Managing Physical Hazards

Lecture Title:
Radiation Hazards: Ionising & Non-Ionising

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Undergraduate Diploma in
Occupational Health and Safety

Welcome and Objectives

The lecture covers ionising (X-rays, gamma, particle radiation) and non-ionising radiation (UV, IR, EMF, lasers). Students learn exposure effects, ALARA principles, shielding techniques, monitoring devices, PPE, and regulatory obligations. Applications in medicine, manufacturing, welding, and communications are reviewed.

Welcome, Module Roadmap & Transition from Risk Management

Lecture 1 — Introduction to Physical Hazards & Regulatory Frameworks
Lecture 2 — Measurement & Monitoring Techniques for Physical Hazards
Lecture 3 — Noise & Vibration Hazards: Exposure, Measurement & Control
Lecture 4 — Thermal Hazards: Heat Stress, Cold Stress, and Thermal Comfort
Lecture 5 — Radiation Hazards: Ionising and Non-Ionising
Lecture 6 — Lighting, Visibility, and Workplace Ergonomics
Lecture 7 — Machinery, Mechanical Hazards & Machine Safeguarding
Lecture 8 — Workplace Environment Hazards: Slips, Trips, Falls, and Confined Spaces
Lecture 9 — Integrated Physical Hazard Management & Continuous Improvement
Lecture 10 — Physical Hazard Control Strategies: Engineering, Administrative & PPE

This module focuses on physical agents and their technical, physiological, and legal considerations

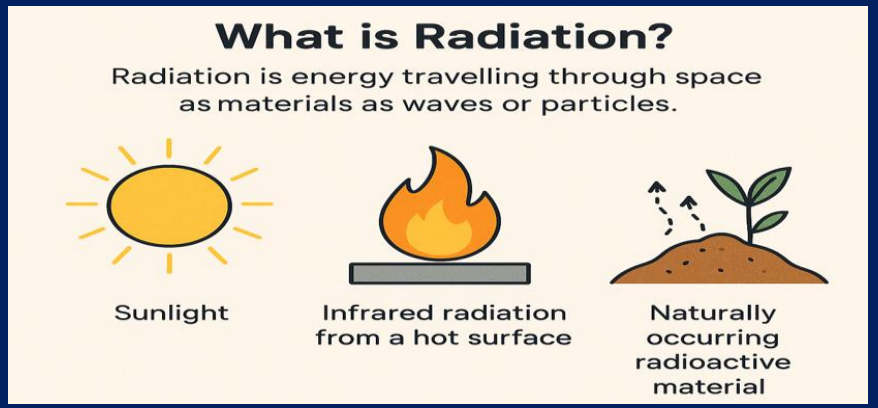
Introduction

What is Radiation?

Radiation is the emission or transmission of energy through space or a material medium, in the form of waves or particles.

- Radiation is a natural **part of our environment**:

1. Sunlight (visible light and UV)
2. Heat (infrared radiation)
3. Naturally occurring radioactive materials in soil and rocks



Introduction

What is Radiation?

Radiation can also be man-made:

1. Medical imaging (X-rays, CT scans)
2. Industrial radiography
3. Nuclear power generation
4. Telecommunications and radar systems

Difference Between Ionising and Non-Ionising Radiation

Ionising Radiation

Ionising radiation has sufficient energy to remove electrons from atoms or molecules, creating ions.

Examples:

a) Alpha particles
b) Beta particles
c) Gamma rays
d) X-rays

Difference Between Ionising and Non-Ionising Radiation

Ionising Radiation

Key hazard mechanism:

1. Causes direct damage to cells and DNA
2. Can lead to:
   - Radiation burns
   - Acute radiation sickness (high doses)
   - Long-term effects such as cancer
3. Typical high-risk uses:

Medical imaging and radiotherapy

Nuclear power plants

Industrial radiography

Radioactive material handling and waste management

Difference Between Ionising and Non-Ionising Radiation

Non-Ionising Radiation Definition

Non-ionising radiation does not carry enough energy to ionise atoms, but can still transfer energy into tissues.

