Nonionizing Radiation

• Ionizing radiation has energy above 12 eV.
• \( C = f \lambda \). As the wavelength of electromagnetic radiation increases, the energy decreases, since \( E = hf \).
  – Ultraviolet
  – Visible
  – Infrared
  – Microwave and radiofrequency
  – Extremely low frequency (ELF)
The Waves Represent the Electric and Magnetic Fields

The electric field vector (solid line) is vibrating up and down in the plane of the paper, while the magnetic field vector (dashed line) is vibrating in and out of the plane of the paper. The direction the radiation is moving is defined by a third vector — the propagation vector, \( \mathbf{k} \). Electromagnetic fields are transverse to the direction of propagation and contained within the envelope formed by the axis of propagation and the sinusoidal waves.

The Electromagnetic Spectrum

The spectrum is often divided into two regions: ionizing radiation and nonionizing radiation. The boundary between these regions is a photon energy of 12.4 eV.
## Nonionizing Radiation

<table>
<thead>
<tr>
<th>Region</th>
<th>Wavelength</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultraviolet</td>
<td>100–400 nm</td>
<td>——</td>
</tr>
<tr>
<td>Visible</td>
<td>400–770 nm</td>
<td>——</td>
</tr>
<tr>
<td>Infrared</td>
<td>770 nm–1 mm</td>
<td>——</td>
</tr>
<tr>
<td>Radio-frequency</td>
<td>—— 300 GHz–3 kHz</td>
<td>3 kHz–3 Hz</td>
</tr>
<tr>
<td>Extremely low frequency</td>
<td>——</td>
<td>3 kHz–3 Hz</td>
</tr>
</tbody>
</table>

### Ultraviolet Radiation

- Range: wavelength 0.10 to 0.4 um.
- Divided into regions:
  - 0.10 - 0.16 Vacuum UV
  - 0.16 - 0.28 Far UV (UV - C)
  - 0.28 - 0.32 Middle UV (UV - B)
  - 0.32 - 0.40 Near UV (UV - A)
Ultraviolet Radiation

- Below 0.16, UV can only exist in a vacuum.
- Below 0.29, UV is absorbed by the ozone layer.
- Below 0.30, UV is transmitted thru air, partially absorbed by glass, quartz and water.

Sources of UV Radiation

- The Sun is major source at Earth's surface. 0.3 μm attenuated by stratospheric ozone.
- High pressure metal halide lamps (mercury vapor) two envelopes: quartz inner, opaque outer.
- Welding activity.
- Germicidal lamps (low pressure mercury, .254 μm)
- "Black" lights (.3 - .4 μm)
Uses of UV in the Workplace

- Curing
- Germicidal
- Photo luminescence
- Sun tanning
- Byproduct (welding)
  - Metal cutting
  - Glass manufacture

Effects of Exposure to UV Radiation

- Radiation is absorbed in surface layers of skin. Eyes are also sensitive. Interaction with nucleic acids occurs at approximately 0.26 - .29 μm. (Thymine dimers)
- Effects on the skin:
  - increased pigmentation (tanning)
  - burn 0.25 - 0.30 μm (erythema)
  - skin cancer: non-melanoma skin cancer and melanoma. UV-B is more effective than UV-A. less than 0.3 μm penetrates deeply into the skin.
  - Photosensitization: phototoxicity (erythema) or photoallergy (immune response.)
Effects of Exposure to UV Radiation

• Effects on the eyes
  – Photokeratitis: inflammation of the cornea and conjunctiva: peak effect 0.27 - 0.28 μm. A transient response. 6 - 12 hour latency. 1 to 2 days duration.
  – UV cataracts is a concern from high UV exposure .29 - .31 μm.

• Ozone, phosgene generation: below 0.25 μm

Regulation of UV Radiation

• No PEL for UV radiation exists. The ACGIH recommends a wavelength-dependent TLV, intended to protect against burn and photokeratitis. TLV minimum is at 0.27 μm.
Visible Light

• No health hazard from exposure, but design for good work performance, limit accidents and so on. There are a few OSHA standards (e.g. Hazardous Waste operations), but usually not.

Visible Light

• Use guidelines that are available. ANSI defined nine categories of work, A through I with a range of lighting appropriate to each. Selection of lighting levels will depend on
  – Task detail
  – Consequences
  – Complexity
  – Familiarity
  – Time constraints
  – Object size
  – Age of workers
  – Color contrast
  – Brightness contrast
Infrared Radiation

• Infrared radiation refers to electromagnetic radiation in the range from .75 to 1000 um. It is perceived as a sensation of warmth: very hot objects emit IR radiation, as well as infrared lamps.
• Industrial uses include drying, baking of paints, varnishes and other coatings; heating metal parts; conditioning surfaces; dehydrating textiles, paper, leather, pottery; sand molds.

