1) **Electromagnetic radiations are characterized by their wavelength (λ) or frequency (ν). Order the following electromagnetic radiations in order of <u>INCREASING FREQUENCY</u>.**
   - **i) Visible blue light**
   - **ii) Visible red light**
   - **iii) Infrared**
   - **iv) Gamma rays**
   - **v) Radio waves**
   - **vi) Ultraviolet**

2) **The absolute temperature of Sun A is two times higher that the temperature of sun B. Remembering that Stephan-Boltzmann law states that the flux of electromagnetic radiations emitted by the sun per unit area (F_{sun}; W/m^2) is proportional to the 4th power of its absolute temperature (T_{sun}):**

$$F_{sun} = \sigma (T_{sun})^4$$

Which of the following is TRUE?

   - **A) both suns emit the same energy flux per unit surface area**
   - **B) Sun B emits an energy flux per surface area two times larger than Sun A**
   - **C) Sun A emits an energy flux per surface area two times larger than Sun B**
   - **D) Sun A emits an energy flux per surface area 16 times larger than Sun B**
   - **E) Sun A emits an energy flux per surface area 4 times larger than Sun B**

3) **As we will see in the following lectures, 4.5 billion years ago, the sun was emitting 30% less radiation than today (F_{today}). Was the sun's surface 4.5 billion years ago (i) hotter, (ii) colder or (iii) cannot say. How would you calculate its temperature (T) 4.5 billion years ago?**

   - **A) Cannot say; we cannot calculate its temperature**
   - **B) Hotter; $T = \lambda_m/w$ (Wien's law)**
   - **C) Colder; $T = [F_{today}/\sigma]^{0.25}$ (Stephan-Boltzmann's law)**
   - **D) Colder; $T = [(0.7xF_{today}/\sigma)]^{0.25}$ (Stephan-Boltzmann's law)**
   - **E) Colder; T was 30% lower than today**

4) **Let's consider two solar systems (X and Y) with only one planet each. The two suns have the same surface temperature and the same size. The planet in solar system X (planet Px) has a radius two times larger than the planet in solar system Y (planet Py) but both planets are orbiting at equal distance from their respective sun. Which of the following statements is TRUE?**

   - **i) The solar constant of planet Px is twice that of planet Py or..**
   - **ii) The solar constant is the same for both planets**

iii) Planet Px intercepts four times more solar energy than planet Py or..
iv) Both planets intercept the same amount of solar energy or..
v) Planet Px intercepts twice the amount of solar energy intercepted by Py

vi) The average amount of solar energy received per m^2 by Planet Px is the same as that received planet Py or..
vii) The average amount of solar energy received per m^2 by Planet Px is twice that received planet Py

A) i, iii and vii are true
B) ii, iv and vi are true
C) i, iv and vii are true
D) ii, iii and vi are true
E) i, v and vii are true

5) Let's consider planet X with an orbit radius twice as large as that of Earth. How different would its "Solar Constant" be from that of Earth?

A) two times higher
B) two times lower
C) four times higher
D) four times lower
E) the solar constant would stay the same

6) Knowing that this same planet X has a radius twice as large as the Earth's, how much solar energy would planet X intercept compared to the Earth?

A) Planet X would intercept the same amount of solar radiation as the Earth
B) Planet X would intercept two times more solar radiation than the Earth
C) Planet X would intercept half the amount of solar radiation intercepted by the Earth
D) Planet X would intercept four times more solar radiation than the Earth
E) Planet X would intercept four times less solar radiation than the Earth

7) The upper atmosphere of planet W receives 100 W/m^2 of solar energy. It is covered by ice and its albedo is 90%. What is the flux of solar radiation absorbed by planet W?

8) The most important contributor to Earth's albedo are:

A) Clouds
B) Ice sheets
C) Oceans
D) Deserts
E) Forests

9) For each of these pairs of Earth's surfaces, which has the highest albedo?

i) **Sea ice vs. seawater**
ii) **Deserts vs. tropical forests**
iii) **Grassland vs. deserts**
iv) **Old melting snow vs. fresh snow**

10) The effective radiating temperature of Earth is:

i) **the mean temperature of the Earth's surface (true/false?)**
ii) **the temperature of the upper atmosphere (true/false?)**
iii) **above 0°C (true/false?)**
iv) **the mean temperature of the Earth's surface if there were no greenhouse gases in the atmosphere (true/false?)**

11) If you want to calculate the effective radiating temperature of a planet Pz orbiting around sun Z, which of the following information do you NOT need?

