Non-Ionizing Radiation

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- Exposure involving every person, throughout the world and the level of exposure will continue to increase as techology advances and society demands of techonology increase
- It has been calculated that in the only US there are more than 100 million people who uses wireless communication devices and this number is still increasing with a rate of about 50,000 new user daily
- It has defined as the energy absorbed by any material without causing ionization
- TV and radio signals, radar, transmissions of cordless and cellular phones, microwaves, visible light, IR, UV, lasers.

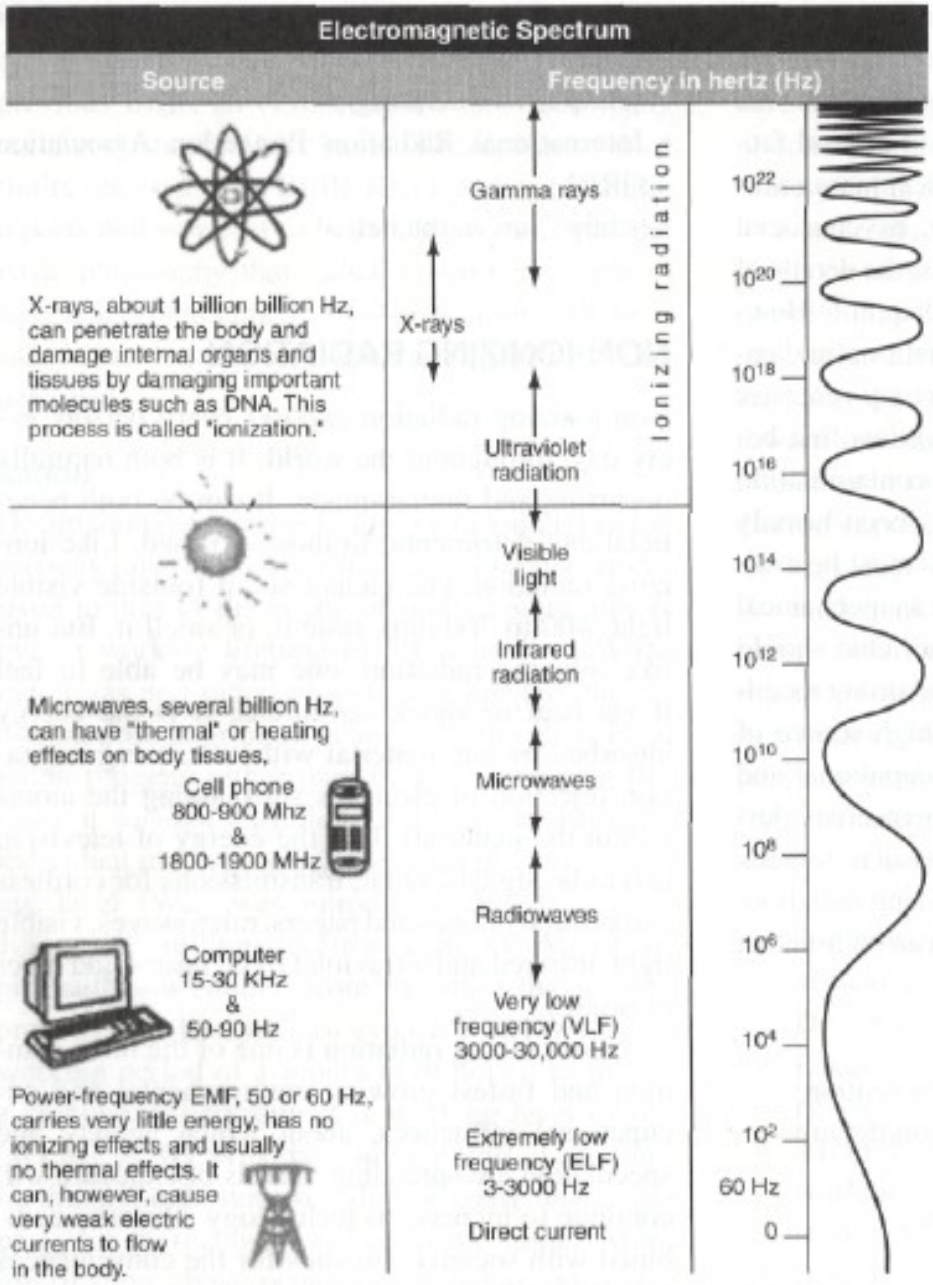


FIGURE 14D-4 ●
Electromagnetic spectrum. (From EMF in the Workplace. Department of Energy, National Institute for Occupational Safety and Health, and National Institute of Environmental Health Sciences, 1996. Note: ELF is defined as 3 to 300 Hz by NCRP Report 119.)

