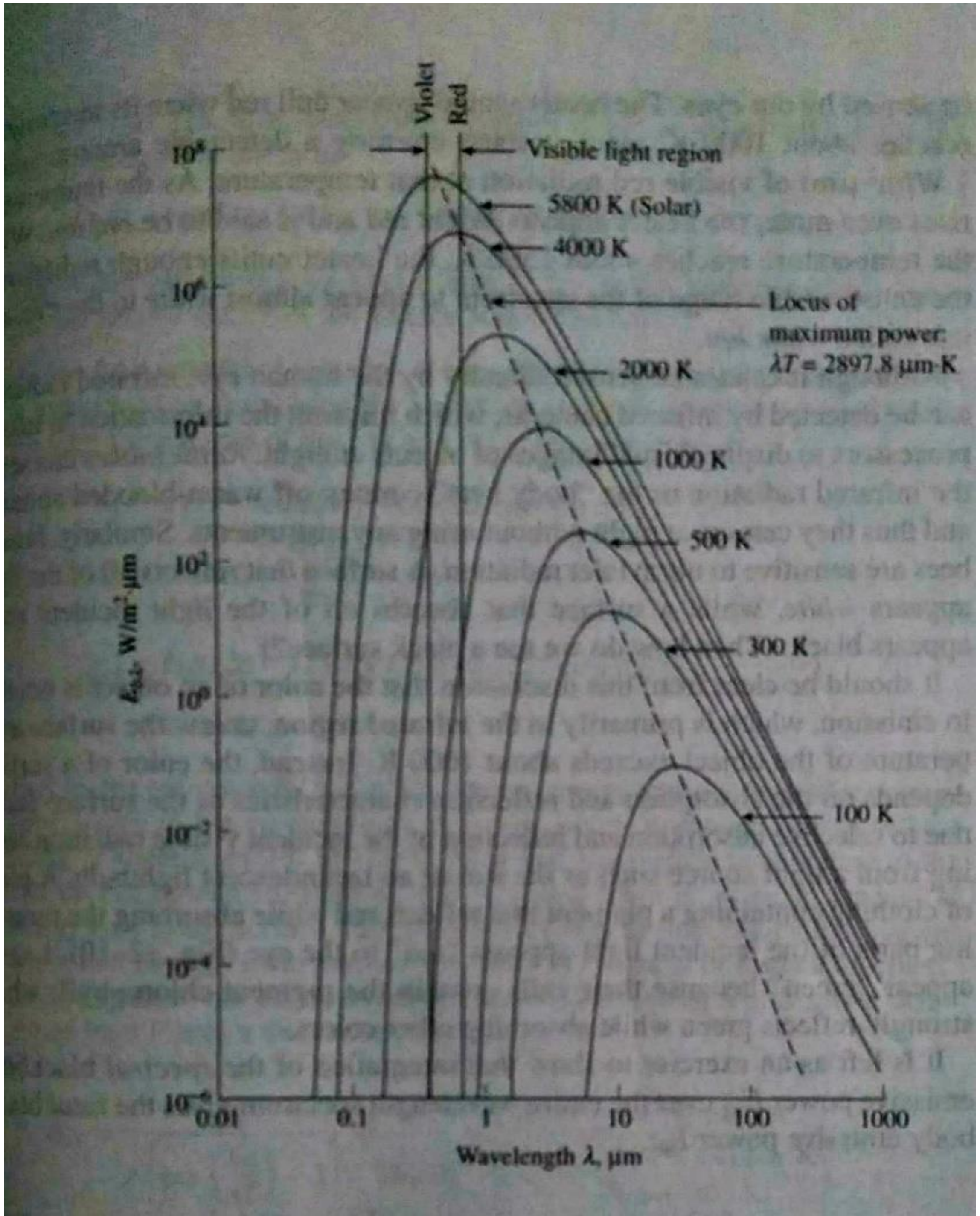
RADIATION HEAT TRANSFER

Planck’s Law

- Emitted radiation is a function of wavelength
- At any temp, it increases with wavelength, reaches a peak, and then decreases with increasing wavelength
- At any wavelength, emitted radiation increases with temperature
- At higher temps larger fraction of the radiation is emitted at shorter wavelength
- At 5800K, the solar radiation reaches its peak in the visible region.
- The wavelength at which the peak occurs for a specified temp is given by **Wien’s displacement law** as

$$\lambda_{max} . T = \text{Constant} = 2898\ \mu m.K$$



Wein's Displacement Law

- **Wein's displacement law** states that "the product of absolute temp and the wavelength(λ_{max}) at which the emissive power is maximum is constant".

- This law suggests that λ_{max} **is inversely proportional to the absolute temperature.**

- So the maximum spectral intensity of a radiation shifts towards the shorter wavelength with rising temp.

