV	20
	2-20 MeV	10
	>20 MeV	5
Protons	>20MeV	5
Alpha-particles, fission fragments		20

Equivalent Dose
(Recent Revisions)

Radiation Type	Weighting Factor (ICRP 103, 2007)
Beta, Gamma, X-ray	1
Alpha	20
Neutrons	Between 2.5 & 20

Conversion between units

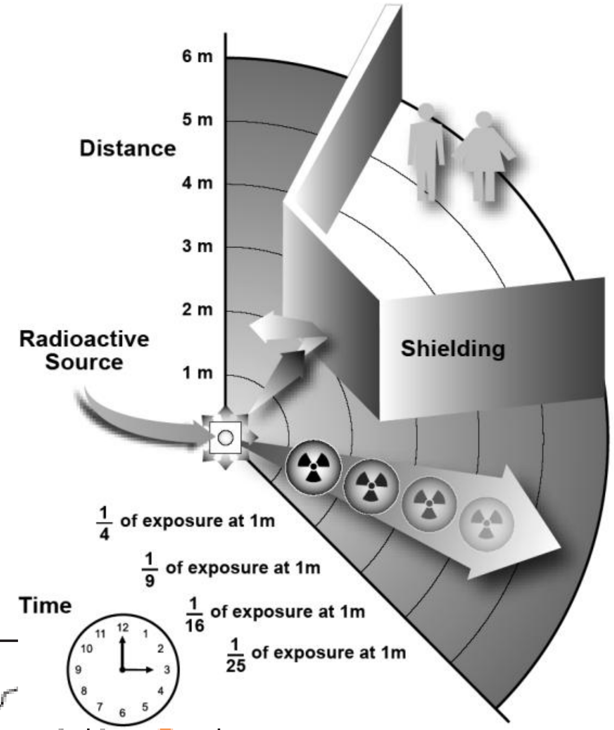
	SI unit	Old unit	Relationship
Activity	Becquerel	Curie (Ci)	1 Ci = 3.7×10^{10} Bq
Exposure	Coulomb/kg	Roentgen (R)	1 C/kg = 3876R
Absorbed dose	Gray (J/kg)	rad	1 Gy = 100 rad
Equivalent dose	Sievert	rem	1 Sv = 100 rem 1 rem = 10mSv
Effective dose	Sievert	rem	1 Sv = 100 rem 1 rem = 10mSv

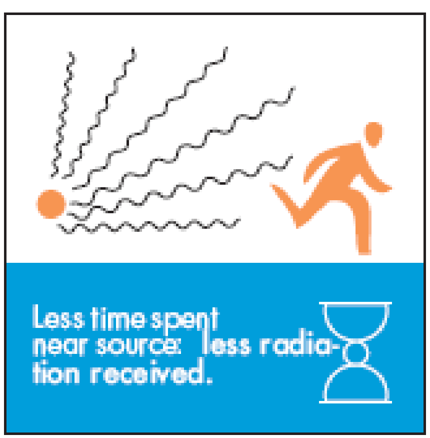
CARDINAL PRINCIPLES OF RADIATION PROTECTION