Examples:

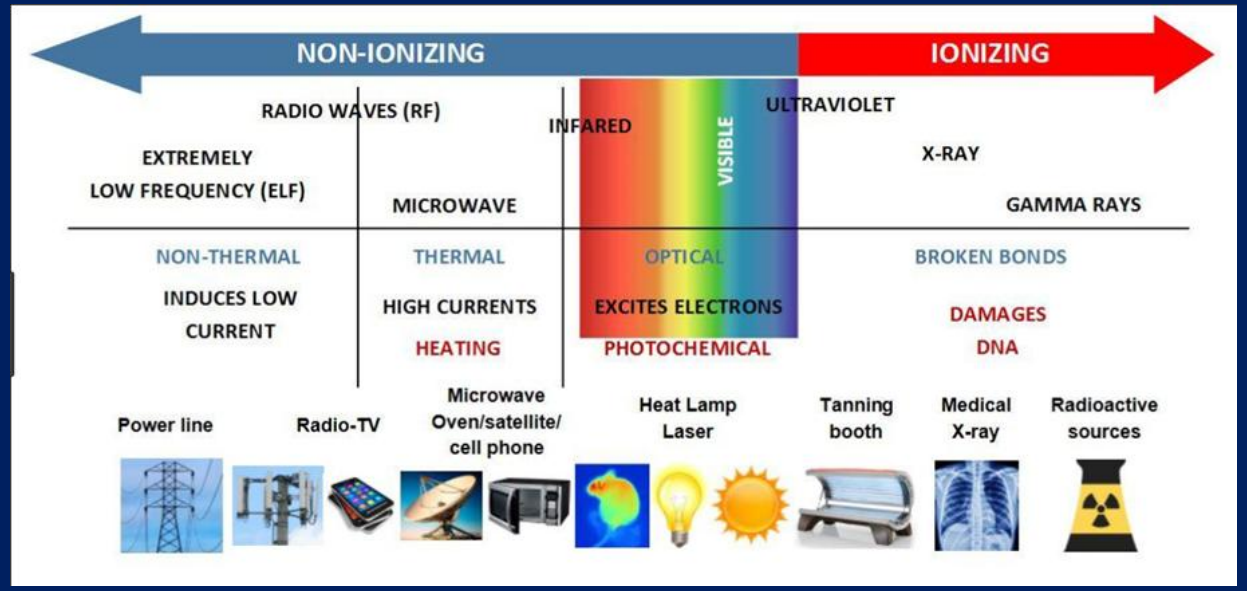
a) Radiofrequency (RF) waves
b) Microwaves
c) Infrared radiation
d) Visible light
e) Ultraviolet (UV) radiation

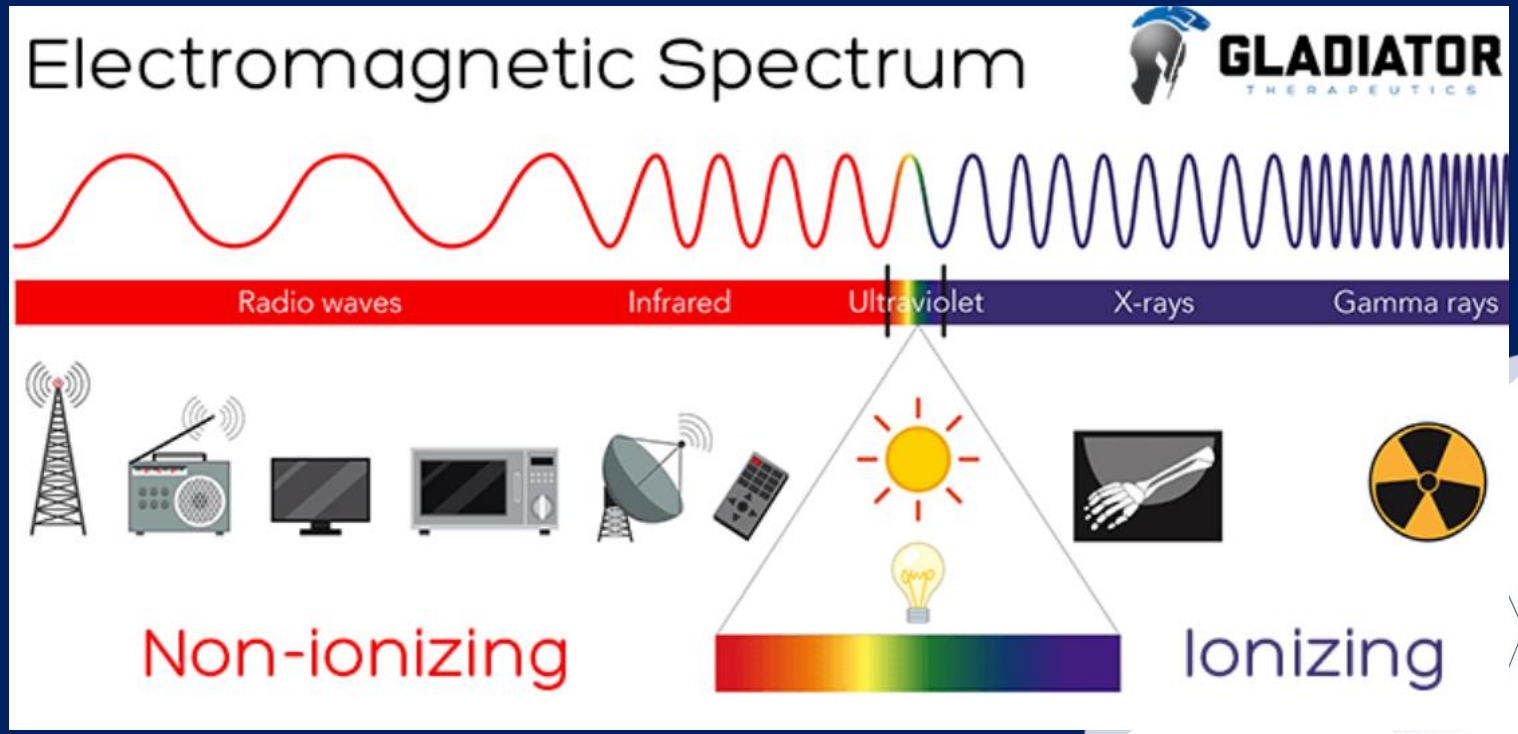
Difference Between Ionising and Non-Ionising Radiation