Intensity of Radiation

- When a plane surface emits radiation, all of it will be intercepted by a hemispherical surface placed over it and the directional distribution of radiation is not uniform.
- So we need a quantity that describes the magnitude of radiation emitted in a specified direction in space called Radiation Intensity (I)
- **Intensity of Radiation** is defined as the rate of energy leaving a surface in a given direction per unit solid angle per unit area of the emitting surface normal to the mean direction in space.
- The direction of radiation is described in spherical coordinates in terms of **zenith angle(θ) and azimuth angle(ϕ).**

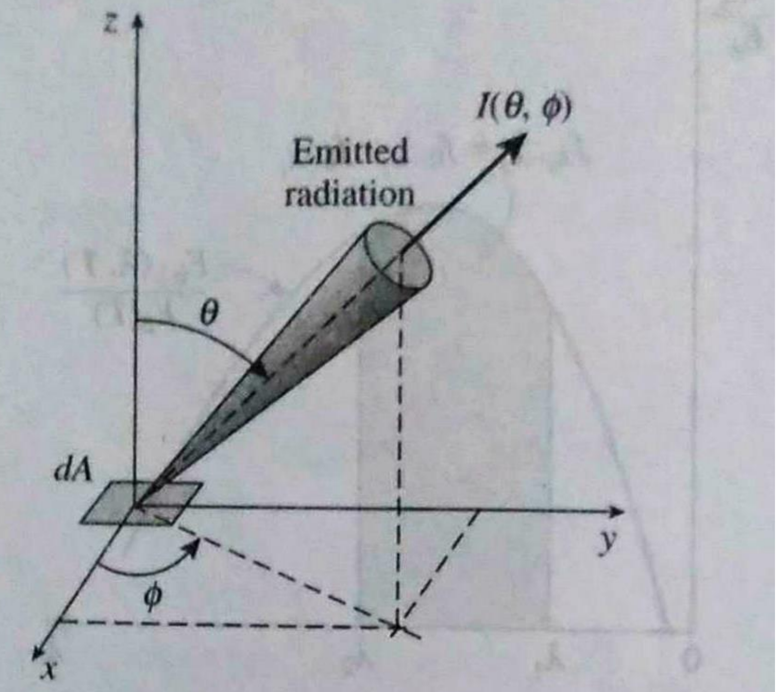


FIGURE 12–16
Radiation intensity is used to describe the variation of radiation energy with direction.

- For a diffusely emitting surface intensity of the emitted radiation is independent of direction and thus

I = constant.

- So fro a diffusely emitting surface: E = πI

- For a black body $E_b = \pi I_b$

- Ie, $I_b = \frac{E_b}{\pi} = \frac{\sigma T^4}{\pi}$

Solid Angle(ω)

- A solid angle is defined as a portion of the space inside a sphere enclosed by a conical surface with the vertex of the cone at the center of the sphere.
- It is denoted by ‘ω’ and its unit is steradian(sr).
- For a sphere ω = 4π sr. and for a hemisphere ω = 2π sr.
- The differential solid angle dω subtended by a differential area dS on a sphere of radius ‘r’ can be expressed as

$$d\omega = \frac{dS}{r^2} = \sin\theta \, d\theta \, d\emptyset$$

- Where dS is the area normal to the direction of viewing.

