

Notes on:

NON - IONIZING RADIATION

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Electromagnetic Radiation behaves as if it were energy packets (photons). Photons have energy proportional to the frequency of the radiation and are selectively absorbed by matter (molecules). This absorption increases the vibration of molecules which causes no specific chemical or biological change but is converted into heat (i.e. thermal absorption). As the frequency (and thus energy) of the radiation increases so does the rate of absorption, thus at high frequency the radiation is absorbed in the first few centimeters of the body surface and "non-thermal" effects, including the photo-chemical effects of ultra violet light, are concentrated there.

The radiation considered here does not have sufficient energy to break down (i.e.ionize) molecules.

Electromagnetic Spectrum

WAVELENGTH	100m (radio) to 10 ⁻¹⁰ m (UV)
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FREQUENCY 10⁶ to 10¹⁷ Hz

 $C = f\lambda$. where C= velocity of light 3 x 10⁸ m/sec. f = frequency (Hz) i.e. sec.⁻¹ λ = wavelength in metres.

<u>UNITS</u> – large range of frequency and wavelength.

Radio and microwaves usually refer to frequency (Hz, MHz megahertz, i.e. 10⁶Hz, GHz gigahertz, i.e.10 ⁹Hz) but sometimes in wavelength.

Infra red, visible and ultraviolet energies usually refer to wavelength in nm, (nanometres, 10⁻⁹m)

PERCEPTION, humans are sometimes more fearful of hazards which can not be recognised by the senses than of those which can. Low frequency energy (radio waves etc) cannot be detected by the senses.

<u>STANDARDS FOR HEALTH PROTECTION</u> – usually expressed in power density. Watts/m². (U.S.A. uses milliwatt/Cm² 1mW/Cm² = $10W/m^2$ – see National Standard.

Up to 30 W/Kg in tissue, e.g. heart.

NATURAL ENVIRONMENT

SUN. Energy incident on earth (UK Noon)	1000W/m ² of which
Infra red Visible light Ultra light	500W/m ² 400W/m ² of which 100W/m ² (damaging UVB only ½% of incident
energy).	
EARTH and humans radiate infra red energy at 3×10^4 G	GHz 300-500W/m ²

MICROWAVES AND RADIOWAVES

Absorption in tissue increases with frequency, penetration decreases with frequency. Least favourable combination for living tissue is best for cooking (2450MHz, microwave ovens).

Higher absorption in muscle (water content) than in fat.

Human body generates 1.3W/Kg at rest (i.e. 100 watts)

Below 30GHz, thermal effects only, no mutagenic effects. No possible carcinogenic effects at less than 10⁶GHz (i.e. ultra violet light).

Occupational Exposure Standard - based upon generalised body heating

Limit wholebody specific absorption rate (S.A.R.) to less than 0.4W/Kg in 0.1hours in range 3 x 10^6 - 3 x 10^{11} Hz. (Basal metabolic rate 1.3W/Kg running 5W/Kg) S.A.R. exceeding 4W/Kg can give detectable changes in core temperature and behavioural changes in animals.

At rest 100W of metabolic heat is dissipated over 2m² of body surface (50W/m²). T.L.V. of 100W/m² gives rise to half the heat increase incurred in walking.

Localised Heating

Human body has good blood circulation thus heat transfer and stable temperature within the body. Exception is the <u>eve</u> - if overheated $(45^{\circ}C - 55^{\circ}C)$ transparent cells of lens may die and become opaque (cataract). Unlikely in human eye below S.A.R. 30W/Kg. Epidemiology has not revealed excess human cataract from radio/microwave exposure.

Other possible hazards - vasculitus, sterility, genetic damage, central nervous system. Little evidence for serious or long term harm at community exposure.

Cardio-vascular effects - increased heart rate, above 500W/m². Behavioural changes noted in animals at S.A.R. above 4 to 8W/Kg. S.A.R. 0.4W/Kg gives safety factor >10. Microwave pulses may be heard at non-damaging levels - heat - vibration due to thermal expansion -> change in electrical potential of brain.

Sources - communication, military, RF heaters, plastic welders, glue setters, short wave diathermy, etc. Low power devices of total emission less than 7W are harmless, e.g. small radio transmitters, intruder alarms. Microwave ovens - emission limit (BS5175, 1970) is 50W/m² at 50mm.