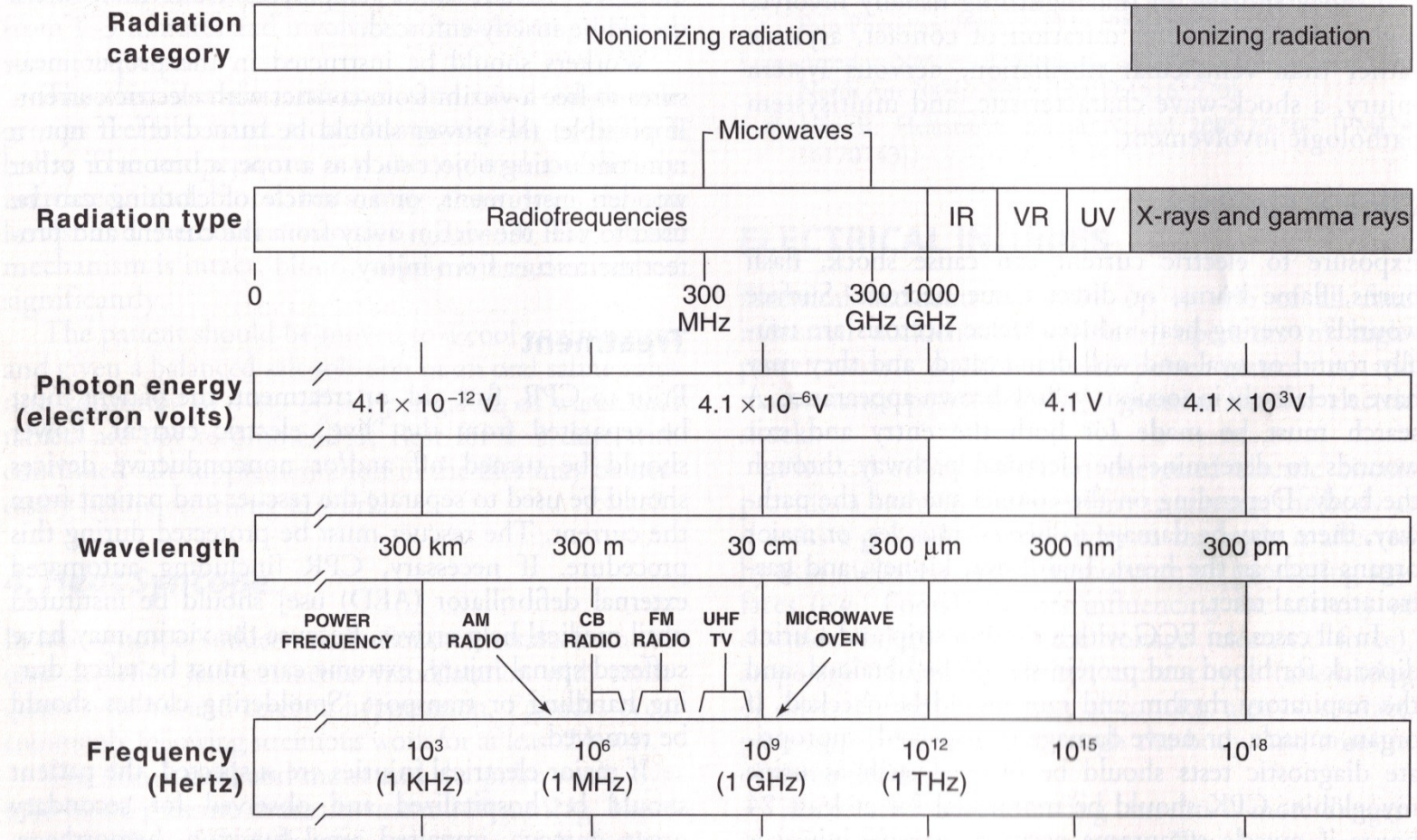


Figure 11–4. The electromagnetic radiation spectrum. GHz = gigahertz; IR = infrared radiation; kHz = kilohertz; MHz = megahertz; THz = terahertz; UV = ultraviolet light; VR = visible radiation (light).