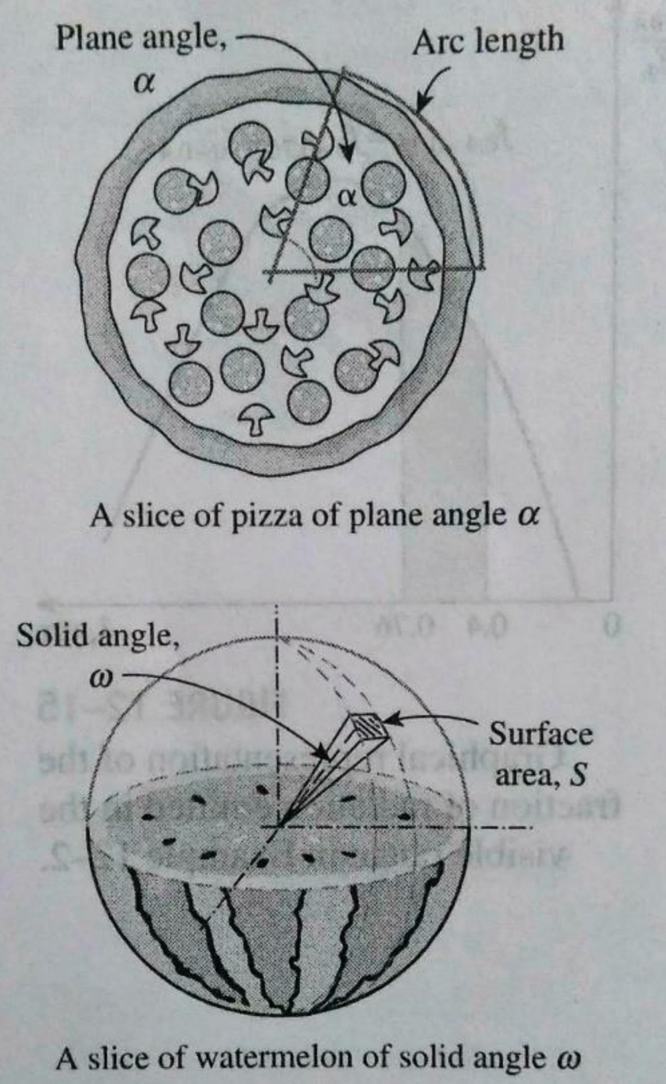
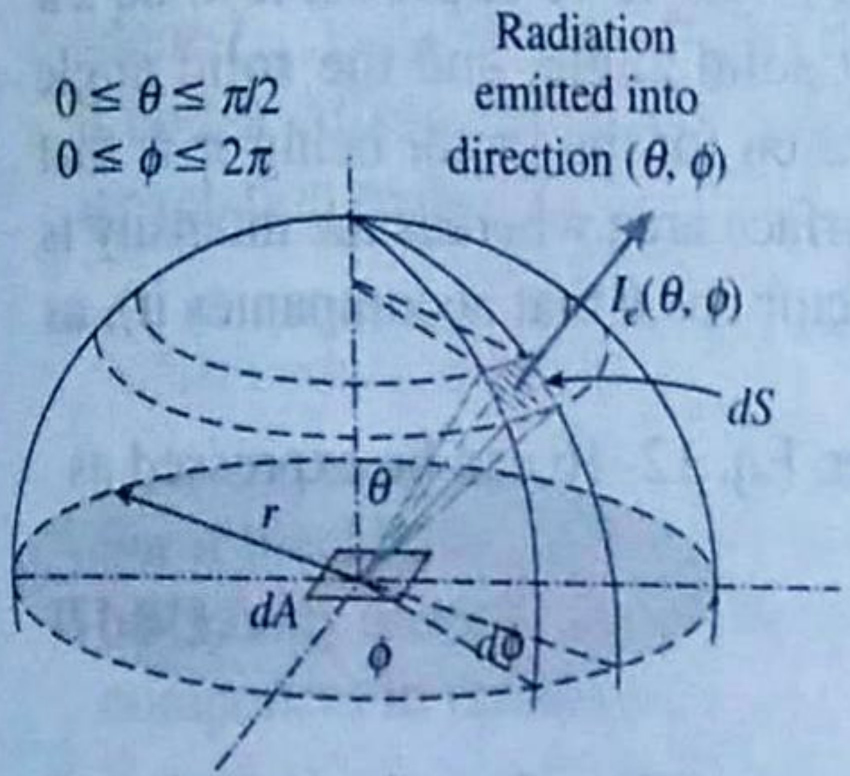
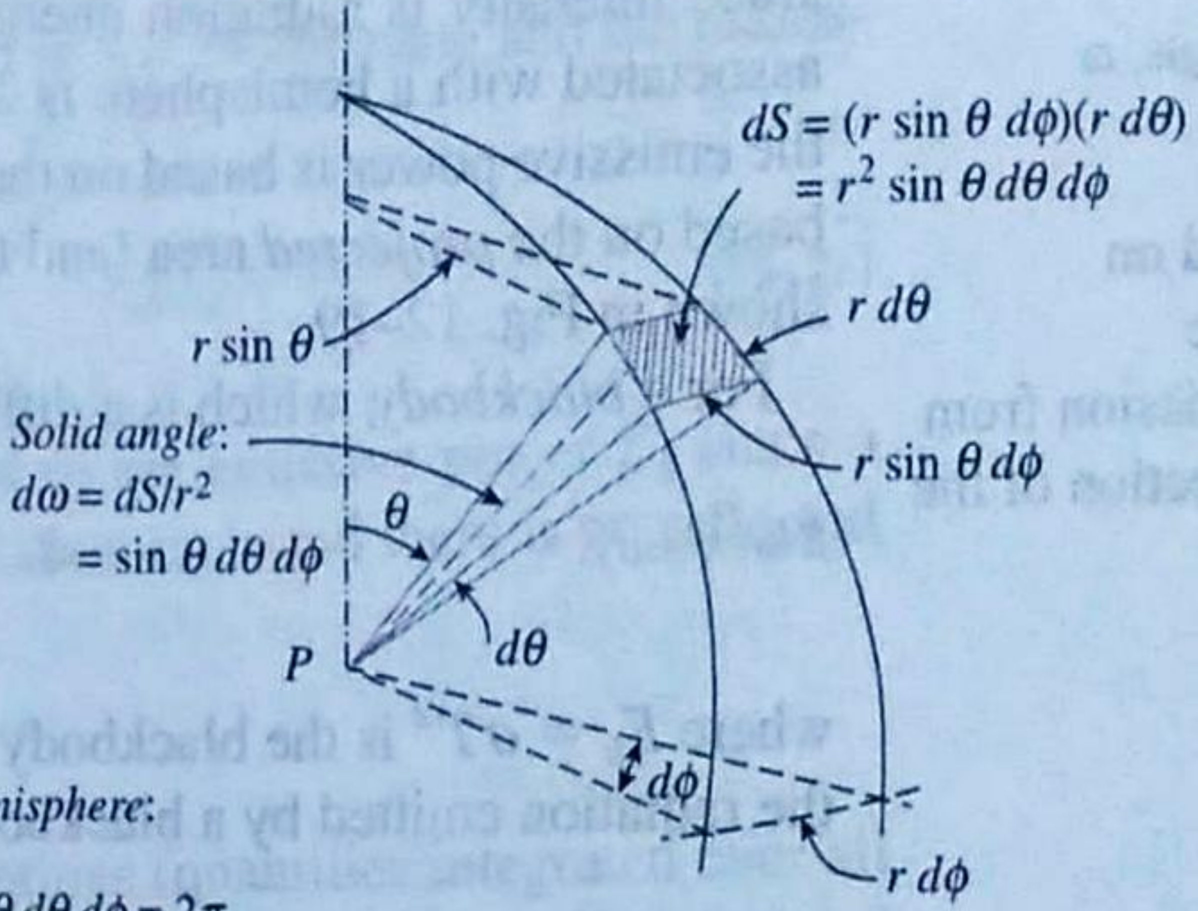


