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We describe a wave by the "sine-function"

$$\cos[ik(x - ct)] = \cos[i(kx - \omega t)]$$

This is the *real part* of the *complex exponential*:

$$\begin{aligned} \cos[ik(x - ct)] &= \Re\{\exp[ik(x - ct)]\} \\ \cos[i(kx - \omega t)] &= \Re\{\exp[i(kx - \omega t)]\} \end{aligned}$$

Description of Waves

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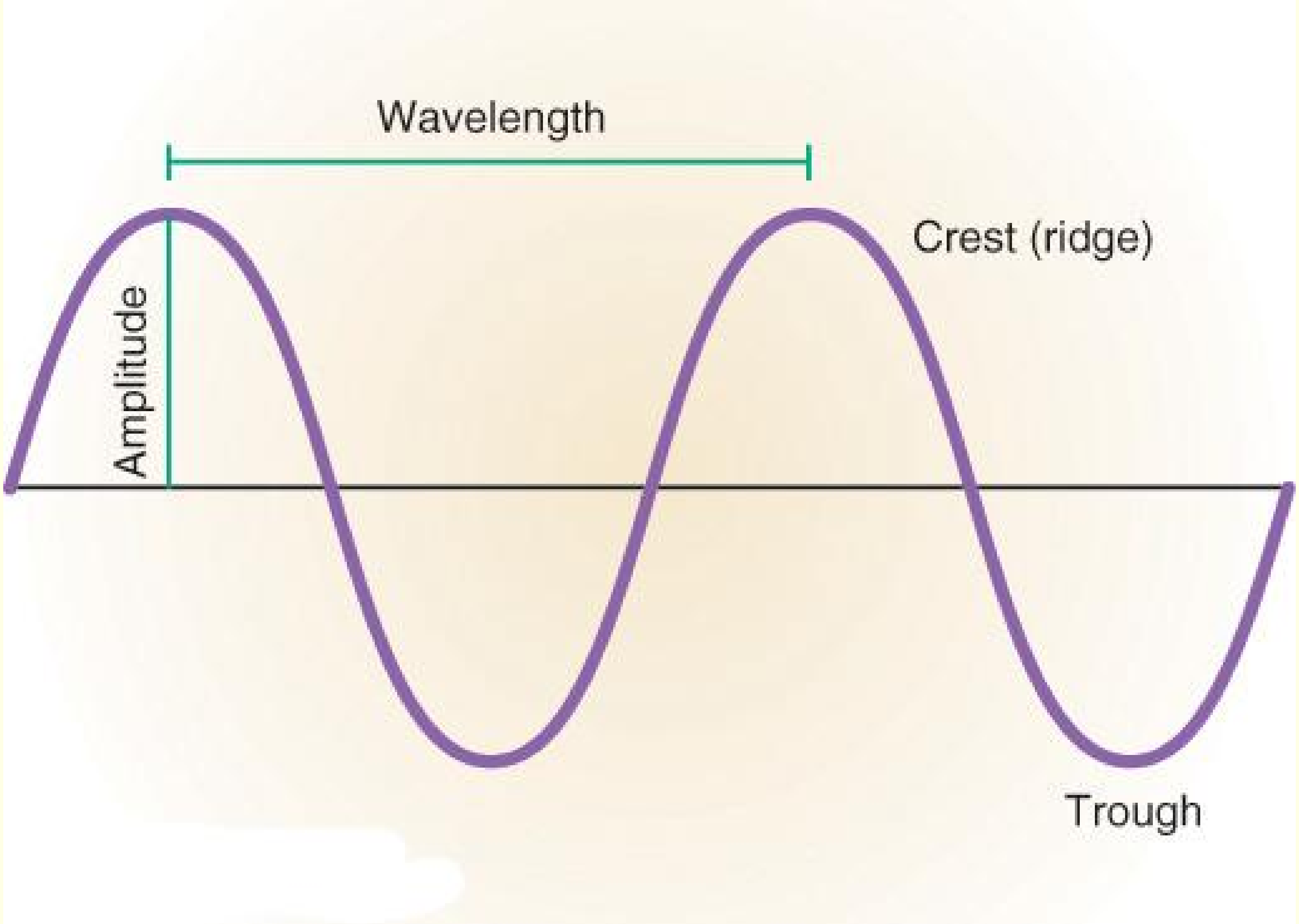
$c =$ **Phase speed**