Basics

- All non-ionizing radiation presents itself in electric and magnetic field (EMFs)
- EMFs can be described by the frequency or the corrisponding wavelenght

  □$\lambda = c/f$ f is measured in Hz
- Electric Field Strength (E), measured in V/m
- Magnetic Field Strength (H), measured in A/m
- Power Density, measured in W/m^2 or VA/m^2

  S = E2/377, or 377xH

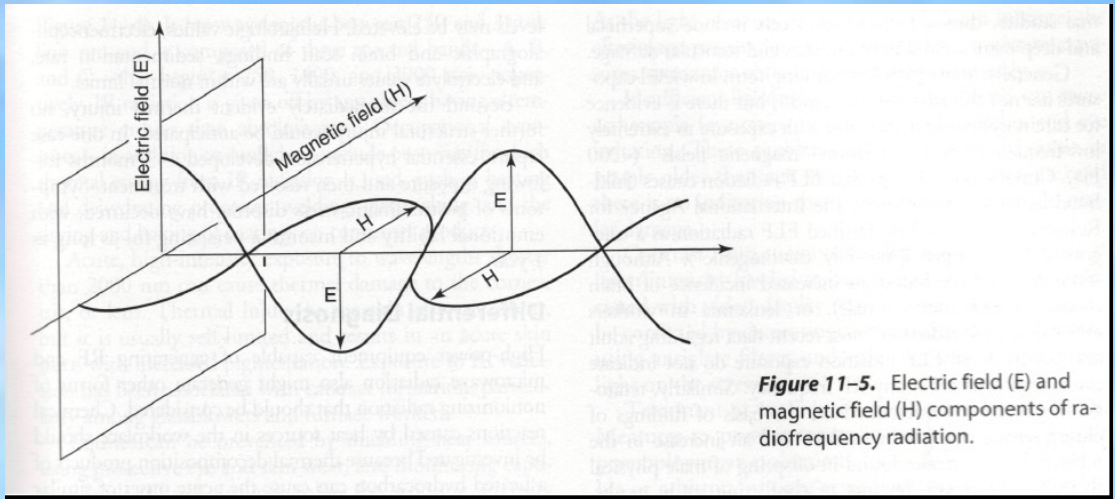


Figure 11–5. Electric field (E) and magnetic field (H) components of radiofrequency radiation.

Magnetic Induction

- Magnetic induction (B), which has has the SI units of tesla (T), equivalent to weber per square meter per (Wb/m^2) or volt seconds per square meter ($V\ s/m^2$)
- **Magnetic field H and magnetic induction field B are linked, in a given material, by the equation:**

$$B = \mu * H$$

- **where μ is the magnetic permeability of the material (in Henry/meter).**

SAR

- **Specific absorption rate** (SAR) is a measure of the rate at which energy from electric and magnetic fields is absorbed by the human body or any material (power absorbed per mass) and has units of W/kg or mW/g.
- "Specific" refers to the normalization to mass of the material exposed
- "Absorption" refers to the absorption of energy
- "Rate" means the time rate of change of the energy absorption

- Reliable indicator or predictor of the potential for biological effects in animal experiment

TABLE 14D-6

Maximum Permissible Exposure for the Occupational Environments

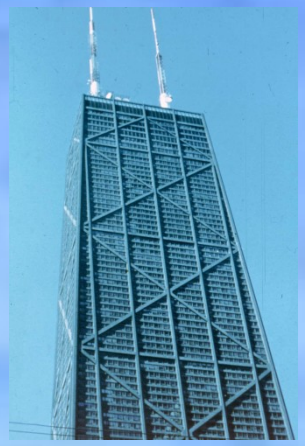
Frequency Range (MHz)	*E*-Field[a] Strength (V/m)	*H*-Field[a] Strength (A/m)	Power Density (*S*) $(mW/cm)^2$	Averaging Time (min)
0.003–0.1	614	163		6
0.1–3.0	614	16.3/*f*		6
3–30	1,842/*f*	16.3/*f*		6
30–100	61.4	16.3/*f*		6
100–300	61.4	0.163	1.0	6
300–3,000			*f*/300	6
3,000–15,000			10	6
15,000–300,000			10	$616{,}000/f^{1.2}$

[a] Institute of Electrical and Electronics Engineers (IEEE) report C95.1 1999 Edition.