FIGURE 12–17
Describing the size of a slice of pizza by a plane angle, and the size of a watermelon slice by a solid angle.





Solid angle for a hemisphere:

$$\omega = \int_{\text{Hemisphere}} d\omega = \int_{\theta=0}^{\pi/2} \int_{\phi=0}^{2\pi} \sin\theta \, d\theta \, d\phi = 2\pi$$

Projected area

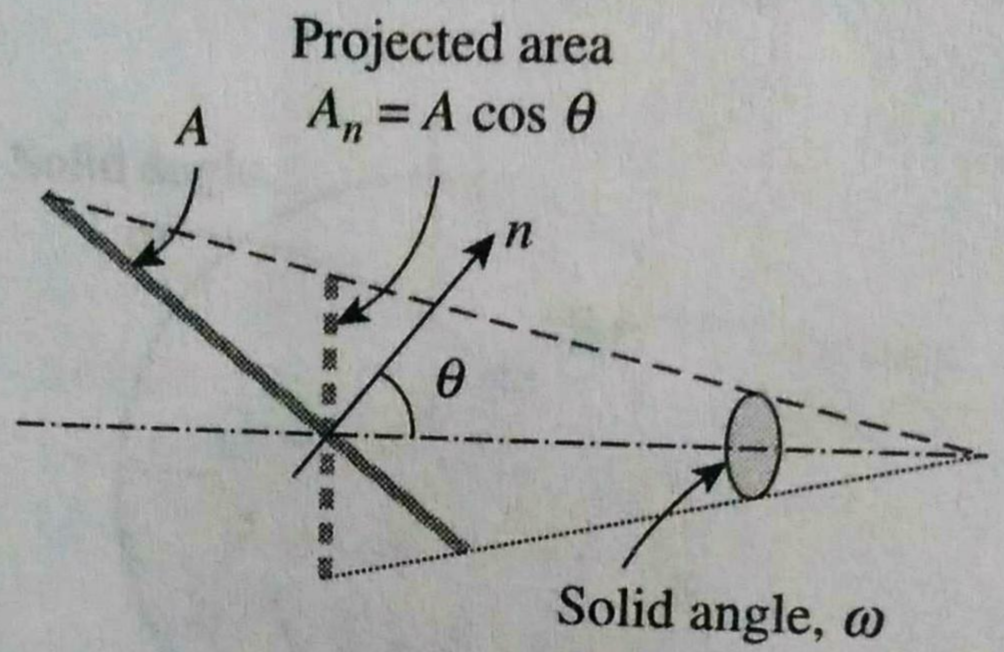


FIGURE 12–19

Radiation intensity is based on projected area, and thus the calculation of radiation emission from a surface involves the projection of the surface.