INFRA RED RADIATION

I.R A (near infra-red)	780 - 1400nm
I.R B	1400 - 3000nm
I.R C	3000 - 1,000.000nm (1mm)

- I.R. A absorbed in eye but some reaches the retina (cornea is transparent).
- I.R. B almost all absorbed in cornea and aqueous humour. Thus temperature rises development of opacities in lens or capsule - cataract. Prescribed diseases 25 and 26 in furnacemen and glass blowers (1907, USA 1921).
- I.R. **B&C** damage to skin and cornea at 1000W/m² in 1 second Sensation of warmth at 100W/m² over 1cm diameter. Standard for health protection, approx 100W/m²

Much more infra-red energy is needed to produce retinal lesions than visible light energy. CO² (infra-red) laser - causes tissue coagulation and is used to stop surgical bleeding and fix detached retina.

VISIBLE LIGHT (see LIGHTING)

ULTRA - VIOLET RADIATION

U.V A 400 - 315nm	Black light (fluorescence)	SUN major source, mainly thermal effects
U.V B 315 - 280nm	"Erythermal" radiation	SUN major source, photochemical effects
U.V C 280 - 100nm	"Germicidal" radiation	Generated artificially

Wavelengths less than 295nm completely absorbed by the ozone layer (where present !).

Wavelengths less than 200nm rapidly absorbed in air so few direct biological effects.

Human exposure largely limited to 400nm - 200nm.

265nm peak effectiveness against small organisms but Mercury line, 254nm, used as a germicidal agent. Soda glass absorbs wavelength below 300nm.

U.V. strongly absorbed by nucleic acids and tissue protein, thus low penetrating power in body.

Biological Effects principally skin, eyes (face, hands, interior of mouth in dental procedures).

Ear	ly Effects	(hours/days)			
SKI	Ν	-darkening of skin pigmentation (melanin-optical filter) - UVA - increase in pigmentation (sun tan) - UVB (+UVA ?) - erythema (sunburn) - photochemical effect UVB & UVC (+high dose UVA) - changes in cell growth (protective mechanism), increase in cell division, oedema, scaling			
EYE	E	Keratitis (inflammation of cornea), conjunctivitis - UVB, UVC, effect in time x irradiance,peak effect at 270nm. No protective mechanism; cornea does not transmit UV less than 310nm thus lens protected against UVB & C. Known as arc-eye, welders-flash, snow-blindness, etc. Very painful, latent period (few hours) before onset, remits without permanent injury.			
Late	e Effects	(months/years)			
1.	Non-stochas	tic (certainty).	SKIN - ageing, degeneration, decrease in elasticity.		
			EYE	UVA exp people.	osure may cause cataract but common in older
2.	Stochastic (c	shance).	SKIN CANCER - much increased incidence amongst white skinned people with prolonged exposure to sunlight. (75% of white population of Queensland, Australia will sustain skin cancer). <u>BUT</u> no case of industrially induced skin cancer reported after millions of hours exposure to welding and other U.V. sources.		
			EYE - No	o tumours	s so far reported.
Indirect Effects Photochemical Sensitivity		UV <250 UV <160 UVC dis UVB & U chemica dye.	onm onm associate IVA used Is - tar co	disassociates O_2 to O_3 disassociates N_2 to NO_x es CCI4 & trichloroethane to HCI & phosgene. therapeutically. Skin cancers resulted. Industrial mponents, organic solvents, anthracene, synthetic	
<u>Sta</u>	<u>ndards</u>		UV-A. UV B an	d C	10W/m ² Wavelength dependent. Minimum 10 ⁻³ W/m ²
<u> </u>	cupational Ri	<u>sk</u>	Welders population	, plasma on after s	torch operators (welding gives second UV exposure to unlight), printing, laboratory work, dentists.
<u>Pro</u>	tection				
1.	Administratio	on:	limitatior	of acces	s, notices, limit of time and proximity
2.	Design:		shielding	/screenir variety o	ng, glass and plastic sheeting available in a f cut off frequencies.
3.	Personal Pro	otection:	eyes, sk	in.	

U.V. emission from fluorescent lamps for lighting (as distinct from sun tanning) does not constitute a public hazard.

LASERS

Light <u>Amplification by the Stimulated Emission of Radiation</u>.

Coherent, highly directional, low divergence. Radiation can be UV, visible, I.R., may be tunable and continuous or pulsed. Power range, less than 1mW to 10¹²Watts. Even at 1mW the narrowness of the light beam is such that the spectral brightness within the beam exceeds any known source.