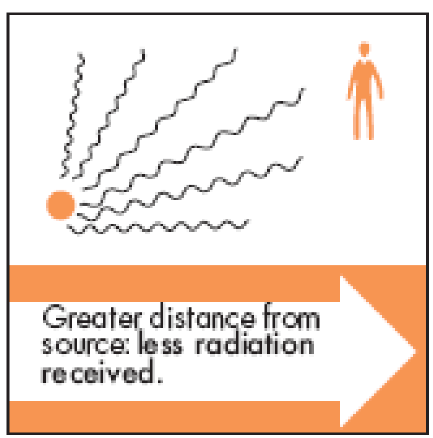
Time

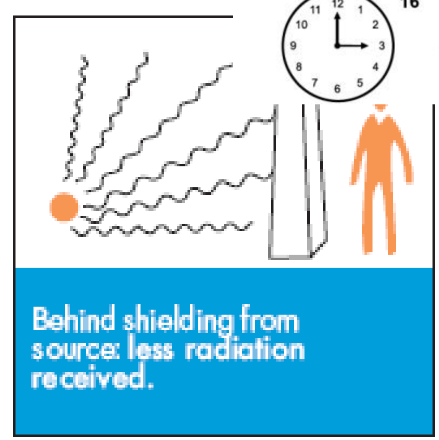
Distance

Shield







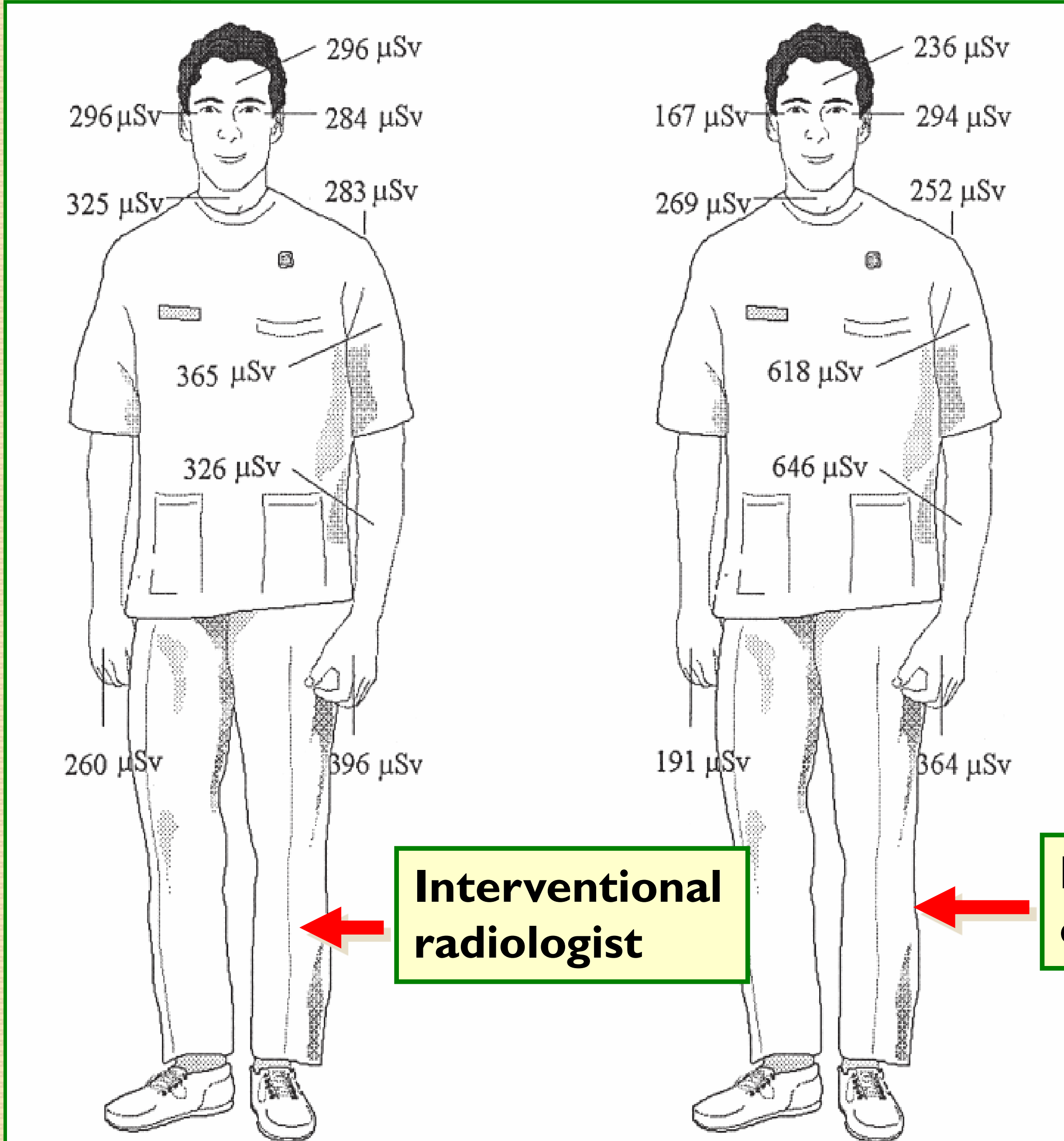


Factors Affecting Patient Dose

- There are many factors that determine the level of radiation received by the patient during a radiographic examination. These include:
  - The selection of the x-ray machine
  - The use of technique factors that result in low patient exposure
  - The use of fast films and screen/film combinations
  - Adherence to correct film processing methods
  - The use of digital sensors
  - The use of collimators and filtration
  - The use of lead aprons and thyroid collars to protect the patient from
  - Limiting unnecessary radiation exposure

Annual limits of radiation exposure

Occupational workers	20 mSv
General Public	1 mSv
Medical Exposures	No Limit



(a) (b)

Vañó et al.
Br J Radiol
1998; 71:954-960

Health Effects of Radiation

Non-stochastic Effects

Stochastic Effects

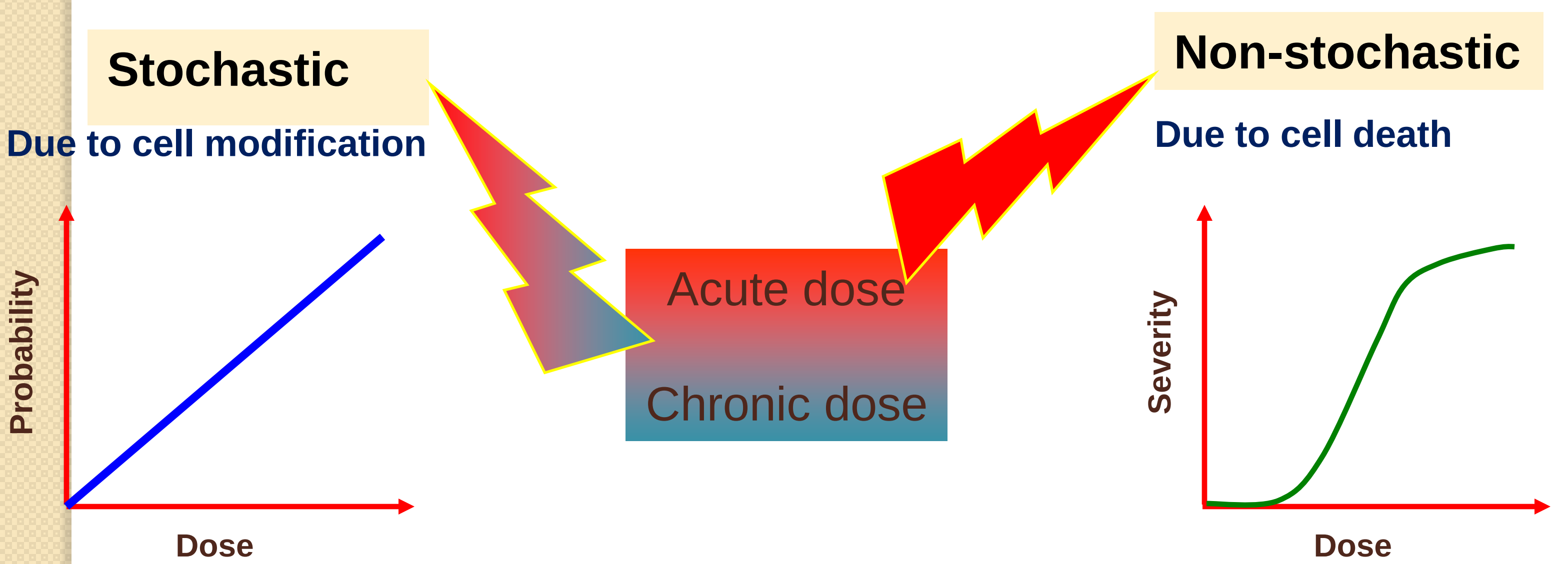
(Also Known as Probabilistic Effects)

If damage occurs in:

the **somatic cells** the effects are restricted only to the exposed individual (Somatic effects)

the **germ cells** the effects are manifested in the future generations (Genetic effects)

Generally radiation effects are classified into



There are two kinds of radiation monitors used for medical purposes:

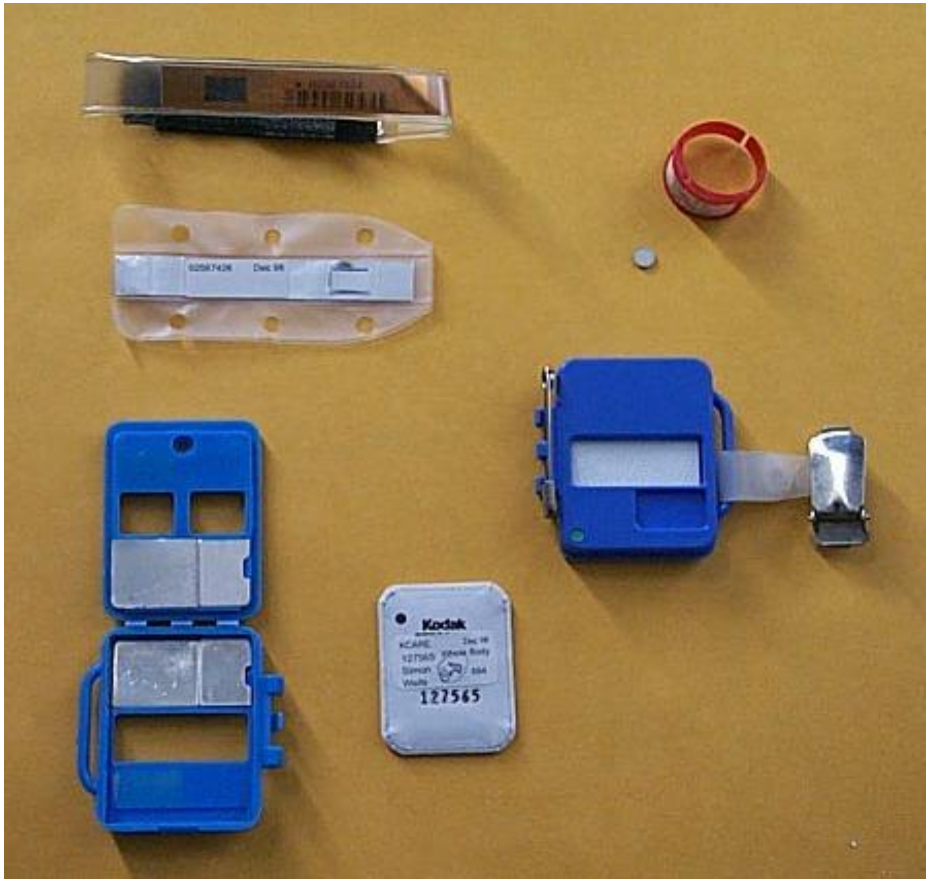
- Survey monitors
- Personal monitors

Personnel Monitoring

Film Badges

Personnel Monitoring

Film and TLD



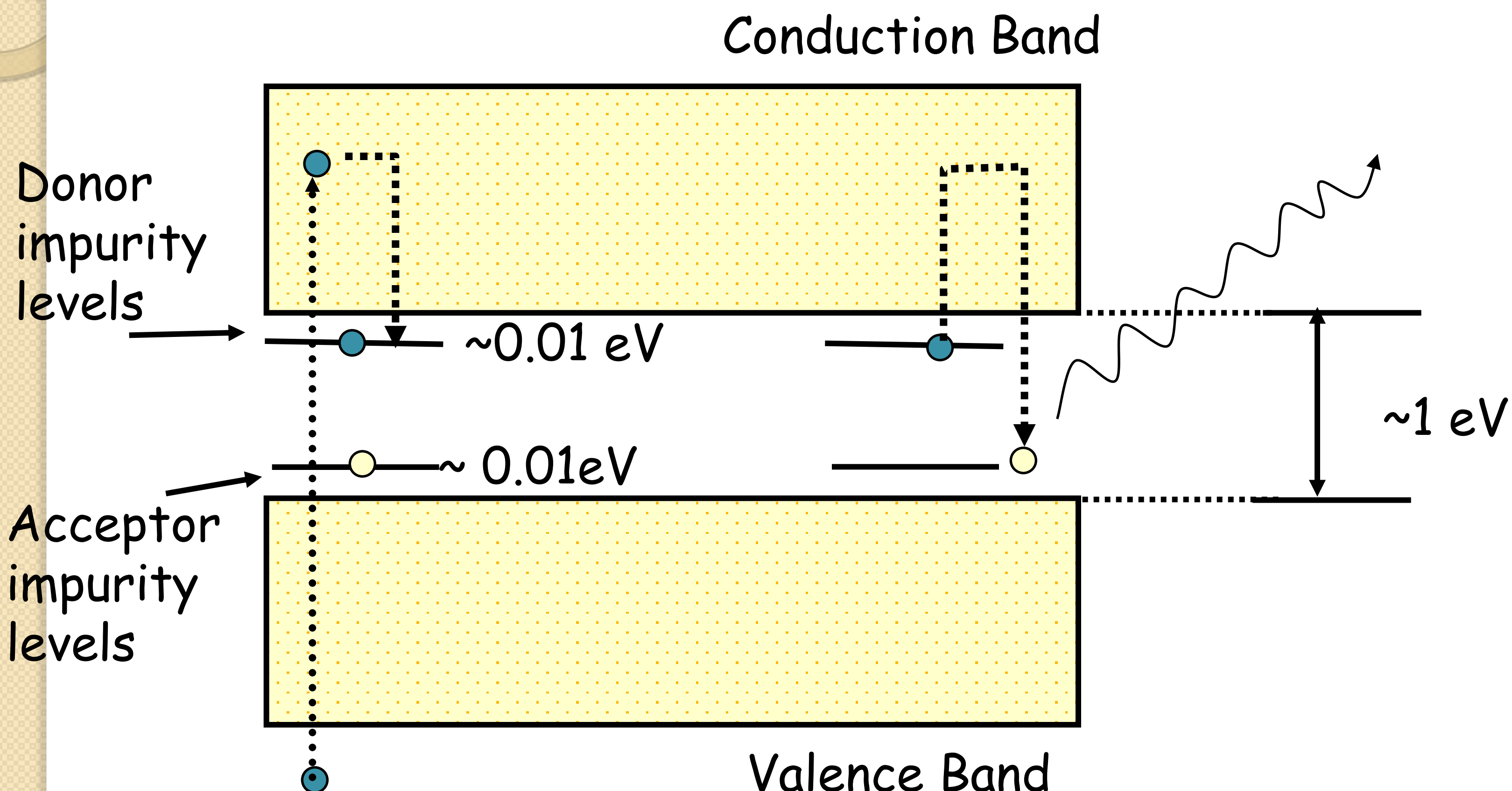
Personnel Monitoring

TLD

Whole body

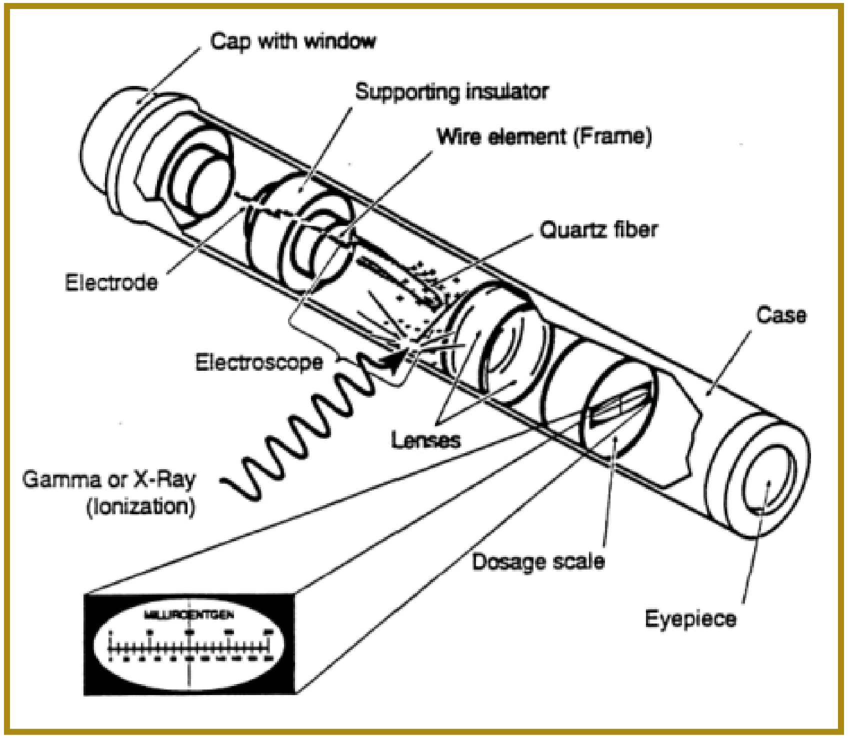
Extremity

Introduction of Impurities



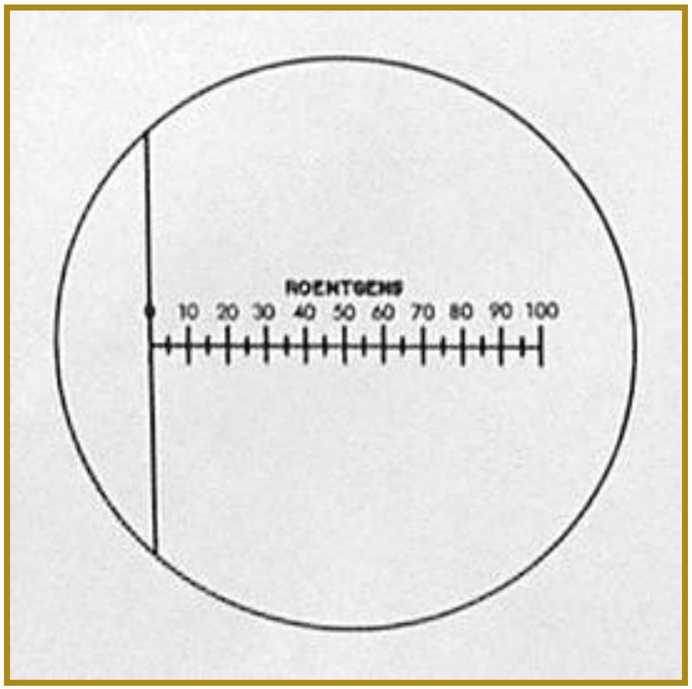
Pocket dosimeter

The pocket dosimeter or pen dosimeter is a common small sized ion chamber which measures the originated charge by direct collection on a quartz fiber electroscope.

