ALMUSTAQBAL UNIVERSITY COLLEGE
Iraq – Babylon

RENEWABLE ENERGY TECHNOLOGY

Sustainable Path For a Carbon Free Future

Refrigeration and Air conditioning Techniques Engineering Department

Subject : Renewable Energy

Grade: 4th Class

Lecture :2 Introduction of Radiation

Dr.Haleemah Jaber Mohammed

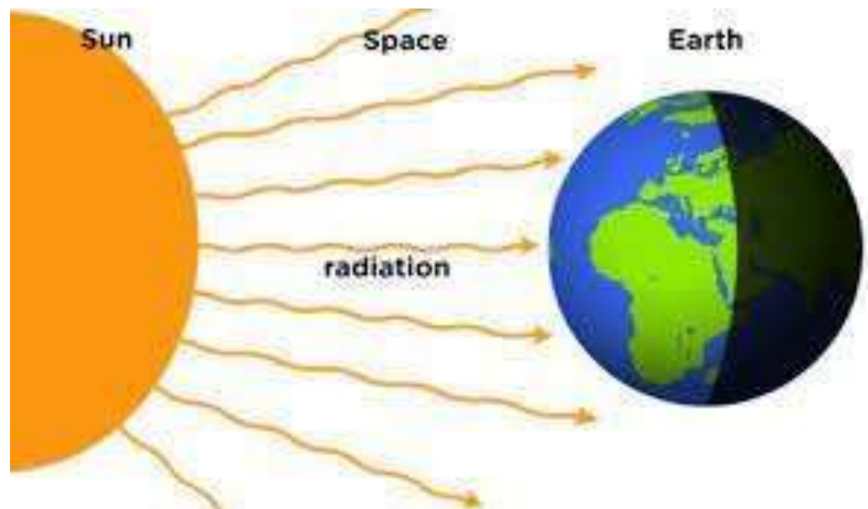
2023-2024

RADIATION

Radiation :Mode of Energy transfer by electromagnetic waves only mode to transfer energy without the presence of a substance (fluid or solid). works best in a vacuum (empty space

- Radiation = the only way for Earth to receive energy from the Sun

Weather systems are powered by radiation



From Earth-Sun geometry we know:

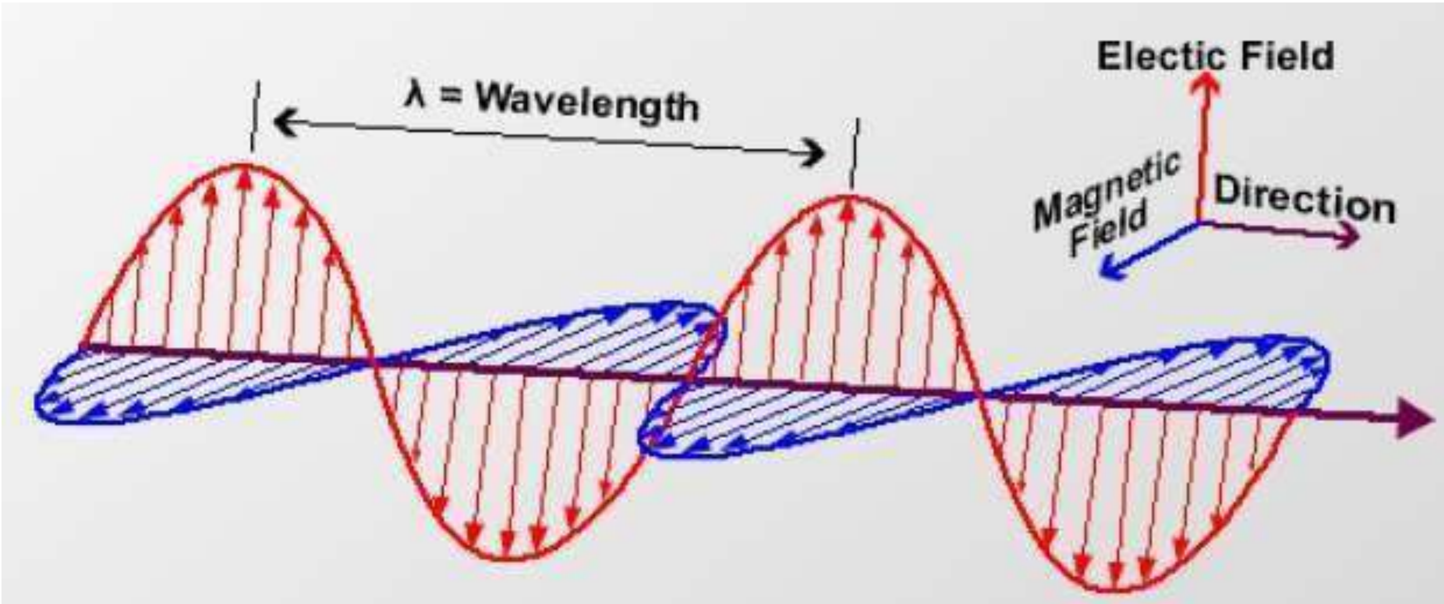
- Spatial and temporal variations of receiving of radiation at the top of the atmosphere