- Eye is the critical organ for all users focussing effect of the eye creates a retinal image of 10 -20μ from a 5mm pupil, increase in energy density by 10⁵. Retinal damage by heating (continuous) or shock wave (pulsed) irreversible.
- 2. Skin, output >100mW; thermal and photochemical damage. Skin damage may be repairable or reversible. Immediate effects, erythema, blisters, charring, de-pigmentation, ulceration, scarring.
- 3. Chronic damage to eye from long term exposure to lasers and bright light? Not known but may occur at levels not much brighter than direct sunlight.

Classification of Lasers - dependent upon accessible emission level.

- Class 1 inherently safe because of such low power that MPE cannot be exceeded or safe by reason of engineering design (totally enclosed, interlocked). Beware Maintenance.
- Class 2 Low power (up to 1mW) visible lasers (400-700nm). Not inherently safe but aversion response protects. Accidental viewing not hazardous.
- Class 3A Up to 5mW visible lasers. Protection for the unaided eye by aversion response. Direct viewing may be hazardous if optical aids used.
- **Class 3B** visible plus invisible, up to 0.5W. Direct viewing hazardous but not diffuse reflection.
- **Class 4** high power. Direct viewing and diffuse reflections dangerous. Skin hazard, fire hazard.

Maximum Permissible Exposure (MPE) Levels: - see British or National Standard.

Administration: Keep register of lasers;- users Research, Defence, Medicine, Entertainment.

Designate areas, exclusion and power interlocking with door may be needed.

Medical Assessment: advisory only Class 3B and 4 users, post incident assessment.

Other Hazards: electric hazards (shock), intense light, toxic chemicals, toxic by-produce of thermal degradation, explosion hazard, fire, cryogenic coolants (N₂, O₂, He), Ozone, X-Rays.

STATIC AND LOW FREQUENCY ELECRICAL & MAGNETIC FIELDS

1. NATURAL BACKGROUND AND MAN-MADE MAGNETIC FIELDS

Earth's natural magnetic field 50μ T = 40A/m (I Tesla = 10^4 gauss = 8 x 10^5 A/m) with smaller varying fields from 0.1Hz to 3KHz.

Household electrical appliance produce up to 30μ T (and up to 100μ A in the hand) (kettles, cookers, heaters, drills etc.).

Occupational exposure (electrical furnaces, welding) up to 10mT, new technology up to 50mT. Medical diagnosis (nuclear magnetic resonance) up to 2T (i.e. 40,000 times natural background).

2. STATIC FIELDS

NO ADVERSE EFFECT UP TO 2T (STATIC)	(SHORT TERM)
NO ADVERSE EFFECT UP TO 100mT (STATIC)	(CHRONIC EXPOSURE)

POSSIBLE PROBLEMS: (1) – BLOOD FLOW - produces electrical potential in static magnetic field but no cardiovascular stress reported up to 2T.

(2) – METABOLISM – may be altered (ion pairs).

(3) – MAGNETIC RESONANCE SYSTEMS – for medical diagnosis.

>2T. Research needed.

3. ELF MAGNETIC FIELDS

Up to 300Hz (Principally the use and distribution of electricity at 50 or 60Hz).

Reports linking proximity of electric power lines to childhood cancer – epidemiology questioned – maximum field 0 25µT.

Laboratory studies – no adverse clinical/physiological changes at 50Hz up to 5mT. Above this – sensation of flashing lights (magneto phosphines) – electric current in retina. Biological thresholds induced current densities less than 10mA/m² – no effect.

10-100mA/m² (5-50mT) biological effects noted but consequences for health of chronic exposure known.

Above 1000mA/m^2 (5-50mT) acute health hazard (heat fibrillation, electric shock, at a few mA through body, death above 10mA).

Natural electrical fields 100-200V/m, thunderstorms, etc. 1000V/m. Laboratory exposures up to 20KV/m, 5 hours – no effect, domestic exposure up to 0.2μ T, 30V/m.

Standard.Keep exposures below 10KV/m, exposure over 20KV/m inducing currents
<500μA in body undesirable.</th>

Thresholds well established. Electrical power has been used for so long and it is so widespread that significant health risks (electrical shock apart) probably do not remain to be discovered.

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Reading Lists:

Natural Radiological Protection Board, Chilton, Oxon. (www.nrpb.org.uk)

Many Publications on all types:

WORLD HEALTH ORGANISATION - Environmental Health Criteria Papers.

Health and Safety Executive:	PM 51 Radio Frequency heating equipment.
(www.hse.gov.uk)	Gs 18 Commercial U V Training
	Electrial Arc Welding
	PM 19 Lasers for Display Purposes.