Non-Ionising Radiation Definition

Key hazard mechanism:

1. Primarily causes thermal effects (heating of tissues)
2. Some types (e.g. UV) can cause:
   - Skin burns
   - Eye damage
   - Increased skin cancer risk with chronic exposure
3. Typical workplace sources:
   - Telecommunications equipment
   - Radar systems
   - Lasers
   - Welding arcs
   - UV curing systems


NON-IONIZING
IONIZING
RADIO WAVES (RF)
EXTREMELY
LOW FREQUENCY (ELF)
MICROWAVE
INFARED
VISIBLE
ULTRAVIOLET
X-RAY
GAMMA RAYS
NON-THERMAL
INDUCES LOW
CURRENT
THERMAL
HIGH CURRENTS
HEATING
OPTICAL
EXCITES ELECTRONS
PHOTOCHEMICAL
BROKEN BONDS
DAMAGES
DNA
Power line
Radio-TV
Microwave
Oven/satellite/
cell phone
Heat Lamp
Laser
Tanning
booth
Medical
X-ray
Radioactive
sources


Electromagnetic Spectrum
GLADIATOR
THERAPEUTICS
Radio waves
Infrared
Ultraviolet
X-rays
Gamma rays
Non-ionizing
Ionizing

Quick comparison

Ionising vs Non-Ionising Radiation

Aspect	Ionising Radiation	Non-Ionising Radiation
Energy level	High	Low to moderate
Can ionise atoms?	Yes	No
Main health effect	DNA & cellular damage	Heat, burns, eye & skin damage
Examples	X-rays, gamma rays	RF, microwaves, UV
Typical control focus	Dose limitation & shielding	Exposure time & distance

Why Radiation Hazards Matter in High-Risk Workplaces

Radiation hazards are often invisible, odorless, and not immediately felt, making them particularly dangerous without proper controls.

Reasons radiation hazards are critical:

1. **Health effects may be delayed**

- Cancer and genetic effects can appear years after exposure
- Workers may underestimate long-term risk

2. **High-risk industries involve powerful sources**

- Energy production
- Healthcare
- Manufacturing
- Research laboratories

Why Radiation Hazards Matter in High-Risk Workplaces

Radiation hazards are often invisible, odorless, and not immediately felt, making them particularly dangerous without proper controls.