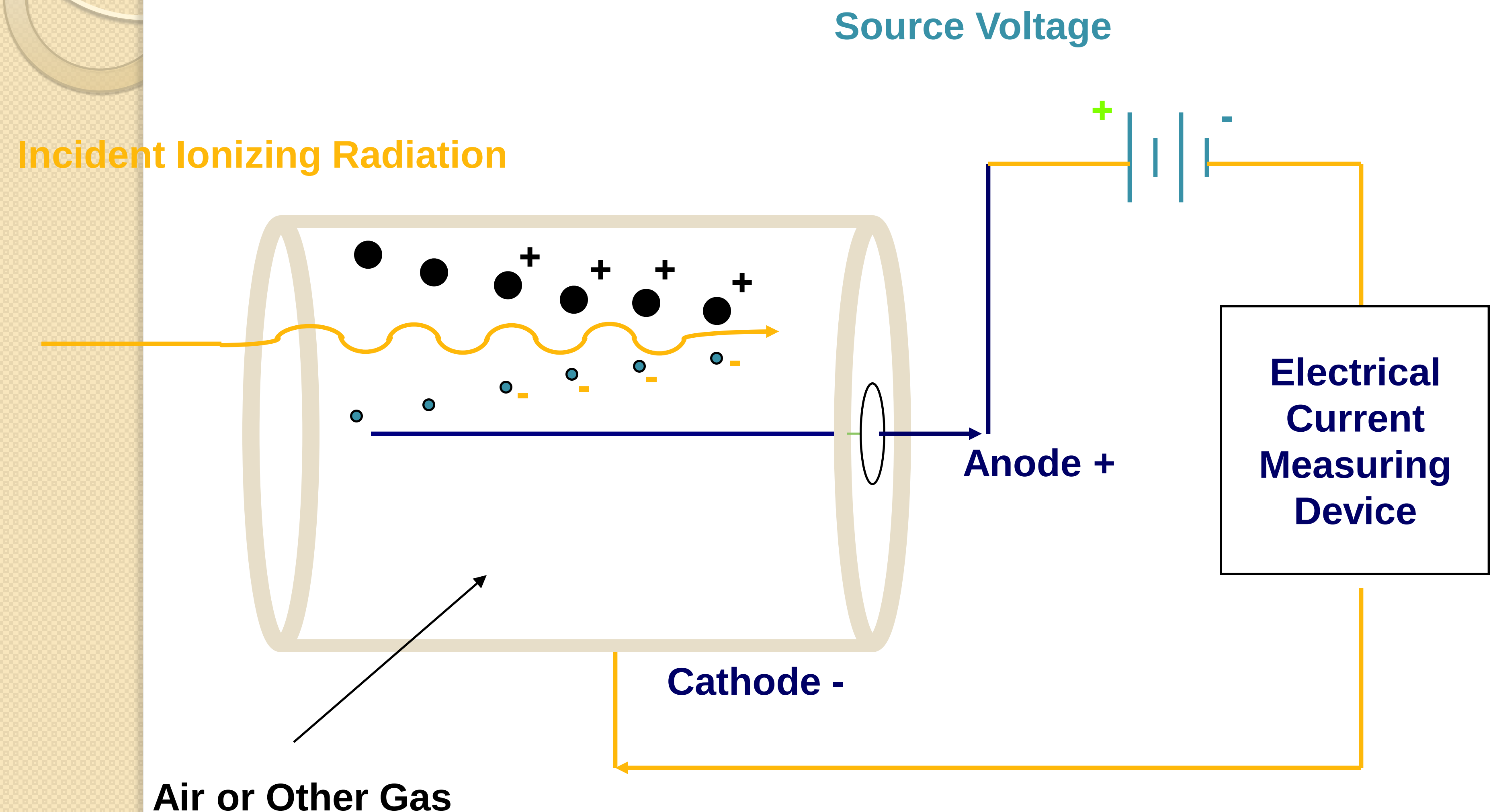


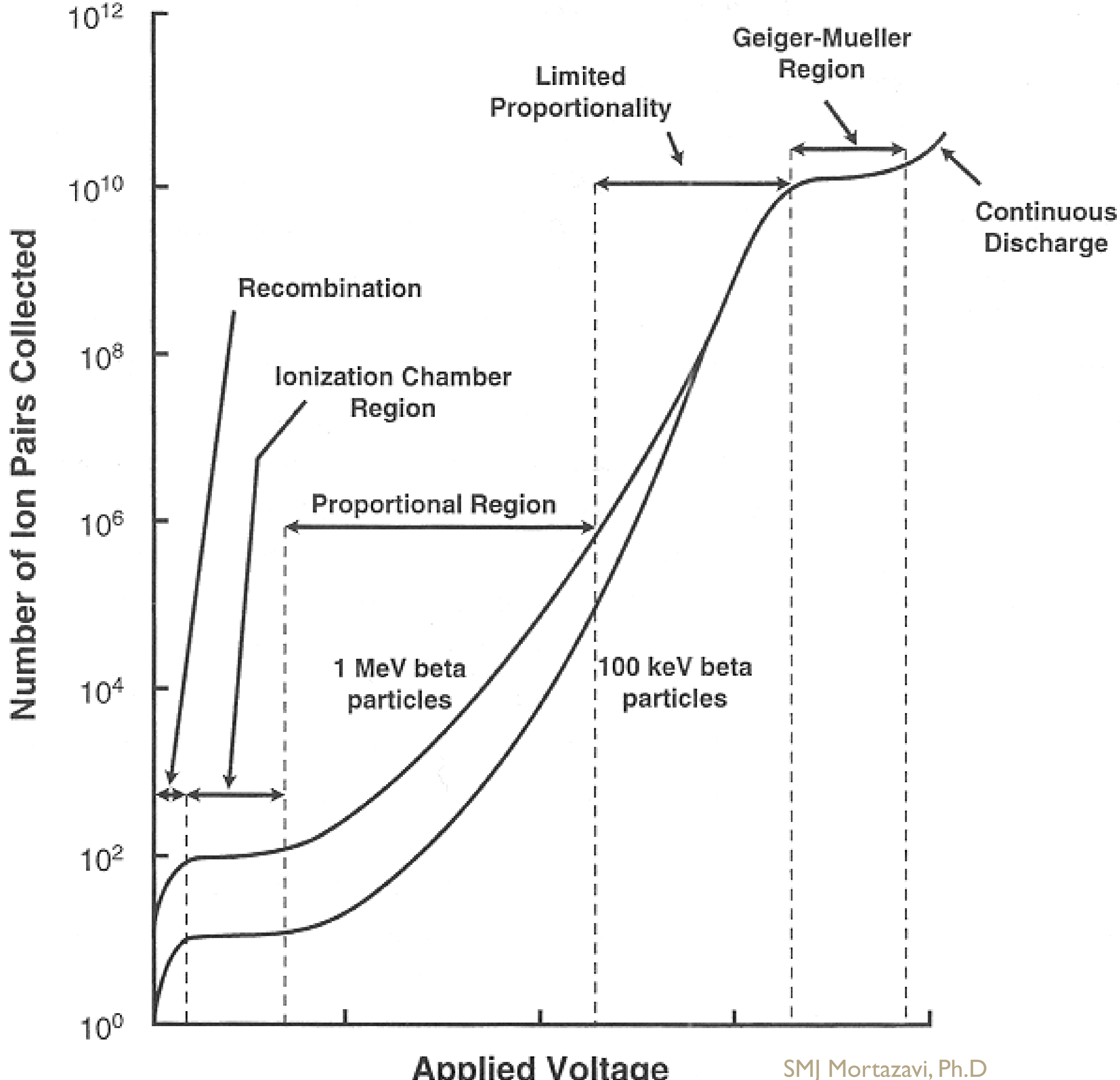
The U-shaped fiber is close to a U-shaped wire. If the fiber is charged it will be deflected away from the wire. The position of deflection is a measure of the accumulated radiation dose.

Dosimeters, which are also available in high or low ranges, can be in the form of a badge, pen/tube type, or even a digital readout and all **measure exposure** or the total accumulated amount of radiation to which you were exposed. (The Civil Defense pen/tube tube would show a reading like below when looking through it.) It's also similar to the odometer of a car; where both measure an accumulation of units. The dosimeter will indicate a certain total number of R or mR exposure received, just as the car odometer will register a certain number of miles traveled.



Radiation Detection
