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

Dr. Eng. Azher M.Abed

E-email : azhermuhson@gmail.com

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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 التغيرات المكانية والزمانية في استقبال الإشعاع في أعلى الغلاف الجوي

➢ need to consider different types of radiation

2.1 Electromagnetic spectrum

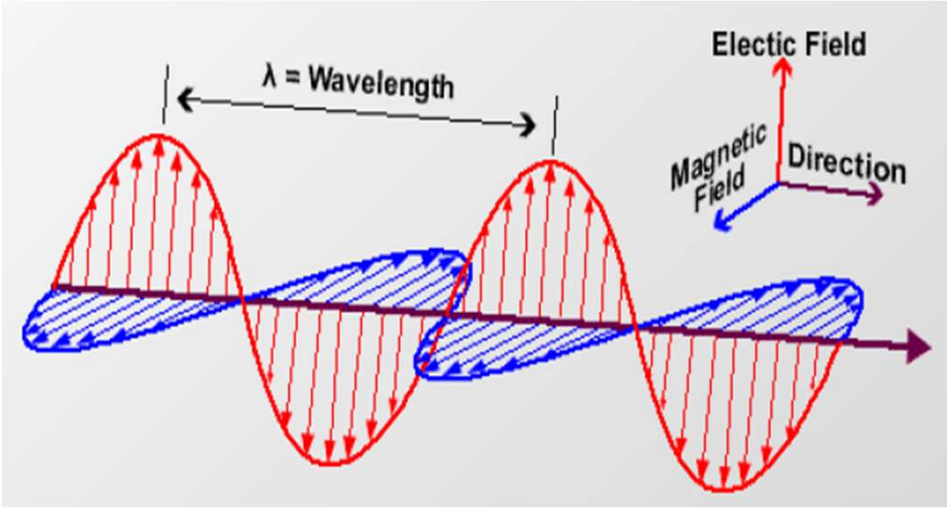
- Radiation waves exhibit characteristics of both electric fields and magnetic fields
- Electromagnetic radiation moves at "speed of light"
- Radiation spreads in all directions and moves in straight lines

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 ,v 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.

الطيف الإشعاعي هو توزيع الطاقة الإشعاعية على أطوال موجية مختلفة، أو الترددات

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

- three important ranges:

- ultraviolet radiation (UV) — الأشعة فوق البنفسجية
- **visible** radiation — الإشعاع المرئي
- infrared radiation (IR) — الأشعة تحت الحمراء

2.2 Radiation 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

2. part or all can be **absorbed**:

→ fraction absorbed: absorptivity, a_λ

→ this part raises the temperature of the object

→ radiative energy is converted to heat

3. part or all can be transmitted:

→ fraction transmitted: transmissivity, t_λ

→ 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.

ينص قانون ستيفان بولتزمان على أن الطاقة الكاملة المنبعثة من الجسم الأسود واط في الثانية لكل وحدة مساحة تتناسب مع القوة الرابعة لدرجة حرارة الجسم كلفن

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):