Reasons radiation hazards are critical:

3. Exposure can occur unintentionally

- Equipment failure
- Poor maintenance
- Inadequate shielding
- Unsafe working procedures

4. Regulatory and legal importance

- Strict exposure limits apply (dose limits for workers and public)
- Employers have legal duties to:
- Assess radiation risks
- Apply control measures
- Monitor **exposure**
- Train and protect workers

Radiation is a powerful tool in modern industry and healthcare, but without proper control it presents serious occupational health risks. Understanding the type of radiation involved is the foundation of effective risk management.

Measures of Ionising and Non-ionising Radiation

Non – ionizing radiation:

- Watt per square metre (W/m^2)→ Power density (RF, microwaves)
- Volts per metre (V/m)→ Electric field strength (RF / EMF)
- Amperes per metre (A/m)→ Magnetic field strength (ELF fields)

Ionising radiation is measured by activity and biological dose (Bq, Sv), while non-ionising radiation is measured by field strength, power, or energy absorption (V/m, W/m^2)

Local Context: Radiation Exposure in Malta

1. Malta has no nuclear power plants, but radiation exposure is still occupationally relevant
2. Exposure arises from healthcare, industry, services, and emerging sectors
3. Both ionising and non-ionising radiation are present in everyday workplaces

Radiation hazards in Malta are common, varied, and often underestimated.

Ionising Radiation: Where It Occurs in Malta

- Medical imaging (X-ray, CT)
- Non-Destructive Testing (NDT)I
- Industrial X-ray inspection

Example:

1. Medical Imaging → X-rays → Radiographers → cumulative exposure
2. NDT → Gamma/X-rays → Technicians → high-energy sources

Malta does have ionising radiation risk
Even without nuclear power

Non-Ionising Radiation in Malta

- Telecommunications
- Manufacturing & IR processes
- Welding Lasers in cosmetics and aesthetics

1. “Invisible” hazards
2. Often underestimated
3. Increasing prevalence

Non-ionising ≠ non-hazardous

Ionising Radiation

Introduction to Ionising Radiation

1. Radiation with sufficient energy to remove electrons from atoms
2. Results in ion formation
3. Can damage human tissue and DNA
4. Main concern in occupational health and safety
5. Sources may be natural or artificial

Types of Ionising Radiation

1. X-rays
2. Gamma rays
3. Alpha particles
4. Beta particles
5. Neutrons

Different types have different penetration, hazards, and control requirements

X-Rays

1. Man-made ionising radiation
2. No mass and no electrical charge
3. Highly penetrating
4. Common occupational uses:
    - Medical imaging
    - Industrial non-destructive testing (NDT)
    - Security screening
5. Typical shielding: lead, concrete

Gamma Rays

1. Emitted from radioactive materials
2. No mass and no electrical charge
3. Even more penetrating than X-rays
4. Common occupational uses:
   - Industrial radiography
   - Sterilisation processes
5. Shielding: thick lead or concrete

Alpha Particles

1. Heavy, positively charged particles
2. Very low penetration power
3. Can be stopped by paper or skin
4. Very dangerous if inhaled or ingested
5. Mainly an internal exposure hazard

Beta Particles

1. Light, electrically charged particles
2. Moderate penetration
3. Can penetrate skin and damage eyes
4. Shielding materials: Plastic, Aluminium
5. Internal and external exposure risk

Neutron Radiation

1. Uncharged particles
2. Very high penetration capability
3. Highly damaging due to secondary radiation effects
4. Found in: Research reactors - specialised industrial applications
5. Shielding: concrete, water, hydrogen-rich materials

Biological Effects of Ionising Radiation

Biological Effects on the Human Body

1. Ionisation damages cells and tissues
2. Breaks chemical bonds in DNA
3. Can interfere with cell division and repair
4. Damage severity depends on:
    - Dose
    - Exposure time
    - Type of radiation

Biological Effects of Ionising Radiation

Sensitive Organs and Tissues

1. Bone marrow
2. Thyroid gland
3. Gonads
4. Gastrointestinal tract
5. Eyes (lens)

Biological Effects of Ionising Radiation

Deterministic Effects

1. Effects have a threshold dose
2. Severity increases with dose
3. Examples: Skin burns, Radiation sickness & Cataracts
4. Usually associated with high exposures

Biological Effects of Ionising Radiation

Stochastic Effects

1. No dose threshold
2. Probability of occurrence increases with dose
3. Severity independent of dose
4. Main example: CancerLong-term health concern