Gas Filled Detectors





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Ionization chambers

- If gas is air and walls of chamber are of a material whose effective atomic number is similar to air, the amount of current produced is proportional to the exposure rate
- Air-filled ion chambers are used in portable survey meters, for performing QA testing of diagnostic and therapeutic x-ray machines, and are the detectors in most x-ray machine phototimers
- Low intrinsic efficiencies because of low densities of gases and low atomic numbers of most gases

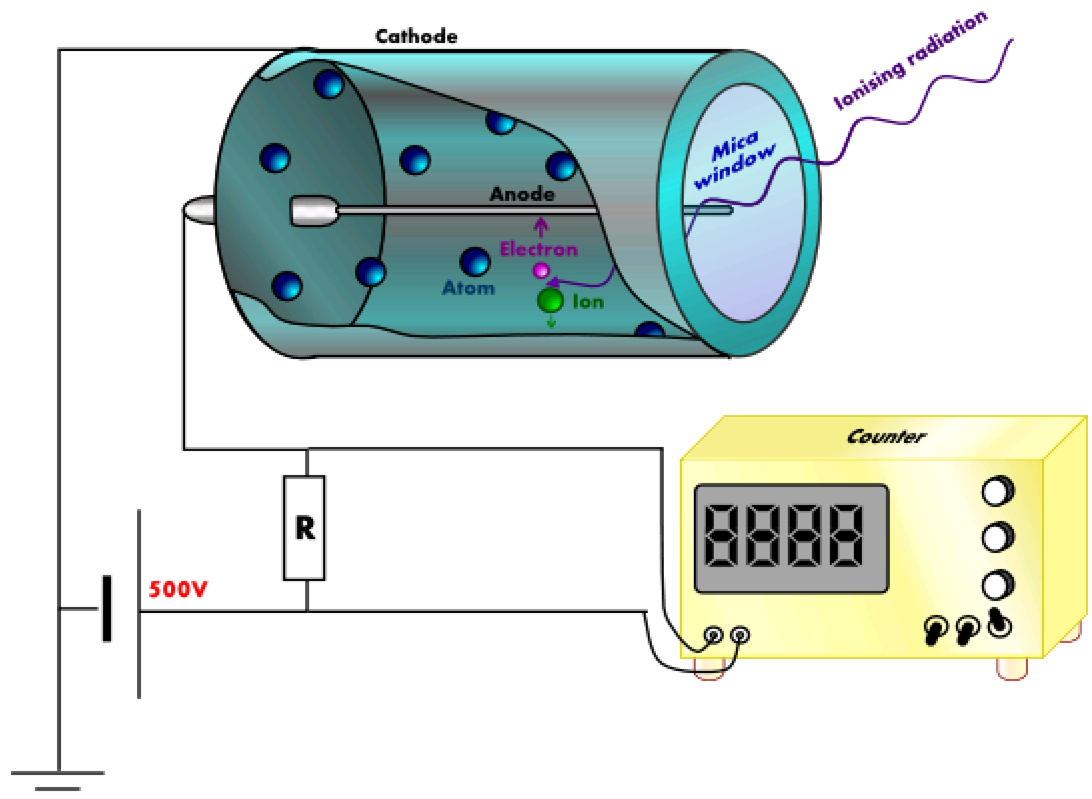
Monitoring Instrument

Ionization Chamber

Proportional counters

- Must contain a gas with specific properties
- Commonly used in standards laboratories, health physics laboratories, and for physics research
- Seldom used in medical centers