A) **The temperature and size of sun Z to calculate the amount of solar radiation emitted by sun Z**
B) **The distance between sun Z and planet Pz to calculate the solar constant of planet Pz**
C) **The albedo of planet Pz to calculate the amount of solar radiation absorbed by planet Pz, which dictates the amount of energy that must be emitted by Earth to outer space to keep its temperature constant**
D) **The concentration of greenhouse gases in the atmosphere of planet Pz to evaluate the extent of greenhouse warming on its surface**

12) The temperature of Sun A, B and C is 8000°K, 6000°K and 5000°K, respectively. The wavelength of maximum emission has been measured for each sun but the scientist who did the measurements forgot to label the data. The wavelength of maximum emission measured were:

i) **0.48 μm**
ii) **0.58 μm**
iii) **0.36 μm**

Match the three suns with their correct wavelength of maximum emission

13) Which of the three suns above emits more ultraviolet radiations?

14) Which ONES of these gases are not a greenhouse gases?

i) **Carbon dioxide (CO_2)**
ii) **Nitrous oxide (N_2O)**
iii) **Nitrogen (N_2)**
iv) **Methane (CH_4)**
v) **Water vapor (H_2O)**
vi) **Oxygen (O_2)**
vii) **Ozone (O_3)**
viii) **Freon-11 (CCl_3F)**

15) Which is the most abundant greenhouse gas in the atmosphere today?

A) Carbon dioxide (CO_2)
B) Nitrous oxide (N_2O)
C) Nitrogen (N_2)
D) Methane (CH_4)
E) Water vapor (H_2O)

16) Match each problem (i to iv) with the equation needed to solve it (a to d)

i) Calculate the flux of electromagnetic radiations emitted by a radiating object
ii) Calculate the wavelength of maximum intensity of electromagnetic radiations emitted by a radiating object
iii) Calculate absolute temperature
iv) Calculate the flux of solar energy intercepted by the Earth

a. = °C + 273
b. = Solar Constant x π(radius of Earth)^2
c. = Stefan-Boltzmann's constant x (absolute temperature)^4
d. = Wien's constant / absolute temperature

17) Which ones of these statements are TRUE?

i) Earth emits infra-red radiations to outer space
ii) Earth emits ultraviolet radiations to outer space
iii) Earth reflects solar radiations to outer space
iv) The electromagnetic radiations emitted by the sun have higher frequencies than the electromagnetic radiations emitted by Earth
v) The electromagnetic radiations emitted by the sun have longer wavelengths than the electromagnetic radiations emitted by Earth

18) Which ONE of these statements is FALSE?

A) The Earth's atmosphere is very transparent to visible light and very opaque to infrared radiations
B) Ultraviolet radiations are strongly absorbed by the Earth's atmosphere
C) The Earth's surface transfer energy to the atmosphere only in the form of infrared radiations
D) Water evaporation and condensation is an important means whereby the Earth's surface transfer heat to the atmosphere
E) Latent heat is released to the atmosphere when water vapor condenses to produce clouds

19) The upper atmosphere of Planet Y receives 200 W/m2 of solar energy. Its albedo is 20%. (i) How much solar radiation is absorbed by the planet? (ii) What is its effective radiative temperature?

A) (i) 200 W/m^2 x 1.2 = 240 W/m^2
(ii) T_e = (240 Wm^{-2} / 5.67 10-8 Wm^{-2} k^{-4})$^{0.25}$ = 255°K (-18°C)