Biological Effects of Ionising Radiation

Acute Radiation Syndrome (ARS)

1. Caused by high whole-body doses in a short period
2. Symptoms may include:
    - Nausea and vomiting
    - Hair loss
    - Fatigue
    - Bone marrow damage
    - Rare in occupational settings
3. Usually linked to accidents

Ionising Radiation

Control Concepts

Fundamental Radiation Protection Principles

1. Time – reduce duration of exposure
2. Distance – increase distance from source
3. Shielding – use appropriate protective barriers

Basis of radiation protection practices worldwide

Ionising Radiation

Control Concepts - ALARA Principle

1. ALARA = As Low As Reasonably Achievable
2. Applies at all exposure levels
3. Considers: Technical feasibility, Economic and social factors
4. Requires continuous optimisation of protection

ALARA Principle

As Low As Reasonably Achievable

It does NOT mean:

"As low as possible", "Zero radiation", "Only below legal limits"

Reduce radiation exposure as much as is reasonably practicable, even if you are already below dose limits.

ALARA is applied through three things:

1. Time: Shorten exposure duration, Pre-planning tasks, Avoid unnecessary repetition
2. Distance: Maximise distance from source, Remote handling, Restricted access zones
3. Shielding: Barriers between source and worker

Ionising Radiation

Monitoring & Protection

Personal Radiation Monitoring

1. Used to assess individual radiation dose
2. Common dosimeters:
    a) Thermoluminescent Dosimeters (TLD)
    b) Optically Stimulated Luminescence (OSL)
3. Worn by occupationally exposed workers

Issue -> wear -> return ->lab readout -> dose report

Thermo luminescent Dosimeters (TLD)

- Looks like a film badge
- Contains a lithium fluoride crystal
- Responds to radiation similarly to skin
- Measured by a TLD analyzer
- Crystal will luminescence if exposed to radiation, then heated
- More accurate than a film badge

Optically stimulated luminescence (OSL) dosimeter

- Radiation-sensitive aluminum oxide → exposure to radiation → electron trapping in an excited state
- Irradiation with laser (specific λ) → emission of light → determine radiation dose
- More recent device of choice for occupational exposure monitoring
- More sensitive than film badge or TLD
- Results can be read up to a year following exposure
- Available for use on torso and finger

OSL badges have become the standard for routine personal monitoring

- OSL detects doses low-dose environments
- OSL can be re-read multiple times because the readout is light based and non destructive whilst the TLD can only be read once!

Area Radiation Monitoring

1. Fixed radiation detectors
2. Portable survey meters
3. Used to:
    - Identify radiation zones
    - Detect abnormal radiation levels
    - Verify effectiveness of controls

Fixed Area Radiation

These are permanently mounted in rooms or zones where radiation sources are used

1. GM-tube area monitors
2. Ionization chamber area monitors
3. Neutron area monitors
4. Scintillation based area monitors

Portable Area Radiation Instruments

Used for surveys, inspections and routine checks

1. **Portable ionization chambers:** accurate dose-rate measurements for X-ray and gamma fields.
2. **Portable GM survey meters**: versatile, used for contamination checks and general surveys
3. **Neutron survey meters:** rem-meters, used in research and industrial neutron fields

Shielding Materials

1. Lead: X-rays
2. Concrete: gamma rays and neutrons
3. Water or plastics: neutron radiation
4. Shielding selected based on radiation type and energy

Engineering Controls

1. Shielded rooms and enclosures
2. Interlocked access doors
3. Warning lights and alarms
4. Remote handling systems
5. Automatic source shut-off mechanisms

Administrative Controls and PPE

Administrative Controls

1. Radiation risk assessments
2. Designated supervised and controlled areas
3. Training and authorisation of workers
4. Exposure record keeping

Personal Protective Equipment

1. Lead aprons, Thyroid shields, Lead glasses

Legal Requirements
Malta (Ionising Radiation)

Maltese Legal Framework (Ionising Radiation)

1. **Nuclear Safety and Radiation Protection Act (Cap. 585)**
    - Main governing legislation
    - Protection principles
    - Licensing, inspections and enforcement

2. **S.L. 585.01 – Basic Safety Standards Regulations**
    - Dose limits
    - Employer responsibilities
    - Designated radiation areas