Review of the parameters describing a wave

We describe a wave by the function

$$\cos[ik(x - ct)] = \cos[i(kx - \omega t)]$$

This is the *real part* of the complex exponential:

$$\exp[ik(x - ct)] = \exp[i(kx - \omega t)]$$

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The relationships between the parameters are

$$n = \frac{1}{\lambda} \qquad k = \frac{2\pi}{\lambda} \qquad k = 2\pi n$$

$$\omega = 2\pi\nu \qquad \omega = \frac{2\pi}{\tau} \qquad \omega = kc$$

$$\nu = \frac{1}{\tau} \qquad \nu = \frac{\omega}{2\pi} \qquad \nu = nc$$

$$c = \frac{\lambda}{\tau} \qquad c = \frac{\nu}{n} \qquad c = \frac{\omega}{k}$$

Electromagnetic radiation may be viewed as an ensemble of waves propagating at the speed of light

$$c \approx 3 \times 10^8\,\mathrm{m\,s^{-1}}$$

[c **is about 600 million knots(!) or 670 million m.p.h.**]

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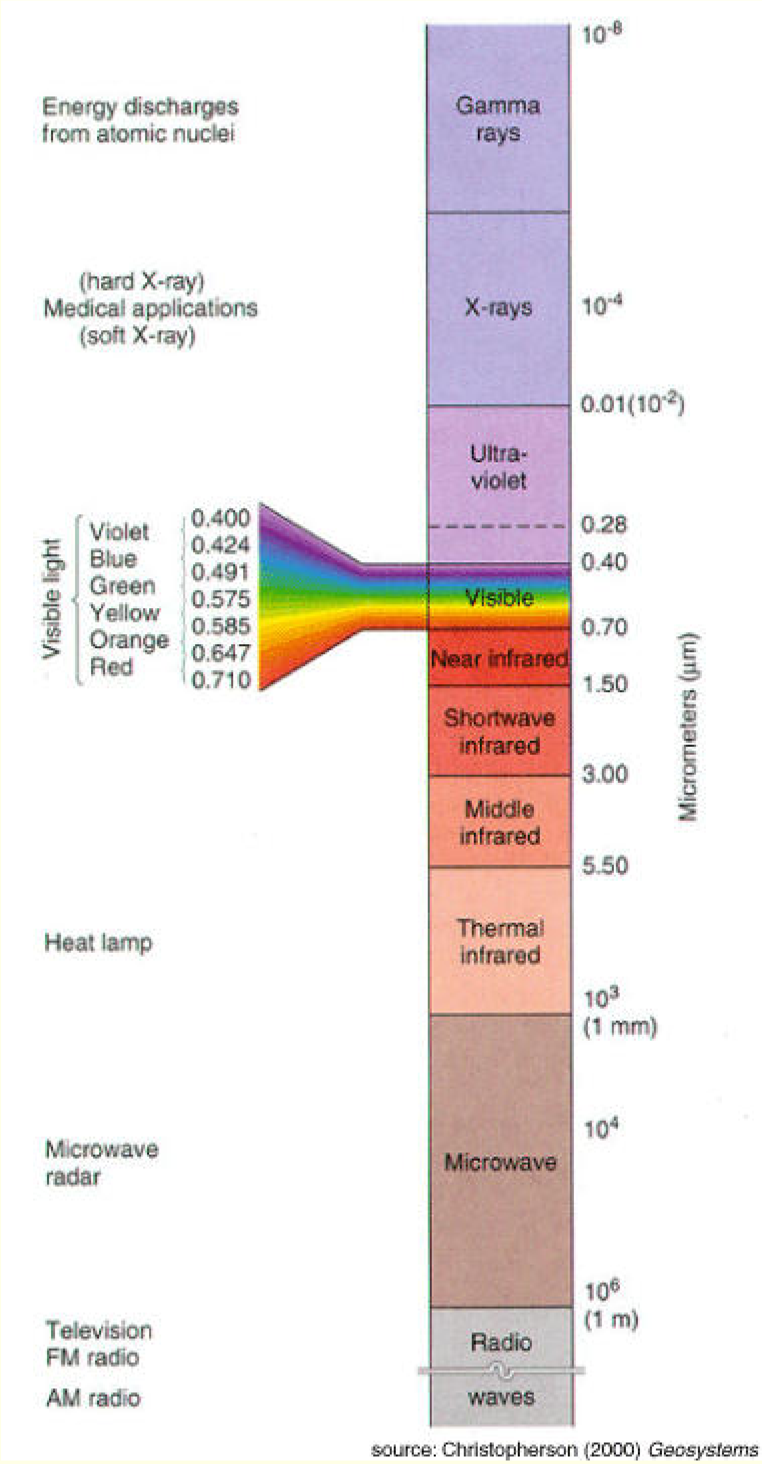
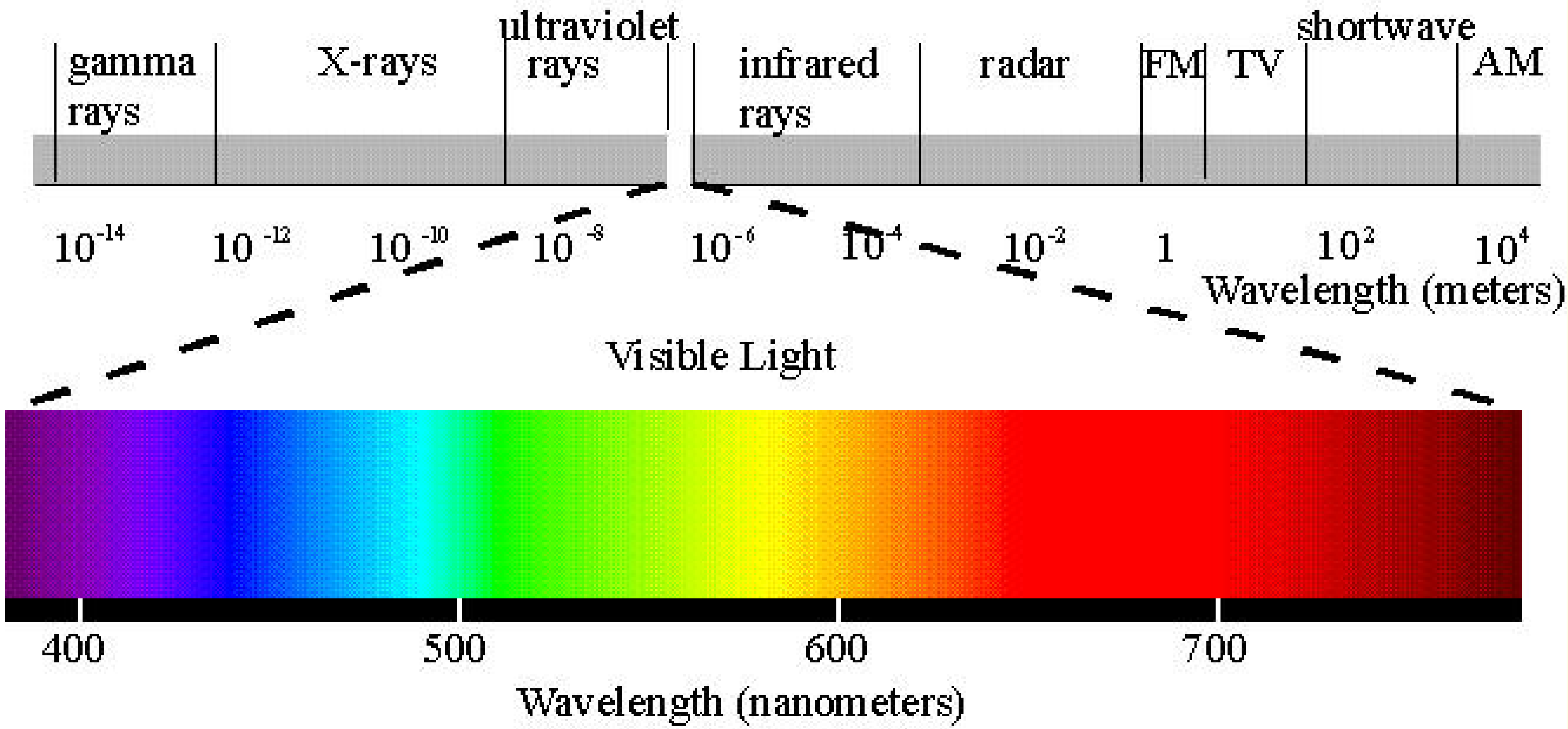
Small variations in the speed of light within air give rise to a number of distinctive optical phenomena such as mirages. For present purposes, these variations will be neglected.



The electromagnetic spectrum.