Infrared Radiation

• Most serious potential hazard is cataracts: short IR region (nearest visible light) is thought to be responsible for "glass blowers cataracts", a known occupational hazard for glass blowers for many years.
Infrared Radiation

• No OSHA PEL, but ACGIH does have a recommended TLV, for infrared lamps.

Microwaves and Radiowaves

• Microwaves and radiowaves find many applications in the workplace. Microwaves are used in heating and cooking applications; radiowaves are commonly used in heaters/sealers for plastic welding, heat sealing. Communications, medical applications.
• Defined by frequency, not wavelength. Wavelength greater than 1 mm.
Microwaves and Radiowaves

- Microwave: on the order of megahertz (MHz) to gigahertz (GHz)
- Radiowave: lower frequencies, down to kHz range
- Extremely low frequency: less than 3 kHz
Microwaves and Radiowaves

Health Effects

- Microwaves and radiowaves thermal effects: warming of tissues, cataracts. Fertility effects in men possibly thermal. Cataracts observed in animals. Cancer: some suggestive data but no confirmation yet. Current assumption is that effects must be related to absorbed dose. Absorbed dose is related to wavelength - which is related to body size.
Microwaves and Radiowaves

- Extremely low frequency radiation: Recent data have led some agencies (for example, IARC) ELF radiation, emitted by power lines (leukemia.) Recent NAS report: 1.5 fold association children near power lines, and EF radiation is classified as a 'potential' human carcinogen. No evidence of reproductive effect in several large studies (e.g. VDT workers.)

RF emissions (shown as curved surfaces) from an aperture antenna must pass through the near field then a transition region before having the characteristics of radiation. The power density in the near field and far field as well as the distance to the boundary between the two zones may be determined from the equations. Note that the power density in the far field is dependent on distance, while the power density in the near field is not.
Microwaves and Radiowaves

Measurement of Microwaves

- Measurement of microwaves and radiowaves is complicated. Measurement techniques are different in 'near field' (less than 5 wavelengths from source) and in 'far field' (more than 10 wavelengths from source). Measurement depends on wavelength.
- 300 GHz to 300 MHz: measurement is easier, E-field or H-field or energy (power density) power meter may be used. The units of power used is mW/cm².
Microwaves and Radiowaves

- 300 MHz to 100 MHz: measure E field and H field.
- A different antenna must be used for each measurement.
- The strength of the average electric field is expressed in Volts$^2$/meter$^2$.
- The strength of the average magnetic field is expressed in Amperes$^2$/meter$^2$.

Types of RF Measurements

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 GHz–300 MHz</td>
<td>E or H or W: spatial average</td>
</tr>
<tr>
<td>300 MHz–100 MHz</td>
<td>E &amp; H: spatial average</td>
</tr>
<tr>
<td>100 MHz–3 kHz</td>
<td>E &amp; H: spatial average $^A$</td>
</tr>
<tr>
<td></td>
<td>Induced currents</td>
</tr>
<tr>
<td></td>
<td>Contact currents $^B$</td>
</tr>
</tbody>
</table>

$^A$ Consideration should be given to remote monitoring of low-frequency E fields, since the evaluator’s body may significantly perturb these fields.

$^B$ Only required if there are conductive objects that may contain/store RF energy as an electrical current.
Microwaves and Radiowaves

- Current TLV recommendation: between 30 and 100 Hz, power density = 1 mW/cm².
- Near field: Electric field 200 V/meter, magnetic field .5 amperes/meter.
- This TLV is defined as a 6 minute (0.1 hour) time-weighted average.
Temperature Extremes

• The body must maintain a heat balance, under hot or cold conditions, to remain healthy.
  – Hypothermia refers to a reduced body temperature (below 35 degrees C).
  – Hyperthermia refers to an increased core body temperature (above 40.6 degrees C).

Temperature Extremes

• Maintenance of body temperature depends on Work level (metabolic energy), radiant heat load, convective heat load, and evaporation loss.
Metabolic Load

• Metabolic load depends on the intensity of work. It can be measured by the oxygen consumption by the body.
• One liter of oxygen is equivalent to a metabolic load of 5 kcal.
• At rest, an average man consumes about 0.3 liters of oxygen per minute, or 1.5 kcal/min.