- The RF exposure limits correspond to a SAR of 0,4 W/Kg (4 W/Kg would be the same increase in temperature associated to a moderate activity level, such as housecleaning).
- RF exposure below these levels should prevent adverse health effects.
- However, exposures in excess of the limits are not necessarily harmful

RF Measurement Data

- **Emission limits**
  - "They are the maximum power output authorized by local government authorities for companies or individuals".
  - These are applicable, i.e. to cell-phone base stations or towers



- The ***exposure limits*** take into account the concepts of Spatial and Time Averaging.
- Exposure Limits in fact are fixed considering the whole body- and time-averaged SAR

Industrial applications of RF and MW

- Welding
- Metal fusion
- Sterilization procedures
- Drying procedures
- Polymers synthesis
- Sealing procedures
- Heating and cooking

CENELEC

- **CENELEC** is the *European Committee for Electrotechnical Standardization*
- CENELEC is responsible for European Standardization in the area of electric engineering, together with ETSI (telecommunications) and CEN (other technical areas) CENELEC forms the European system for technical standardization.
- Standards harmonised by these agencies are regularly adopted in many countries outside Europe which follow European technical standards

Static Magnetic Fields

Biological effects in humans

Field (T)	Time duration of Exposure	Effects	References
0.25	Not provided	Change in pulse and respiratory rate	Peterson Kennelly (1982)
0.50	3 days/year /person	No effects	Beischer (1962)
1.5	Not provided	Abnormal taste	Beischer (1962)
2.0	15 minutes	toothache	Beischer (1962)
10	short	Extensive numbness, bone pain, shivering	Beischer e Reno (1971)

(Ketchen et al., 1988, modified)

Static Magnetic Fields

Occupational exposure:	Magnetic induction
whole-body exposure time averaged (a working day)	200 mT
ceiling	2 T
extremities	5 T

Exposure Limits for static magnetic fields (ICNIRP 1994)

Electric Magnetic Fields

Prevention measures:

Access must be denied to

- **Pace-maker holders**
- **Post-surgery patients with surgical metallic clips**
- **Pregnant women**
- **Patients suffering with some CNS disoders**
- **Patients suffering with arrythmias**

Interaction with biology

- Hazards potentially associated with exposure to EMFs in the various bands may result in
  a. Currents being produced within the body via contact with energized sources or induced within the body without contact with sources or nearby metallic objects
  b. Increased internal body temperature
  c. Increased body surface temperature

- Several factors may affect the efficiency of EMFs effects on human body
  - Materials with a high water content (i.e. muscles) adsorb EMF energy at a higher rate than dry materials
  - The absorption rate is higher when incident electric field is parallel vs. perpendicular to the body
  - The absorption is higher when the incident magnetic field is perpendicular to larger cross-sectional areas vs. smaller areas
  - Sharp corners, edges, and points concentrate electric fields
  - Depth of penetration decreases as conductivity increases and as frequency increases