3. **Regulatory authority: Radiation Protection Commission (RPC)**

https://rpc.gov.mt/laws-and-regulations/
ABOUT US
CONSULTATION
GENERAL INFORMATION
GUIDES
REPORTS
FORMS
Laws & Regulations
Chapter 585 – Nuclear Safety and Radiation Protection Act
S.L. 585.01 – Basic Safety Standards for Ionising Radiation Regulations
S.L. 585.02 – Nuclear Safety Regulations
S.L. 585.03 – Management of Radioactive Waste Regulations
S.L. 585.04 – Commission for the Protection from Ionising and Non-Ionising Radiation Regulations
Radioactive Waste Management Programme.pdf

Regulatory Authority in Malta

1. Radiation Protection Commission (RPC)
2. National competent authority
3. Responsibilities include:
    - Authorisation and licensing
    - Inspections and enforcement
    - Guidance on radiation protection

Sector Application
Ionising

Occupational Applications of Ionising Radiation

1. **Medical imaging:** X-rays, CT scans, Fluoroscopy
2. **Industrial:** Non-destructive testing (NDT), Weld inspections
3. **Manufacturing**: Material analysis, Thickness gauges
4. **Sterilisation and irradiation technologies**

Ionising Radiation - Summary

1. Ionising radiation has sufficient energy to damage DNA
2. Health effects depend on dose and exposure
3. Protection is based on: Time, distance, shielding
4. ALARA principle
5. Monitoring and controls are essential
6. Strong legal framework applies in Malta

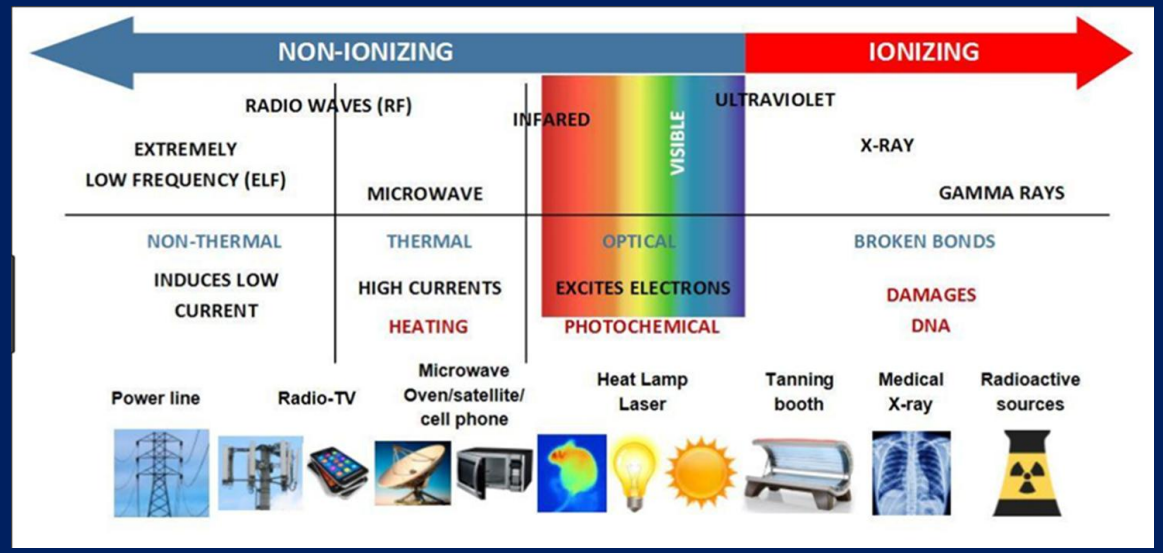
Non-Ionising Radiation

What is Non-Ionising Radiation?

1. Electromagnetic radiation without sufficient energy to remove electrons
2. Causes thermal, photochemical or mechanical effects
3. Widely present in: Industry, Healthcare, Telecommunications, Domestic and commercial environments

Non-Ionising Radiation Spectrum

1. Ultraviolet (UV)
2. Visible Light
3. Infrared (IR)
4. Microwaves
5. Radiofrequency (RF)
6. Extremely Low Frequency (ELF) fields
7. Lasers (optical radiation, class-based)



Types of non-ionizing radiation

Ultraviolet (UV) Radiation

1. Wavelength range: 100–400 nm
2. Sub-types:
    - UVA (Long-term skin & eye damage)
    - UVB (Acute skin & eye injury; cancer risk) &
    - UVC (Severe tissue damage; usually artificial sources)
3. Common sources: Sunlight, Welding arcs & UV curing lamps

depending on wavelength, intensity and exposure duration.