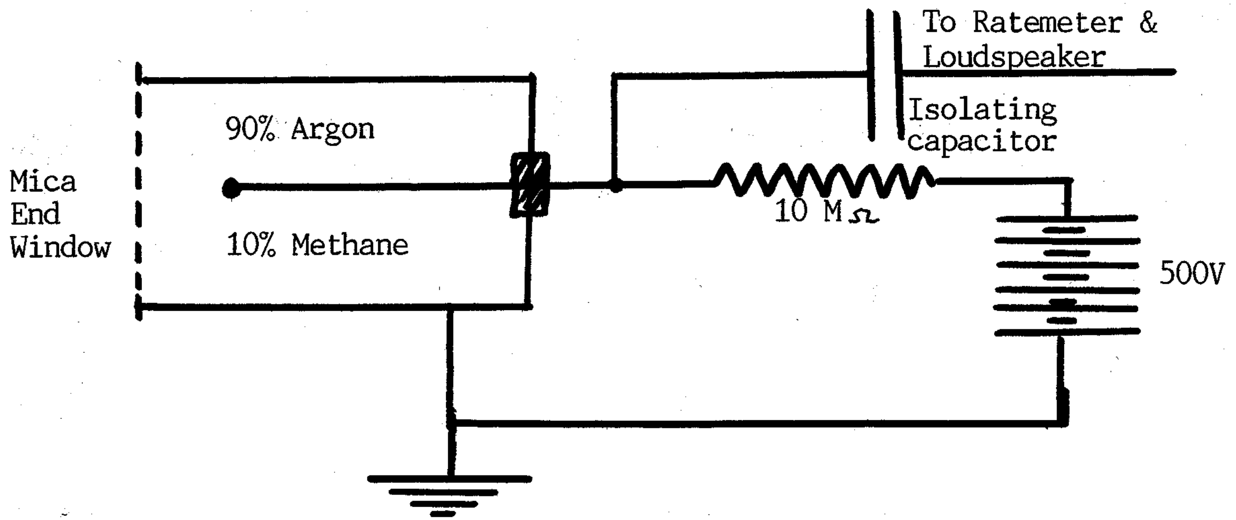
Geiger-Müller tube

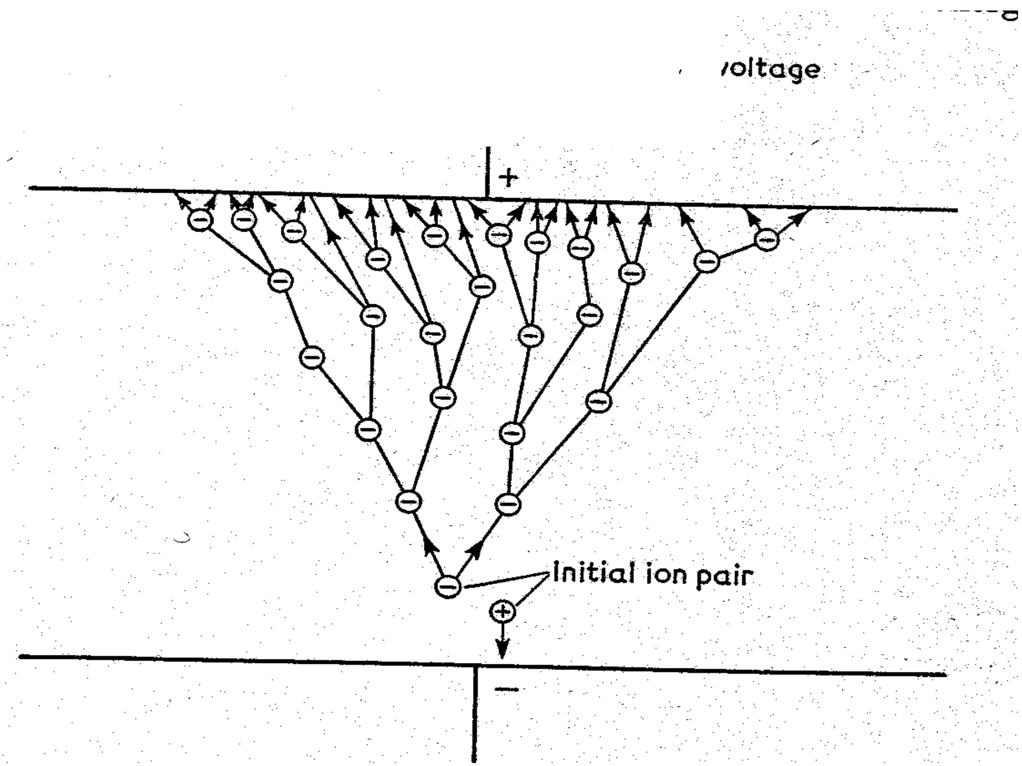


GM counters

- GM counters also must contain gases with specific properties
- Gas amplification produces billions of ion pairs after an interaction – signal from detector requires little amplification
- Often used for inexpensive survey meters
- In general, GM survey meters are inefficient detectors of x-rays and gamma rays
- Over-response to low energy x-rays – partially corrected by placing a thin layer of higher atomic number material around the detector