Biologic effects at different frequencies

TABLE 14D-5

Frequency Bands and Their Associated Biological Impacts

Band	Frequency Range (Hz)	Wavelength Range (m)	Biological Impact
SELF (Sub-extremely-low frequency)	0 to 30	0 to 10^7	0–10^5 Hz 0–3,000 m
ELF (Extremely-low frequency)	30 to 300	10^7 to 10^6	Electrostimulation (primary dosimetric parameter is internal current density)
VF (Voice frequency)	300 to 3,000	10^6 to 10^5	
VLF (Very-low frequency)	3,000 to 3×10^4	10^5 to 10^4	
LF (Low frequency)	3×10^4 to 3×10^5	10^4 to 10^3	
MF (Medium frequency)	3×10^5 to 3×10^6	10^3 to 10^2	10^5 to 6×10^9 Hz 3,000 to 0.05 m Specific absorption rates (heating effects)
HF (High frequency)	3×10^6 to 3×10^7	10^2 to 10	
VHF (Very high frequency)	3×10^7 to 3×10^8	10 to 1	
UHF (Ultrahigh frequency)	3×10^8 to 3×10^9	1 to 0.1	
SHF (Super-high frequency)	3×10^9 to 3×10^{10}	0.1 to 10^{-2}	
EHF (Extremely-high frequency)	3×10^{10} to 3×10^{11}	10^{-2} to 10^{-3}	Above 6×10^9 Hz Below 0.05 m Surface heating (Radiant)
SEHF (Supra-extremely-high frequency)	3×10^{11} to 3×10^{12}	10^{-3} to 10^{-4}	
Infrared radiation	**IR-C**	0.3 μm to 1 mm	Corneal burns, thermal skin burns
	IR-B	0.14 μm to 0.3 μm	
	IR-A	760 nm to 1,400 nm	Retinal burns, cataracts of lens, thermal skin burns
Visible light		400 to 760 nm	Retinal burns, thermal skin burns
Ultraviolet radiation	**UV-A**	400 to 320 nm	Cataract of lens, thermal skin burns
	UV-B	320 to 280 nm	Corneal injuries, cataracts of lens, photokeratitis, photoconjunctivitis, erythema
	UV-C	280 to 200 nm	

mm = millimeter (10^{-3} m); μm = micrometer (10^{-6} m); nm = nanometer (10^{-9} m).

Health effects EMF<300 MHz

- Though extensively studied over the past two decades there no agreement within the international scientific community with regard to the potential for health effects of EM fields <300MHz
- Nevertheless IARC has stated that
  - "there is limited evidence in humans for the carcinogenicity of ELF magnetic fields in relation to childhood leukemia"
  - On the other hand "no data relevant or inadequate evidence" is stated with regard to any relationship between all the other cancers both in childhood and in adults

Non-Ionizing radiation, part 1: Static and extremely low- frequency (ELF) electric and magnetic fields. Vol. 80. Lyon, France: IARC, 2002

Review of the Epidemiologic Literature on EMF and Health

ICNIRP (International Commission for Non-Ionizing Radiation Protection) Standing Committee on Epidemiology: Anders Ahlbom,[1] Elisabeth Cardis,[2] Adele Green,[3] Martha Linet,[4] David Savitz,[5] and Anthony Swerdlow[6]

[1]Institute of Environmental Medicine, Karolinska Institutet, Stockholm, Sweden; [2]International Agency for Research on Cancer, Lyon, France; [3]Epidemiology and Population Health Unit, The Queensland Institute of Medical Research, Brisbane, Australia; [4]Division of Cancer Epidemiology and Genetics, National Cancer Institute, Bethesda, Maryland, USA; [5]Department of Epidemiology, School of Public Health, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina, USA; [6]Section of Epidemiology, Institute of Cancer Research, Sutton, Surrey, United Kingdom

Exposures to extremely low-frequency electric and magnetic fields (EMF) emanating from the generation, transmission, and use of electricity are a ubiquitous part of modern life. Concern about potential adverse health effects was initially brought to prominence by an epidemiologic report two decades ago from Denver on childhood cancer. We reviewed the now voluminous epidemiologic literature on EMF and risks of chronic disease and conclude the following: *a*) The quality of epidemiologic studies on this topic has improved over time and several of the recent studies on childhood leukemia and on cancer associated with occupational exposure are close to the limit of what can realistically be achieved in terms of size of study and methodological rigor. *b*) Exposure assessment is a particular difficulty of EMF epidemiology, in several respects: *i*) The exposure is imperceptible, ubiquitous, has multiple sources, and can vary greatly over time and short distances. *ii*) The exposure period of relevance is before the date at which measurements can realistically be obtained and of unknown duration and induction period. *iii*) The appropriate exposure metric is not known and there are no biological data from which to impute it. *c*) In the absence of experimental evidence and given the methodological uncertainties in the epidemiologic literature, there is no chronic disease for which an etiological relation to EMF can be regarded as established. *d*) There has been a large body of high quality data for childhood cancer, and also for adult leukemia and brain tumor in relation to occupational exposure. Among all the outcomes evaluated in epidemiologic studies of EMF, childhood leukemia in relation to postnatal exposures above 0.4 μT is the one for which there is most evidence of an association. The relative risk has been estimated at 2.0 (95% confidence limit: 1.27–3.13) in a large pooled analysis. This is unlikely to be due to chance but, may be, in part, due to bias. This is difficult to interpret in the absence of a known mechanism or reproducible experimental support. In the large pooled analysis only 0.8% of all children were exposed above 0.4 μT. Further studies need to be designed to test specific hypotheses such as aspects of selection bias or exposure. On the basis of epidemiologic findings, evidence shows an association of amyotrophic lateral sclerosis with occupational EMF exposure although confounding is a potential explanation. Breast cancer, cardiovascular disease, and suicide and depression remain unresolved. *Key words:* cancer, chronic disease, epidemiology, extremely low-frequency EMF, review. — *Environ Health Perspect* 109(suppl 6):911–933 (2001).
http://ehpnet1.niehs.nih.gov/docs/2001/suppl-6/911-933ahlbom/abstract.html