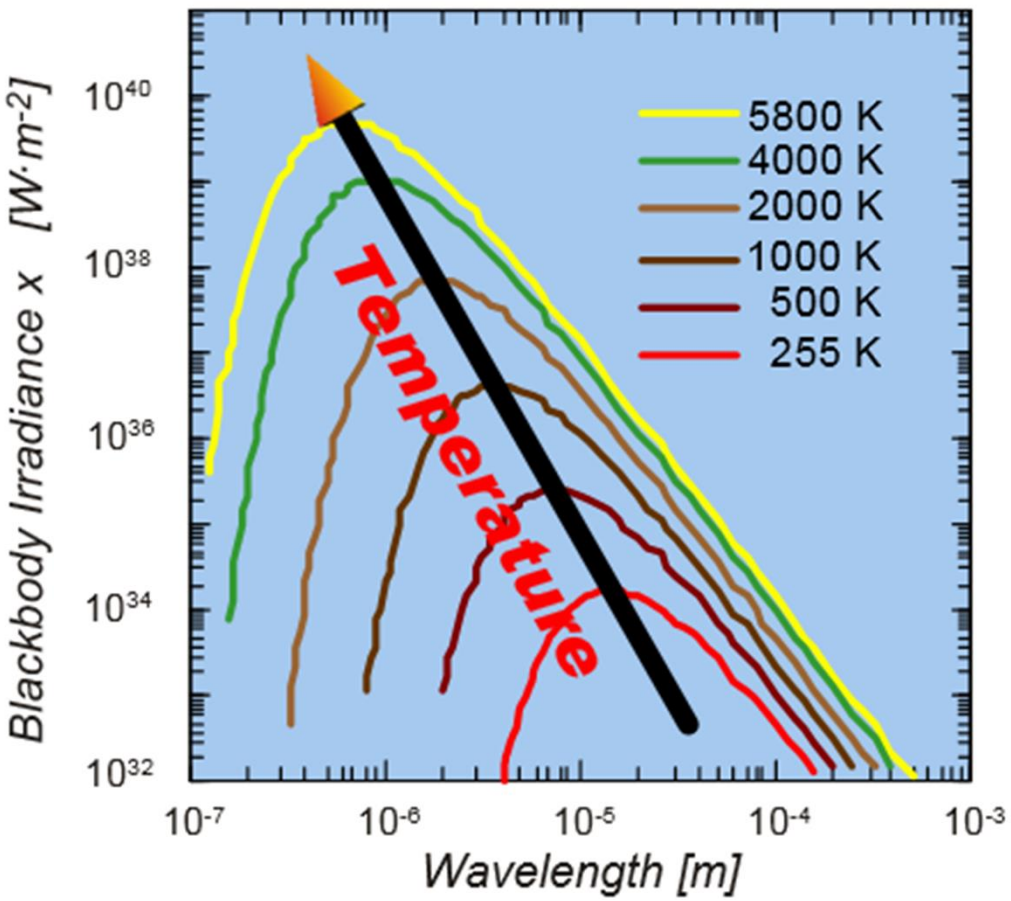
$F_{cloud} = \varepsilon \cdot \sigma \cdot T^4 = 1 \times 5.67 \cdot 10^{-8} \times (263.15)^4$

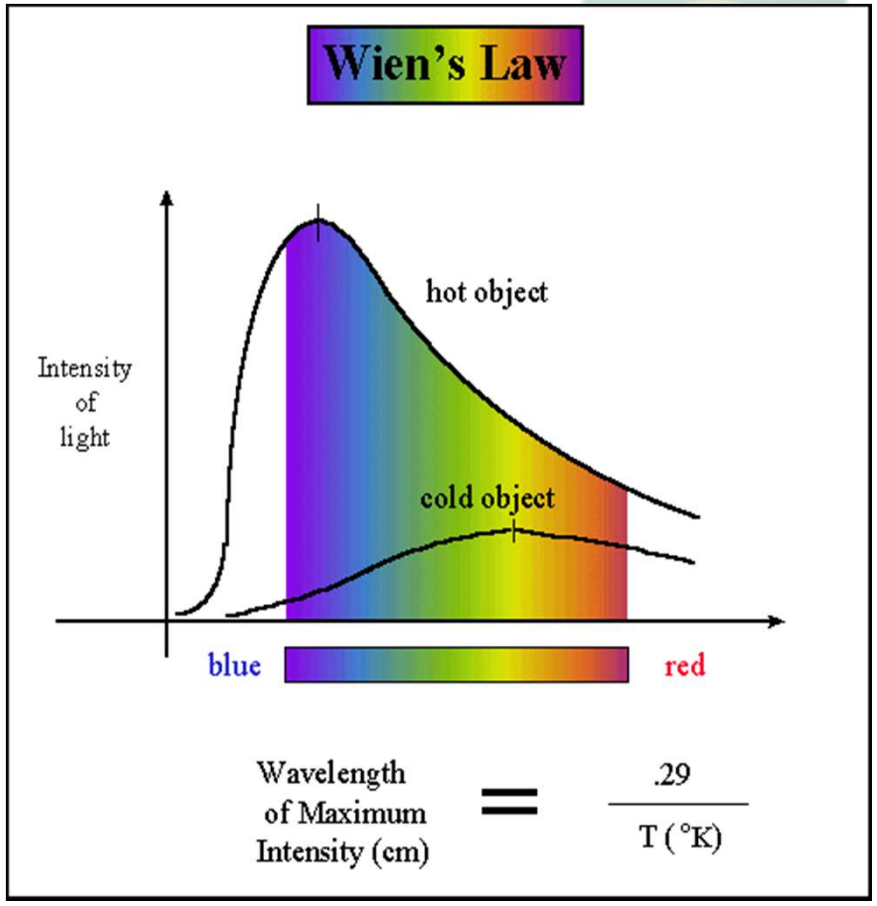
$= \mathbf{271.9\ W\ m^{-2}}$

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

1. 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