Metabolic Load

• There is relatively little variation between people for metabolic load at rest, but wide variation may exist for increasing work loads, depending on conditioning, body size, and other factors.
  – Oxygen consumption can be estimated for various tasks, based upon published information on oxygen consumption for various tasks.
Convective Load

• Convective heat load: If air temperature is greater than skin temperature, then heat is absorbed by the body; if air temperature is lower than skin temperature, heat will be lost by the body.
  – \( C = 0.756 \, V^{0.6} \, (T_{air} - 95 \, ^\circ F) \)

Radiant Load

• Radiant heat load: Heat exchange between the body and physical environment.
• Mean radiant temperature can be measured using a globe thermometer (a thermometer inside a black ball). Also referred to as Globe Temperature
  – \( R = 17.5 \, (GT - 95 \, ^\circ F) \)
Evaporative Cooling

• Evaporation of sweat or water on the skin is an important way to cool the body.
• The ability of the body to cool itself through sweating is primarily limited by water content in the surrounding air.
  • $E_{max} = 2.8 V^{0.6} (42 \text{ mm Hg} - P_{H2O})$

Heat Balance

• $E_{max} = M \pm C \pm R$
• Heat load on a person can be calculated, if all these variables are known.
• An alternative method is to measure the body core temperature, which can also be difficult.
Heat Stress Index

- Heat Stress Index is the ratio of Evaporation required to Maximal evaporation.
- HSI = $E_{req} / E_{max}$
- The Heat Stress Index can be evaluated using a table, and can include cold as well as heat stress.

Wet Bulb Globe Temperature

- Both NIOSH and ACGIH have developed recommended heat stress standards based on **Wet Bulb Globe Temperature, WBGT**
- Outdoors, in sunlight:
  - $WBGT = 0.7 \text{WB} + 0.2 \text{GT} + 0.1 \text{DB}$
- No solar load:
  - $WBGT = 0.7 \text{WB} + 0.3 \text{GT}$
Heat Disorders

• Heat stroke: body temperature becomes so high, body organs may be damaged. High body temperature, cessation of sweating (hot dry skin)

Heat Disorders

• Heat syncope: fainting while standing erect under hot conditions.
• Heat exhaustion: fatigue, nausea, clammy skin, etc.
• Heat cramps
• Heat rash
• Heat fatigue
Control of Heat Disorders

- Acclimatization: workers should be allowed time to get used to the heat. Over a period of one to two weeks, persons become more used to hot conditions, and bodies become less stressed by heat exposure.

- Reduce metabolic load, if possible (limited option)
- Adjust other factors, depending on conditions and the source of the heat load.
Heat Illness Prevention
Title 8 Section 3395

This and several slides following downloaded from Cal/OSHA Consultation Service 2008

Heat Illness Prevention
“Safety Basics”

- POTABLE DRINKING WATER
- SHADE ALLOWING THE BODY TO COOL
- PREVENTATIVE RECOVERY PERIODS
- EMPLOYEE/SUPERVISOR TRAINING
- WRITTEN PROCEDURES
Enforcement Experience
25 Serious Heat-Related Illnesses
May – November 2005

- Agriculture 38%
- Construction 29%
- Service 12.5%
- Transportation 12.5%
- Public Safety 8%

What was discovered...

- 68% of employees spoke Spanish
- Ages 17 to 76 yrs
- 84% of cases involved outdoor work
- 92% of work was moderate \(\Rightarrow\) strenuous
- 46% of cases happened the \textbf{1st day} on the job
- 36% required hospitalization for more than 24hrs
- 54% of cases resulted in death of the employees
Environmental & Physiological Factors

- Average
  - Ambient air temperature 96º F (75 - 116º F)
  - Humidity 29% (12% - 55%)
  - Wind speed 7mph
  - Core body temperature 104º F (98 - 108º F)

Worksite Conditions

- Potable water present - 100% of cases
- Shade available - 77% of cases
- 80% of employers had a written IIPP
- 20% had written Heat Illness Prevention Policy
- 36% had an Emergency Action Plan
Worksite Conditions

- Heat Wave - a sudden and temporary rise of temperature above the seasonal average for a particular region, which last for a prolonged period of time

- Greatly increases the risk of heat illnesses

Note: Direct Relationship Between Temps and Number of Reported Cases 84% of the Cases Occurred During the July 2006 Heat Wave
Figure 22: Displays the average temperature (°F) for July 2006, and the departure from normal. As expected, anomalies warmer than normal were recorded across much of the state of California. Peak readings ranged from 6°F to 8°F.