Laboratory research has given no consistent evidence that EMF of the magnitude encountered in every day life for a substantial period can affect biological processes or that EMF affects the risk of cancer in animals. The epidemiologic literature is therefore particularly worth careful consideration because it is essentially on this evidence alone, at present, that suggestions about long-term effects on human health rest. In this review, therefore, we summarize and discuss critically the current state of epidemiologic knowledge and the strengths and weaknesses of the available evidence on the relation of EMF exposure in man to risk of cancer and other adverse outcomes. We have taken EMF to refer to time-varying electric and/or magnetic fields <300 Hz. Where studies have specifically measured electric and/or magnetic fields, we have indicated the type of field; where they have not, or where it is not clear from the report, we have referred to EMF generically. We have restricted our attention to epidemiology, not experimental human studies; and although we have referred to some research on physiological effects, these are not reviewed systematically, and the review is primarily concerned with pathological end points. Particular attention is paid to methodological

Health effects EMF>300 MHz

- **Cellular level**
  - changes in cell proliferation, reproduction, development, and growth factors (cell cultures)
  - Alteration membrane cell permeability to Calcium
  - Some biochemical effects (increased ODC)
- **Organ level**
  - Cataracts and other ocular effects
  - Cutaneous effects
- **Apparatus level**
  - **Neuroendocrine effects**
  - **Cardiovascular effects**
  - **Alteration immune response**
  - **Alteration hematopoiesis and other hematologic effects**
- **All these measurable effects may or may not be associated with, clinically significant, adverse health effect**

Cell-phone-induced radiation

- The scientific community continues to debate the level of protection necessary to prevent long-term effects from RF exposure
- North American and many European countries as well as WHO promote precautionary approach by discouraging the widespread use of mobile phones by children for nonessential calls because they may be more vulnerable due to their developing nervous system and longer lifetime exposures
- Same recommendations for pregnant women
- WHO
  - Mobile phone calls < 3 minutes
  - 15 minute minimum break between calls

Cell-phone-induced radiation

Exp. Situations	Safety Measures
Children	1. Do not use cell phones
High use of cellar phones	1. Limit use 2. Hands-free headsets can help reduce exposure to head and body. 3. Switch sides (ears) regularly as this limits the power and duration of the electromagnetic field emitted near your ear. 4. Send text messages as they tend to be shorter, and the unit is held away from the body 5. Opt for lower power units (where possible) to help reduce exposure
Proximity of unit close to the body	1. As much as possible, keep or store away from the body. 2. Avoid unnecessary exposures. 3. Carry in the pocket with the board (back) towards the body as this means the fields move away from you rather than through you.
Use while driving	1. For safety, do not use while driving or doing tasks that require your attention

http://www.ccohs.ca/oshanswers/phys_agents/cellular_telephones.html

Protective measures

- Engineering controls
  - Sophisticated level of knowlegde to install
  - Improperly installed controls may enhance workers exposure
  - Shielding materials like perforated screens
  - Appropriate building construction materials and layout (i.e. electrically insulating materials on the ground)
- Administrative controls
  - Distance between the source and workers
  - Duration of exposure
  - Restricting access
  - Warning signs
  - Training
  - Real-time monitoring via dosimetry

Protective measures

- PPE
  - Appropriate insulating footwear
  - The level of RF exposure reduction depends on RF frequency and type of shoes and socks worn
  - Protective suits (wool, polyester, nylon impregnated with a highly conductive threaded metal)
    - Washing reduce the effectiveness
    - May be dangerous for working operating near the wearer
    - May increase the hazard to the wearer by allowing closer proximity to open circuits that may act as secondary sources.