Health Effects

Ultraviolet (UV) Radiation

1. Skin effects:
    - Erythema (sunburn)
    - Photo-aging
    - Increased skin cancer risk
2. Eye effects:
    - Photokeratitis (“welder’s eye”)
    - Conjunctivitis
3. Effects depend on:
    - Exposure time
    - Intensity
    - Lack of eye/skin protection

Types of non-ionizing radiation

Infrared (IR) Radiation

1. Wavelength range: 700 nm – 1 mm
2. Primary effect: thermal
3. Sources:
    - Furnaces
    - Molten metals
    - Glass and metal processing
    - Infrared heaters

Health Effects
Infrared (IR) Radiation

1. Skin effects:
    - Thermal burns
    - Heat stress

2. Eye effects:
    - Cataract formation ("glassblower's cataract")

3. Effects depend on:
    - Proximity to source
    - Poor shielding or PPE

Types of non-ionizing radiation

Radiofrequency (RF) & Microwaves

1. Frequency range: RF: 100 kHz – 300 GHz
2. Microwaves: subset of RF
3. Common sources:
    - Antennas and transmitters
    - Radar systems
    - Microwave ovens
    - Mobile phone infrastructure

S.L. 646.23 - Work Place (Minimum Health and Safety Requirements for the Protection of Workers from Risks resulting from Exposure to Electromagnetic Fields) Regulations

Health Effects

Health Effects of RF / EMF

1. Established effect:
   Tissue heating at high intensities
2. Scientific consensus:
   No proven adverse health effects below ICNIRP limits
3. Public concern:
   Frequently linked to 5G and base stations

Risk perception often exceeds scientific evidence

Types of non-ionizing radiation

Lasers

1. Emit highly coherent, focused optical radiation
2. Classified by hazard potential:
3. Class 1 → Class 4
4. Used in:
    - Industrial cutting
    - Engraving
    - Medical & cosmetic treatments
    - Research applications

Classes of Lasers

- Class1
- Class 1M
- Class 2
- Class 2M
- Class 3R
- Class 3B
- Class 4

1. Classes 1 & 2 are relatively low hazard and only emit light in visible band
2. Classes 3 and 4 - direct eye contact must be avoided. Are more hazardous than Class 1&2. Laser safety office is recommended.
3. Class 4 – can burn the skin and cause permanent eye damage as a result of direct, diffuse or indirect exposure of beam. Can also ignite combustible materials and are a fire risk.
4. All lasers should carry information stating their class and any precautions required during use.

Health Effects

Health Effects of Lasers

1. Eye injury:
    - Retinal burns
    - Permanent vision loss
2. Skin injury:
    - Burns
3. Risk depends on:
    - Laser class, Wavelength & Exposure duration

Non-Ionising Radiation

Monitoring & Protection

Monitoring of Non-Ionising Radiation

1. UV & IR meters for optical radiation
2. EMF field strength meters:
    - Electric field (V/m)
    - Magnetic field (µT)
3. Measurements compared against ICNIRP exposure limits

Control Measures (Engineering & Administrative)

1. Source shielding and enclosure
2. Interlocks and fail-safe systems (especially lasers)
3. Restricted access zones
4. Warning signage and controlled areas

Personal Protective Equipment (PPE)

1. UV/IR protective goggles
2. Face shields
3. Laser-rated eye protection (wavelength-specific)
4. UV-resistant clothing

Exposure Limits

1. Based on ICNIRP Guidelines
2. Adopted across EU regulatory frameworks
3. Focus :
    - Occupational exposure
    - Public exposure
4. Require: Risk assessment, Periodic review of controls

https://www.icnirp.org/

Legal Requirements
Malta (Non-Ionising Radiation)

Maltese Legal Framework
(Non-Ionising Radiation)

1. S.L. 646.22 is the primary workplace health & safety regulation for artificial optical radiation (UV, visible, IR, lasers).
2. S.L. 585.04 operates at the national radiation governance and regulatory authority level, covering both ionising and non-ionising radiation where public or occupational risk exists.
3. They address different legal questions.