Worksite Conditions

Heat Illness Prevention During Heat Waves

- Take Extra Measures - *More Vigilance*
  - Supervisors/employees watch each other very closely & provide more frequent feedback
  - Avoid working alone - “buddy system”
  - Designate person - closely monitor/report employees conditions
  - Account for employee whereabouts throughout the work shift and end of the day
Worksite Conditions

Heat Illness Prevention During Heat Waves

- Take Extra Measures - More Water
  - Employees should drink small quantities of water more frequently before, during and after work
  - Effective replenishment of extra supplies of water
  - Encourage employees to consult with their doctor on salt/mineral replacement

Worksite Conditions

Heat Illness Prevention During Heat Waves

- Take Extra Measures - More Cooling
  - Use other cooling measures in addition to shade
  - Spraying body with water/wiping with wet towels
  - Additional/longer breaks in the shade
Worksite Conditions

Heat Illness Prevention During Heat Waves

- **Take Extra Measures - Change Schedule**
  - Start work earlier or later in the evening
  - Split-up work shifts - avoid working in hotter parts of the day
  - Cut work shifts short or stop work

- **Take Extra Measures - Change Meals**
  - Encourage employees to:
    - Eat smaller/more frequent meals (less body heat during digestion than with big meals)
    - Choose foods with higher water content (for example, fruits, vegetables, salads)
Worksite Conditions

Heat Illness Prevention During Heat Waves

- **Acclimatization Warning**
  - Even employees previously fully acclimatized are at risk for heat illness
  - Body needs time to adjust to sudden, abnormally high temperatures or other extreme conditions

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Heat Illness Prevention
3395(a) Scope and Application

Applies to the control of risk of occurrence of heat illness in all outdoor places of employment

Does not exclude other Title 8 requirements, such as, IIPP, drinking water, first aid
Cold conditions

• Body handles cold by reducing heat loss (restrict blood flow near the skin) and increasing metabolic heat generation (increase glucose in blood, which increases heart rate). Shivering is a state of involuntary muscle contractions that generate heat.

Cold illnesses

• Cold Illnesses include hypothermia (reduced body temperature), blood vessel problems (e.g. Raynaud's phenomenon), frostbite, trench foot, frost nip.
Protection against cold stress

- Acclimatization may be helpful, but is limited in effectiveness.
- Prevent dehydration from water loss due to loss through skin and exhaled breath. (Often cold air is very dry.)

Protection against cold stress

- Engineering control: spot heating, reduce or block air flow from wind or refrigeration units, covering metal tool handles with insulating material, heated rest areas.
- Administrative control: work-rest schedule, warm beverages, buddy system. Protective clothing is also important.
Biological Hazards

• Work-related infectious diseases occur mostly in hospital or health-care workers. However, a significant amount of illness occurs in workers exposed to agricultural and construction dust, animals and insects. Also, workers working in research facilities (medical and biological engineering) may be at risk of exposure.

Biological Hazards

• Health care workers: most significant illnesses are AIDS and Hepatitis B.
  – Transmission of AIDS to US health care workers has been documented (about 10), but is rare. Concern due to high mortality rate.
  – Hepatitis B is much more common among health care workers, particularly those who treat populations with high incidence of Hepatitis B.
Biological Hazards

- Health care workers (cont.)
  - There is a vaccine to provide immunity from Hepatitis B: it is expensive, but should be provided for those at high risk of infection.
- Universal precautions
  - Work practices that are intended to prevent disease transmission from contact with blood or body fluids. Includes consideration of needle handling (puncture-resistant containers, do not recap, etc), wearing gloves and other protective gear, washing thoroughly after contact.

Biological Hazards

- Other workers: exposed to bacteria, viruses, fungi. Workers with greater probability of contact have increased risk of illness. Examples:
  - Encephalitis, transmitted by mosquitoes. Persons working outdoors, in areas where mosquitoes can breed, are at increased risk.
  - Psittacosis, caused by Chlamydia psittaci, is a hazard for pet shop workers, pigeon breeders, zoo workers and vets. Turkey processing plants have been the site of several reported outbreaks.
Biological Hazards

• Other workers (cont)
  – Coccidioidomycosis, or Valley Fever, is usually a benign condition resulting from exposure to Coccidioides immitis, a fungus found in many soils in the southwest. Most people will suffer flu-like symptoms which resolve after a week. In some cases, the disease spreads from the lungs throughout the body, and can be fatal.

Biosafety management

• Biosafety management: adjust work practices to level of risk of infection and pathogen hazard.
  – Biosafety Level 1: low risk, ordinary precautions like in microbiology lab.
  – Biosafety Level 2: moderate risk, PPE, training, biosafety labels, medical surveillance.
  – Biosafety Level 3: high risk, special design of lab and equipment used. More training and PPE
  – Biosafety Level 4: highest risk, no treatment (e.g. Ebola). Beyond scope of most oh professionals.