Infra-Red Radiation

- Nearly 50 percent of the Sun's radiant energy is emitted as IR
- Strongly absorbed by water and atmosphere
- can be detected as warmth by the skin
- All objects with temperatures above absolute zero emit IR
- Primary biological effect is thermal due absorption in water
- The lens of the eye is particularly vulnerable, chronic exposure may result in cataract

Infra-Red Radiation

- Workers typically at risk of IR exposure include:
  - glass blowers, furnace workers, foundry workers, blacksmiths, solderers, oven operators, workers near baking and drying heat lamps, and movie projectionists

- The limits for IR most recognized in the scientific community are published by ACGIH

- Control measures
  a) Shielding and eye protection with appropriate IR filters
  b) Increase of the distance between workers and IR source
  c) Reduction of time spent in areas with high level of IR exposure

Ultra-Violet Radiation

- Produced naturally by the sun and artificially by incandescent, fluorescent, and discharge types of light sources
- UVA (it reaches the earth surface) and UVB (it is absorbed by the ozone layer and oxygen) are the principal UV conmponent of sunlight
- Industrial sources
  - Welding
  - Plasma torches
  - electric arc furnaces
  - germicidal lamps

Ultra-Violet Radiation

- Health effect
  - The most common is sun-burn
  - Skin cancer (basal cell carcinoma, squamous cell carcinoma, malignant mealanoma)
  - Premature aging
  - Cortical cataracts
  - Other eye injuries like photokeratitis, photoconjunctivitis
- Controls
  - Protective clothing and eyewear to reduce UVB (the most harmful)
  - Sunscreen lotions
  - Reduced time of exposure
  - Proper local exhaust verntilation and isolation of UVR sources from solvent process

Laser

- Light Amplification by the Stimulated Emission of Radiation
- Industrial uses
  - heat treatment, glazing, alloying, cladding, cleaning, brazing, soldering, conduction welding, penetration welding, cutting, hole drilling, marking, trimming, and photolithography
- Health and safety decisions are based on the class of laser and the wavelength of the laser source
- Beam exposure
- Nonbeam hazards, i.e.:
  - Laser Generated Airborne Contaminants (LGACs) is a term used for dust and smoke which is generated when a material is processed with a laser
  - Fire hazard
  - Explosion issues from high pressure tubes

Laser classification and Laser-induced health effects

TABLE 14D-7

Laser Classification

Class of Laser[a]	Hazard Potential
1	Pose no potential for injury. No safety measures required to either the eye or skin.
2; 2a	Visible beam posing no significant potential for injury. Blinking response limits exposure.
3; 3a; 3b	Modest potential for injury. Normal aversion response is not sufficient to limit eye exposure to a safe level. Skin hazards normally do not exist. May require safety precautions and personal protective equipment. Class 3b lasers require more safety precautions than Class 3a.
4	Serious potential for injury of the eye and skin. Requires safety precautions and personal protective equipment. Diffuse reflection viewing hazard. Potential fire hazard. Most laser systems for cutting, heat treating, and welding are Class 4.

[a] When Class 3 and 4 lasers are fully enclosed to prevent potentially hazardous laser radiation exposures, the system may be classified as a Class 1 system.

TABLE 14D-8

Laser Injuries

Type of Hazard	Laser Wavelength (nm)	Target Tissue	Comment
UV photochemical injury	180 to 400 180 to 400 295 to 380	Skin Cornea Lens	Eye protection is required whenever a bluish-white light is seen at the laser focal point.
Blue-light photochemical injury	400 to 550	Retina	Retinal burn has been referred to as "eclipse blindness."
Thermal injury	400 to 1,400 1,400 nm to 1 mm	Retina Skin Cornea Conjuctiva	Nd:YAG lasers pose the greatest risk because the beam image can be intensified of the order 100,000. Most common injury from laser radiation exposure. Biggest concern with CO_2 lasers.
Near-IR thermal injury	800 to 3,000	Lens	Results from molten metal or large, heated surface during treatment. This hazard is only of concern for repeated, chronic exposures.