need to consider different types of radiation

2.1 Electromagnetic spectrum

- **Radiation waves exhibit characteristics of both electric fields and magnetic fields**
- **Electromagnetic radiation moves at “speed of light”**
- **Radiation spreads in all directions and moves in straight lines**

Electromagnetic radiation is described by three interdependent variables:



wavelength λ “lambda” [m, µm]
frequency ν “nu” [s-1, Hz]
velocity c [m s-1]
(c = “speed of light” ~ 3 × 108 m s-1)

The relation between the λ ,ν and c for each wave is :

$$\lambda \nu = c$$

2.2 Radiation Spectrum

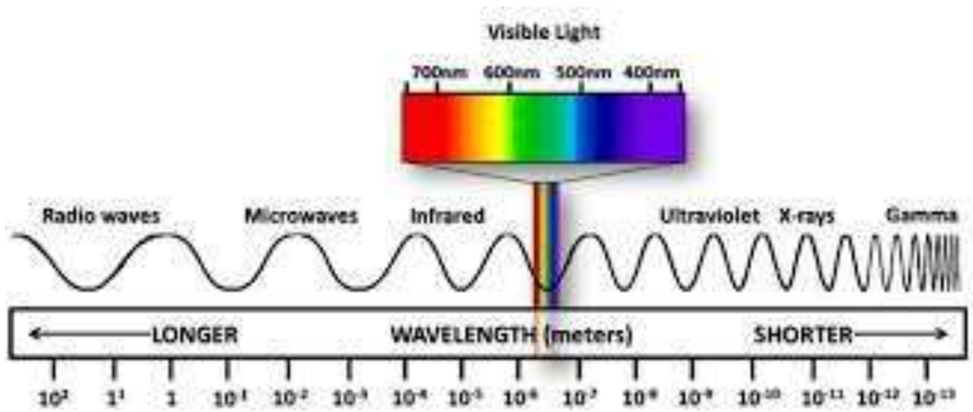
Definition:

The Radiation Spectrum is the distribution of radiative energy over different wavelengths, or frequencies.

In meteorology: only small part of EM- spectrum of interest.

- three important ranges:

- **ultraviolet radiation (UV)**
- **visible radiation**
- **infrared radiation (IR)**



2.2Radiation Spectrum

Radiation in the Earth-Atmosphere System

	Ultraviolet Radiation UV	Visible Radiation	Infrared Radiation IR	
Wavelength	10^{-2} – 0.4 μm	0.4 – 0.7 μm	0.7 – 100 μm	
Effect	Sunburn	"sunlight"	heat-radiation	
		0.4 μm violet blue 0.5 μm green yellow 0.6 μm orange 0.7 μm red	**near IR** 0.7-1.5 [μm]	**far IR** 1.5 – 100 [μm]
Class	← Shortwave radiation →			longwave radiation
sun output	7 %	43 %	37 %	11 %
Earth output	0 %	0 %	~0 %	~ 100 %

shortwave radiation: only solar radiation

longwave radiation: IR radiation emitted by the E/A-system

2.3- LAWS OF RADIATION

(iii)Reflection – Absorption – Transmission

part or all can be absorbed:
**→ fraction absorbed: absorptivity, **
→ this part raises the temperature of the object
→ radiative energy is converted to heat

part or all can be transmitted:
→ fraction transmitted: transmissivity, → this part does not interact with the object, it just goes through it.