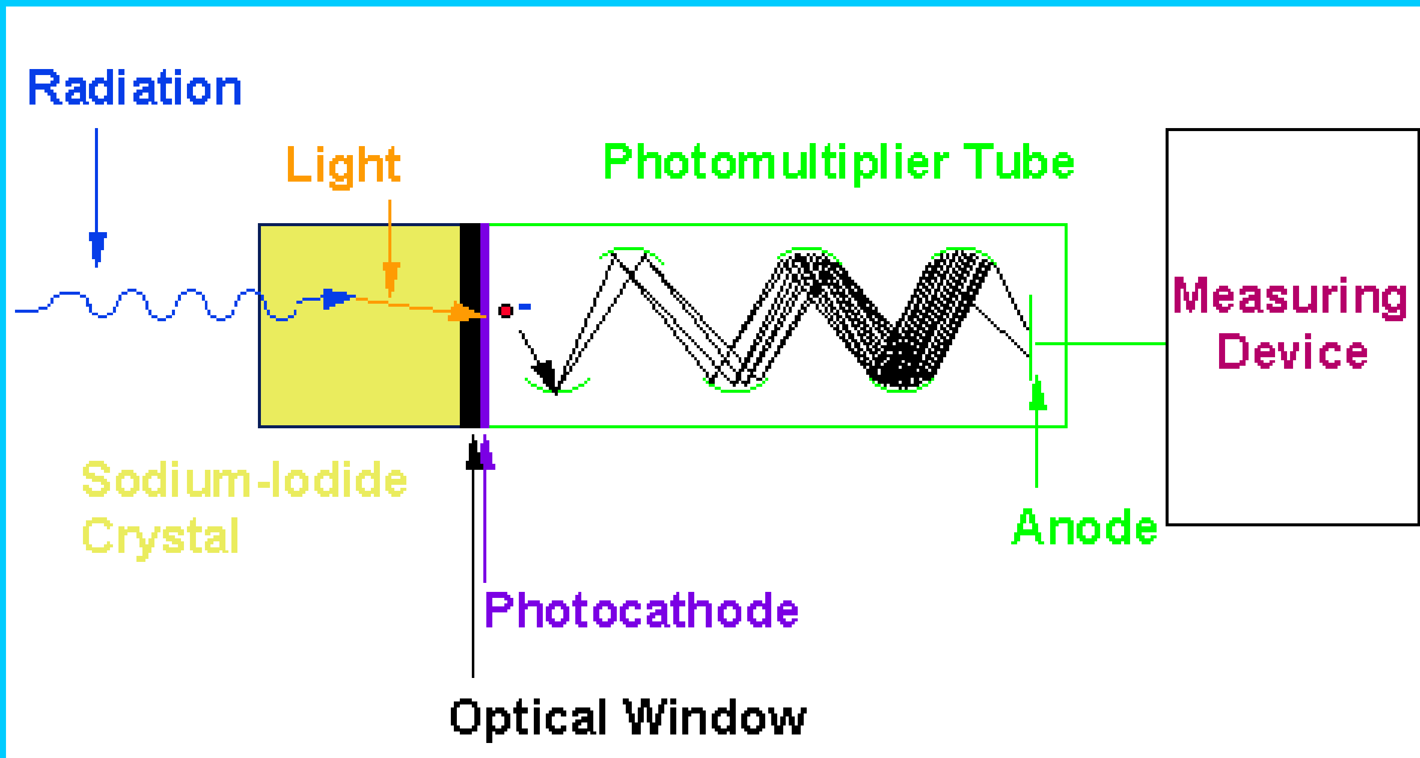
The Geiger-Muller Tube



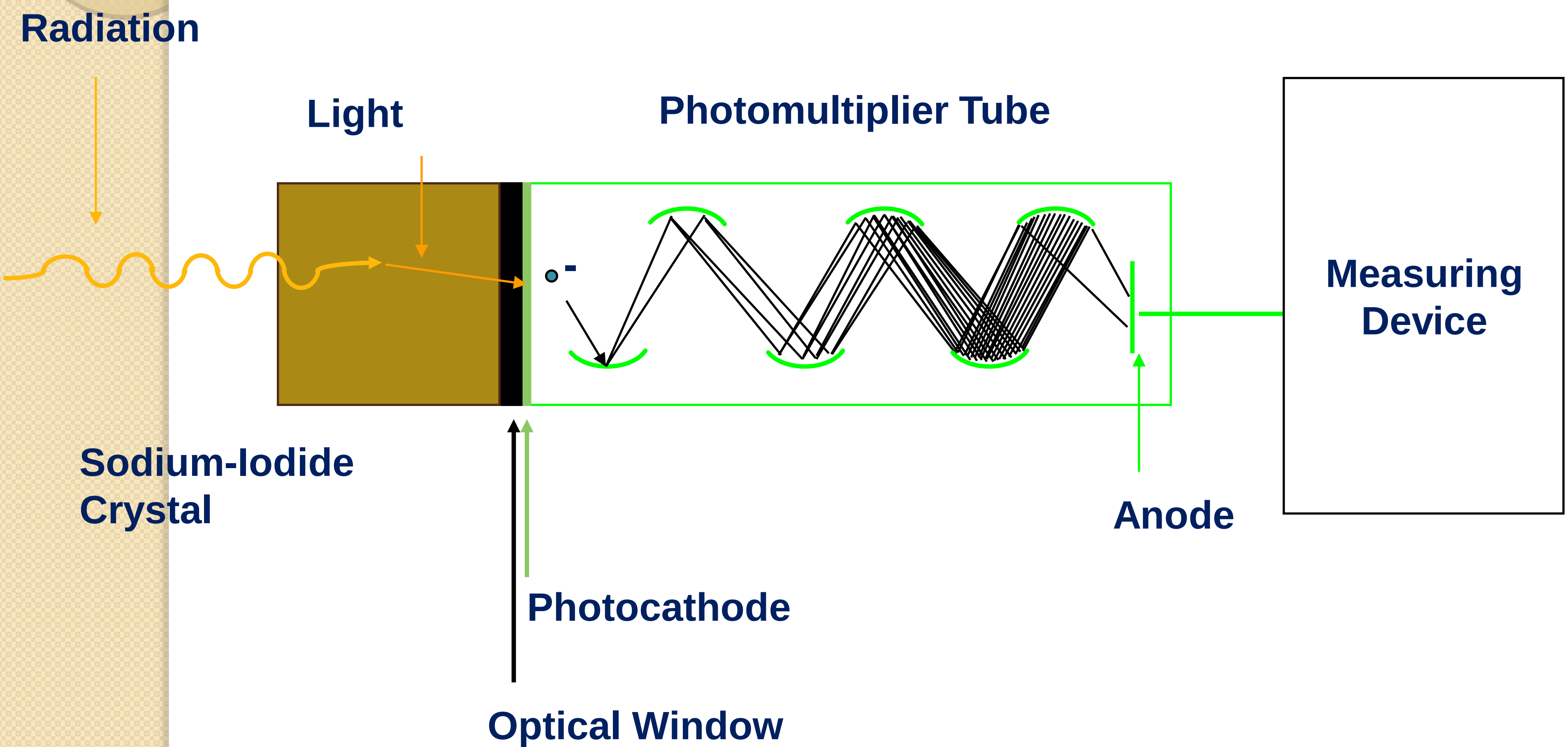



CPM
1K
2K
3K
Bat. test
ON
OFF
AUDIO
RES
HV
LUDLUM
MEASUREMENTS,
SWEETWATER,
MODEL
SURVEY

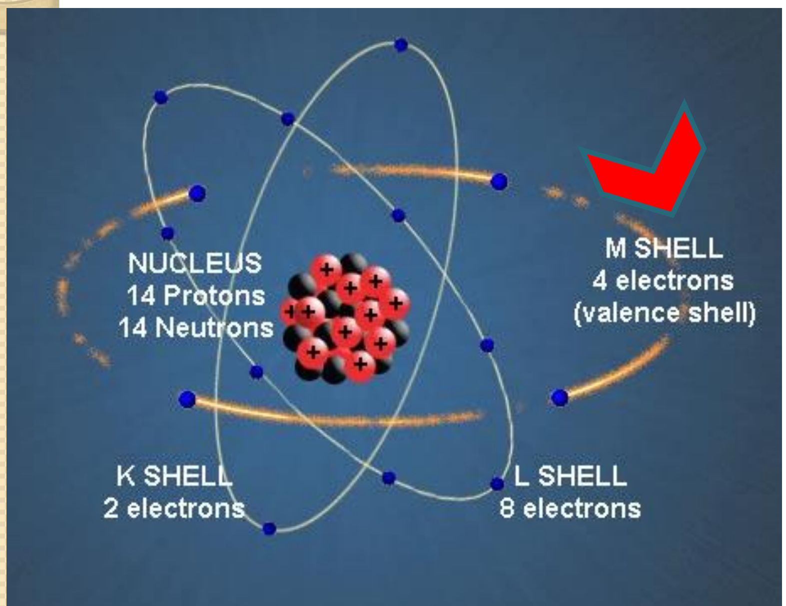
Radiation Detection
Scintillation Detectors

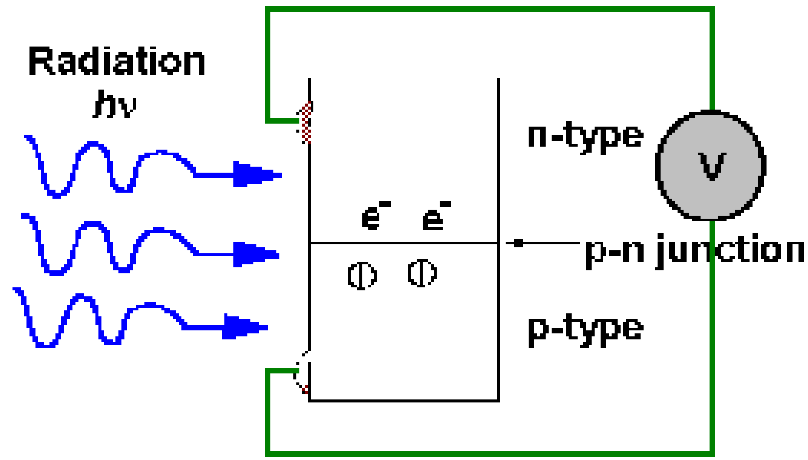


Radiation Detection
Scintillation Detectors



Semiconductor Detector





Schematic of Semiconductor Detector

Well Detector

Scintillation Counter for Wipe & Tube Samples. This configuration is recommended for nuclear medicine.

Radiation is not the only cause of abortion, congenital anomalies and cancer!

It is "Innocent until proven guilty"

Table 2. Background Incidence of Conceptus Complications without Diagnostic Imaging Radiation

RISKS	INCIDENCE
Spontaneous incidence of major malformations	Approximately 1% to 3%
Intrauterine growth restriction	4%
Spontaneous abortion	At least 15%
Genetic disease	8% to 10%
Mental retardation (intelligence quotient less than 70)	Approximately 3%
Severe mental retardation (unable to care for self)	0.5%
Heritable effects	1% to 6%
Spontaneous risk of childhood leukemia and cancer (ages 0 to 15)	0.16%
Children developing cancer up to age 15 (United Kingdom)	0.15%
Children developing leukemia only to age 15 (United Kingdom)	0.03%
Lifetime risk of contracting cancer	33%
Lifetime risk of contracting fatal cancer	20%

Sources: ACOG Committee on Obstetric Practice. ACOG Committee Opinion. Number 299, September 2004 (replaces No. 158, September 1995). Guidelines for diagnostic imaging during pregnancy. *Obstet Gynecol* 2004 Sep;104(3):647-51; Brent RL. The effects of embryonic and fetal exposure to x-ray, microwaves, and ultrasound. In: Brent RL, Beckman DA, editors. *Clinics of perinatology, teratology.* Vol 13. Philadelphia (PA): Saunders;1986:613-48; Coakley F, Gould R. Guidelines for the use of CT and MRI during pregnancy and lactation. Chapter 5. In: UCSF imaging of retained surgical objects in the abdomen and pelvis section handbook [online]. University of California, San Francisco Department of Radiology. 