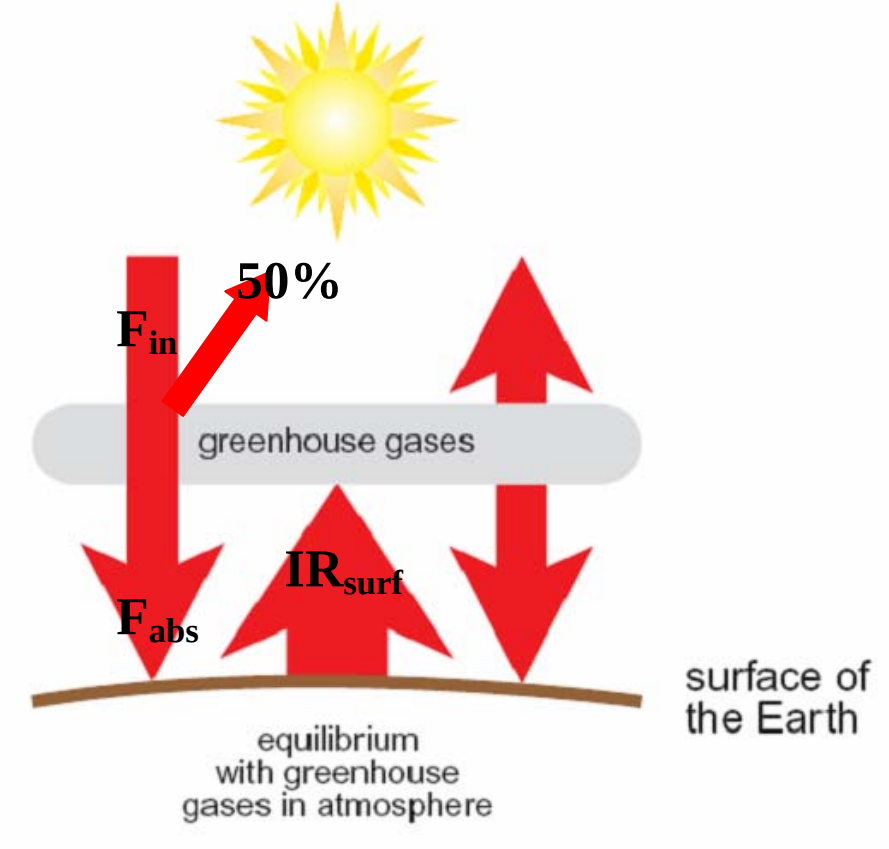
B) (i) 200 W/m^2 x 0.2 = 40 W/m^2
(ii) T_e = (40 Wm^{-2} / 5.67 10-8 Wm^{-2} k^{-4})$^{0.25}$ = 163°K (-110°C)

C) (i) 200 W/m^2 x 0.8 = 160 W/m^2
(ii) T_e = (200 Wm^{-2} / 5.67 10-8 Wm^{-2} k^{-4})$^{0.25}$ = 244°K (-29°C)

D) (i) 200 W/m^2 x 0.8 = 160 W/m^2
(ii) T_e = (160 Wm^{-2} / 5.67 10-8 Wm^{-2} k^{-4})$^{0.25}$ = 230°K (-43°C)

20) Considering the Earth's effective radiating temperature is – 18°C (i) is the wavelength of maximum emission of the above planet Y longer, shorter or the same as Earth's? (ii) If deserts gradually were to replace forests on planet Y, would the effective radiating temperature of planet Y decrease, increase or stay the same?

21) Using this simplified diagram illustrating global warming for planet P and knowing that:
- **its solar constant is 2000 W/m^2**
- **its albedo is 50%**



What is the flux of solar radiation reaching the top of planet P's atmosphere (F_{in})?

i) **2000 W/m^2**
ii) **500 W/m^2**
iii) **1000 W/m^2**

What is the flux of solar radiation absorbed by planet P (F_{abs})?

iv) **1000 W/m^2**
v) **250 W/m^2**
vi) **500 W/m^2**

What is the flux of infrared radiation emitted by the surface of planet P (IR_{surf})?

vii) **2000 W/m^2**
viii) **1000 W/m^2**
ix) **500 W/m^2**

22) Which of these does NOT contribute to cooling the surface of Earth?

i) **Absorption of some solar ultraviolet radiations by the atmosphere**
ii) **Leakage to outer space of some infrared radiations emitted by the Earth's surface**
iii) **Transfer of latent and sensible heat from the surface to the atmosphere**
iv) **Increasing the Earth's albedo**

A) i
B) ii
C) iii
D) iv
E) None (i.e. all contributes to cooling the Earth's surface)

23) Which ONE(S) is(are) TRUE? Energy is transferred from the Earth's surface to its atmosphere in the form of:

i) **Infrared radiations**
ii) **Latent heat of vaporization**
iii) **Ultraviolet radiations**
iv) **Sensible heat**

24) Which ONE of these statements is FALSE?

A) Heat is transferred from the Earth's surface to the bottom of the atmosphere by contact. The resulting convection carries this heat higher up in the atmosphere
B) A fraction of the solar radiations absorbed by the Earth's surface vaporizes water and the resulting water vapor is released into the lower atmosphere
C) As bottom air warms by contact, it expands, rises (because its density decreases) and cools
D) As warm air rises, expands and cools, the water vapor it contains condenses, forming clouds
E) Upon cloud formation, heat is removed from the air, which then cools and sinks back toward the surface