S.L. 646.22 – WORK PLACE (MINIMUM HEALTH AND SAFETY REQUIREMENTS FOR THE PROTECTION OF WORKERS FROM RISKS RESULTING FROM EXPOSURE TO ARTIFICIAL OPTICAL RADIATION) REGULATIONS

1. Artificial optical radiation only, specifically:
    - Ultraviolet (UV)Visible light
    - Infrared (IR)Lasers
    - Applies directly to workplaces
    - Legally binding employer duties

2. Falls under the Occupational Health & Safety Authority (OHSA) framework

S.L. 646.22 – WORK PLACE (MINIMUM HEALTH AND SAFETY REQUIREMENTS FOR THE PROTECTION OF WORKERS FROM RISKS RESULTING FROM EXPOSURE TO ARTIFICIAL OPTICAL RADIATION) REGULATIONS

3. Employer obligations
   - Risk assessment of optical radiation exposure
   - Measurement or calculation of exposure levels
   - Implementation of control measures
   - Provision of PPE
   - Worker information and training
   - Health surveillance where necessary

4. What it does not cover
   - RF, microwaves, ELF fields
   - Public exposure outside workplaces
   - National radiation governance

Risk Management Framework

1. Hazard identification
2. Exposure pathway assessment
3. Dose estimation
4. Control prioritization
5. Emergency procedures for radiation incidents

ALARA Principle in Practice

1. Even for non-ionising radiation:
   - Keep exposure As Low As Reasonably Achievable
   - Achieved through:
     - Optimised work procedures
     - Shielding and distance
     - Time management
   - Equipment calibration
   - Training and refresher courses

Case Study 1: IONISING RADIATION (Medical Imaging)

Scenario

1. Hospital medical imaging department:X-ray, CT and fluoroscopy
2. Staff: radiographers, nurses, maintenance
3. High workload and time pressure
4. Key Hazards: Ionising radiation -> Primary beam and scatter radiation (Repeated low-dose occupational exposure)
5. Risk Management Focus:

   Engineering controls: Structural shielding (lead walls, doors)

   Administrative controls: Controlled areas, staff rotation, local rules

   Monitoring: Personal dosimeters

Are staff exposures being kept ALARA, or is productivity driving risk acceptance?

Case Study 2: NON-IONISING RADIATION (Telecom Maintenance)

Scenario

1. Rooftop telecom tower
2. RF / microwave antennas operating continuously
3. Maintenance carried out close to active transmitters
4. Key Hazards: Non-ionising RF/EMF exposure:
   Invisible and imperceptible, Elevated fields close to antennas
5. Risk Management Focus
   Engineering controls: Antenna shutdown or power reduction
   Administrative controls: Permit-to-work, exclusion zones
   Monitoring :EMF field measurements vs ICNIRP limits

Why is risk perception often higher than actual risk, and ho
should this be managed safely?

1. What is the main difference between ionizing and non-ionizing radiation?
2. Which type of radiation is used in medical imaging like CT scans?
3. True or False: Radiation is only harmful when you are exposed to high doses.
4. Why do workers in radiology wear lead aprons?
5. What does the acronym ALARA stand for in radiation safety?
6. Which industry uses the highest amount of ionizing radiation outside healthcare?
7. Which type of radiation is emitted by the sun and can cause skin cancer?
8. What is the most common shielding material used in nuclear reactors?
9. True or False: Radiation can only come from man-made sources.
10. What is the primary method to reduce radiation exposure in the workplace?

11. What is the difference between alpha particles and beta particles in terms of penetration?
12. What is the purpose of a Geiger counter?
13. What type of radiation is used in smoke detectors?
14. Which type of radiation can travel the farthest through materials?
15. True or False: Cell phones emit ionizing radiation.
16. Which radiation type is used in MRI scans?
17. What is the main difference between gamma rays and X-rays?
18. Which type of radiation is used in cancer treatment to destroy tumor cells?
19. Which type of radiation is stopped by a sheet of paper?

Next: Lecture 6: Lighting, Visibility, and Workplace Ergonomics

This lecture discusses illumination requirements, lux levels, glare, contrast, flicker, and visibility. Students explore the relationship between lighting and ergonomic performance, including visual strain, posture, error rates, and injury risk. Light measurement tools and workplace lighting standards are reviewed.