Since these are the only possibilities, it follows from the principle of conservation:

$$\alpha_\lambda + a_\lambda + t_\lambda = 1$$

2.3- LAWS OF RADIATION

(iv) Stefan-Boltzmann Law:

the total emitted energy flux

All objects or substances emit radiation at a rate proportional to the 4th power of their absolute temperature

Total energy flux emitted: F_{tot} [W m-2]

:

$$F_{tot} = \varepsilon \sigma T^4$$

ε emissivity (0 ~ 1); depends on quality of material .
σ Stefan-Boltzmann constant = 5.67 × 10^-8 [W m-2 K-4] T absolute temperature of emitting object [K]
T ^4 fourth power: faster than linear increase with temperature.

2.3 LAWS OF RADIATION

Example:1

If a cloud bottom has a temperature of –10 °C, how much energy would it be emitting if the emissivity were 1.0?

Solution •

convert temperature to SI-unit: [°C] → [K] T = (-10 °C) + 273.15 = 263.15 K

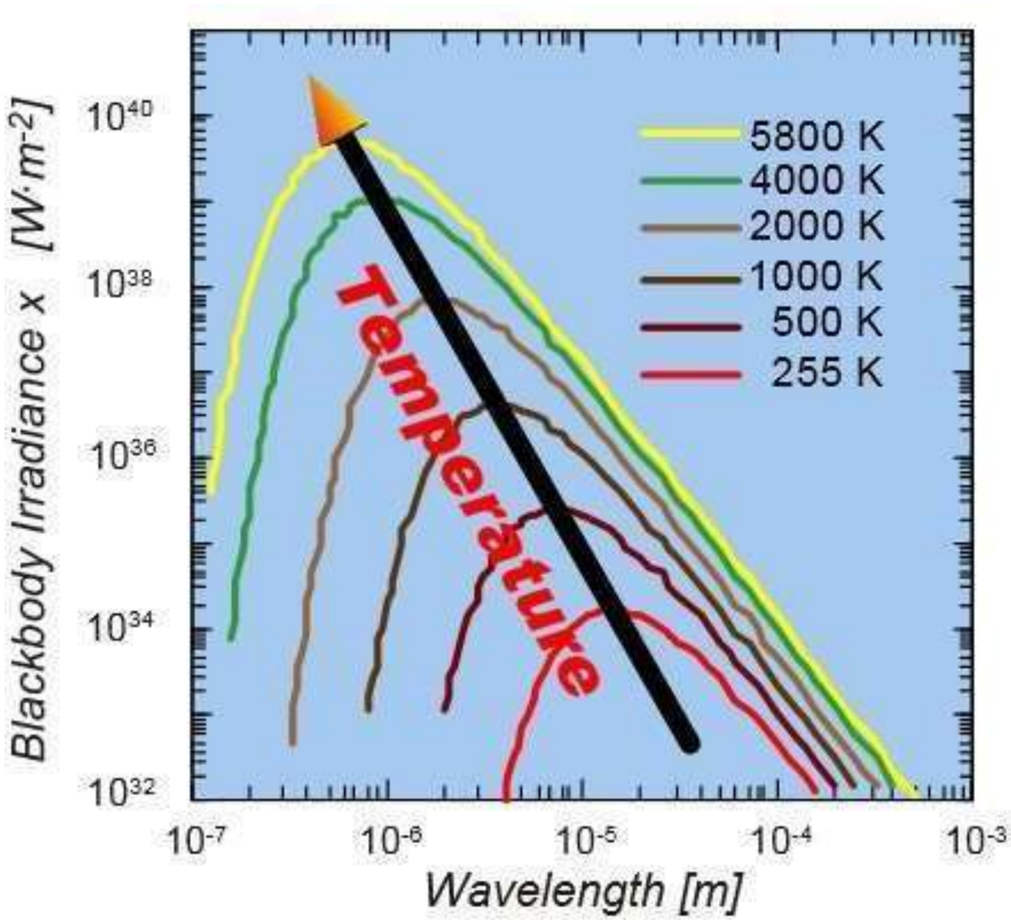
• use Stefan-Boltzmann law for ε = 1 (black body): $F_{cloud} = \varepsilon \cdot \sigma \cdot T^4 = 1 \times 5.67 \cdot 10^{-8} \times (263.15)^4$