2005 [cited 2007 Jun 6]. Available from Internet: http://www.radiology.ucsf.edu/instruction/abdominal/ab_handbook/05-CT_MRI_preg.html; Harding LK, Thomson WH. Radiation and pregnancy. *Q J Nucl Med* 2000 Dec;44(4):317-24; International Commission on Radiological Protection. Radiation and your patient: a guide for medical practitioners. *Ann IRCP* 2001;31(4):5-31; International Commission on Radiological Protection (ICRP). *Biological effects after prenatal irradiation (embryo and fetus).* ICRP Publication No. 90. Kidlington, Oxford (United Kingdom): Elsevier; 2003; International Commission on Radiological Protection (ICRP). *Pregnancy and medical radiation.* ICRP Publication No. 84. Kidlington, Oxford (United Kingdom): Elsevier; 2000; Ratnapalan S, Bona N, Chandra K, et al. Physician's perceptions of teratogenic risk associated with radiography and CT during early pregnancy. *AJR Am J Roentgenol* 2004 May;182(5):1107-9; Ratnapalan S, Bona N, Koren G. Ionizing radiation during pregnancy. *Can Fam Physician* 2003 Jul;49:873-4; Sharp C, Shrimpton JA, Bury RF. Diagnostic medical exposures: advice on exposure to ionizing radiation during pregnancy [online]. Chilton, Didcot, Oxon (UK): National Radiological Protection Board. 1998 [cited 2007 Jul 19]. Available from Internet: http://www.e-radiography.net/regsetc/nrpb_asp8/Diagnostic Medical Exposures Advice on Exposure to Ionising Radiation during Pregnancy.htm; Timins JK. Radiation during pregnancy. *N J Med* 2001 Jun;98(6):29-33; Toppenberg KS, Hill DA, Miller DP. Safety of radiographic imaging during pregnancy. Am Fam Physician [online]. 1999 Apr 1 [cited 2008 Jan 21]. Available from Internet: http://www.aafp.org/afp/990401ap/1813.html.

For sources associated with specific values, contact the *Pennsylvania Patient Safety Advisory* staff.

Thank you for your attention!