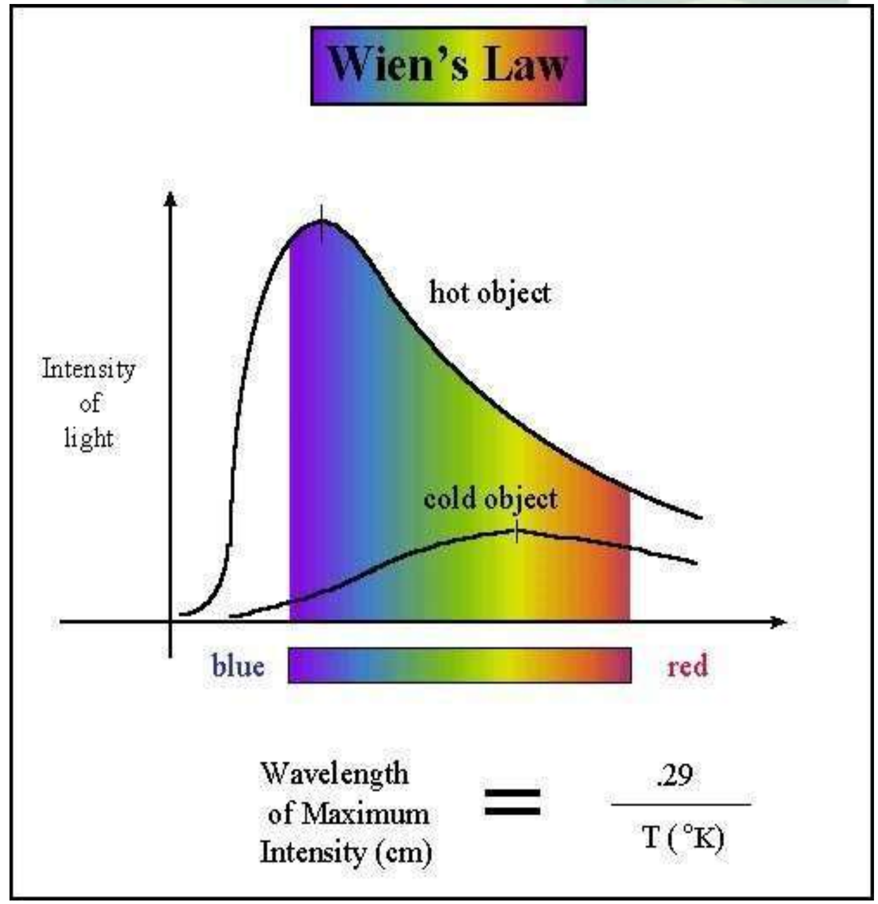
$$= 271.9 \text{ W m}^{-2}$$

Check units: units okay – physics okay.

[ε·σ·T4] = [1] x [W m-2 K-4] x [K4] = [W m-2]

3.3- LAWS OF RADIATION





3.3 -LAWS OF RADIATION

Example: 2

If a cloud bottom has a temperature of -10°C what is the wavelength of the peak energy emission? What part of the electromagnetic spectrum is this in?

Solution

- convert temperature to SI-unit: [°C] → [K]

T = (-10 °C) + 273.15 = 263.15 K

- use Wien's law:

λ_{max} = a·T^-1 = 2898 ÷ 263.15 = **11.0 µm**

Check units: units okay – physics okay. [a·T-1] = [µm·K] x [K-1] = [µm] 9

4- ATMOSPHERIC INFLUENCES ON RADIATION

Introduction

Global Shortwave Radiation Balance (overview)

~ 30 % of solar radiation is reflected by clouds, atmospheric gases and the surface

~ 25 % of solar radiation is absorbed by the atmosphere (clouds, atmospheric gases, aerosol)

~ 45 % of solar radiation is absorbed by the surface (oceans, land surface)

Influence of Clouds on Shortwave Radiation Balance

- Clear conditions (no clouds):
  - ~ 70 % of solar radiation is absorbed by the surface (55% direct, 15% diffuse sky radiation)
  - only ~ 13 % of solar radiation is reflected
- Cloudy conditions (overcast):
  - ~ 25 % of solar radiation is absorbed by the surface (4% direct, 21% diffuse sky radiation)
  - 51 % of solar radiation is reflected