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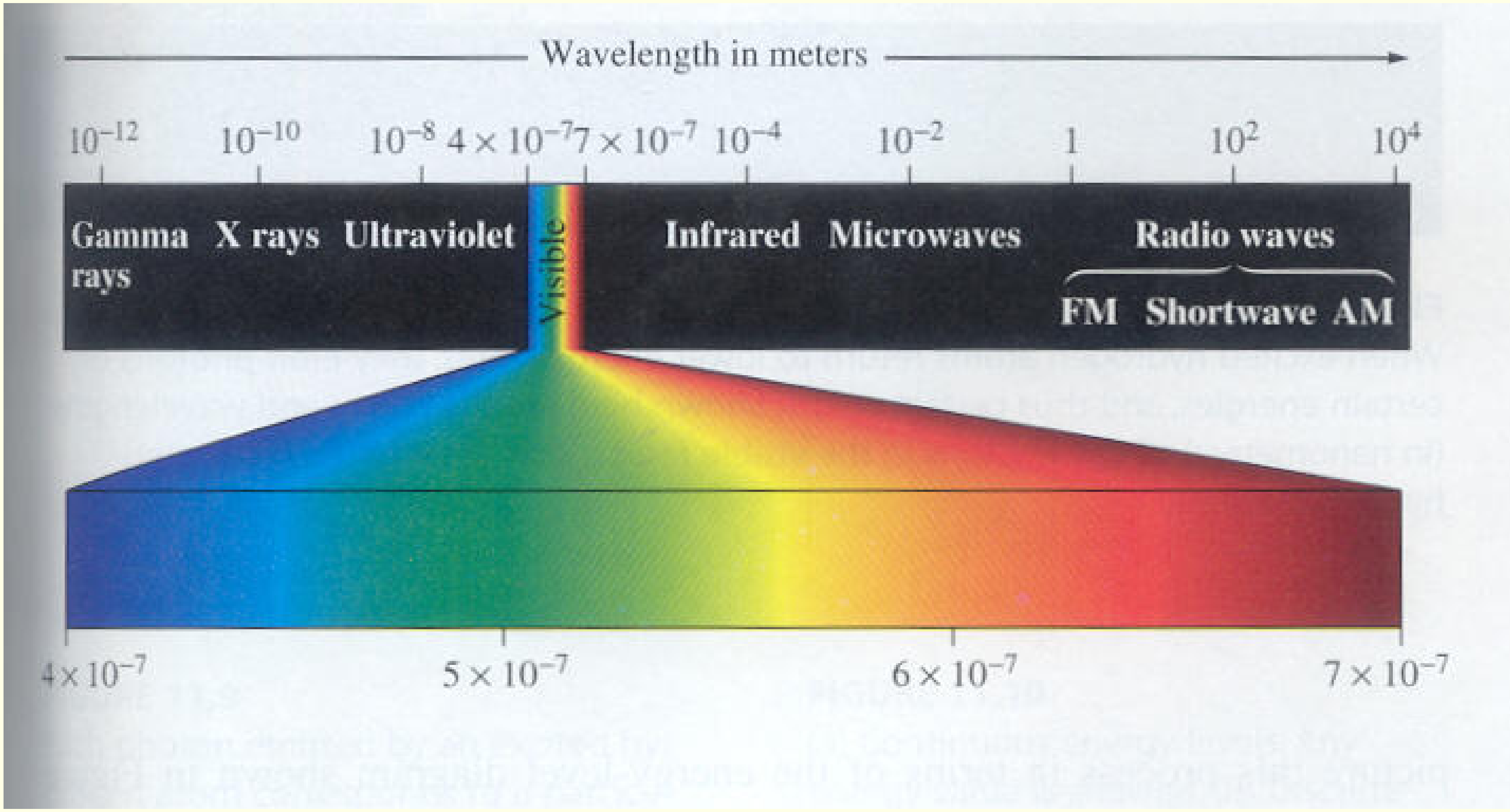
Visual Stimulus



Wavelength in meters
10^{-12}
10^{-10}
10^{-8}
4×10^{-7}
7×10^{-7}
10^{-4}
10^{-2}
1
10^{2}
10^{4}
Gamma rays
X rays
Ultraviolet
Visible
Infrared
Microwaves
Radio waves
FM
Shortwave
AM
4×10^{-7}
5×10^{-7}
6×10^{-7}
7×10^{-7}

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Radiative transfer in planetary atmospheres involves an ensemble of waves with a continuum of wavelengths and frequencies.

Thus, the energy that it carries can be partitioned into the contributions from various wavelength bands.

For example, in atmospheric science the term *shortwave* refers to the wavelength band that carries most of the energy associated with *solar radiation*.

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The term *monochromatic* denotes a single colour; that is, a specific frequency or wavelength.

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***Microwave radiation* is not important in the earth's energy balance but it is particularly useful in remote sensing because it is capable of *penetrating through clouds*.**

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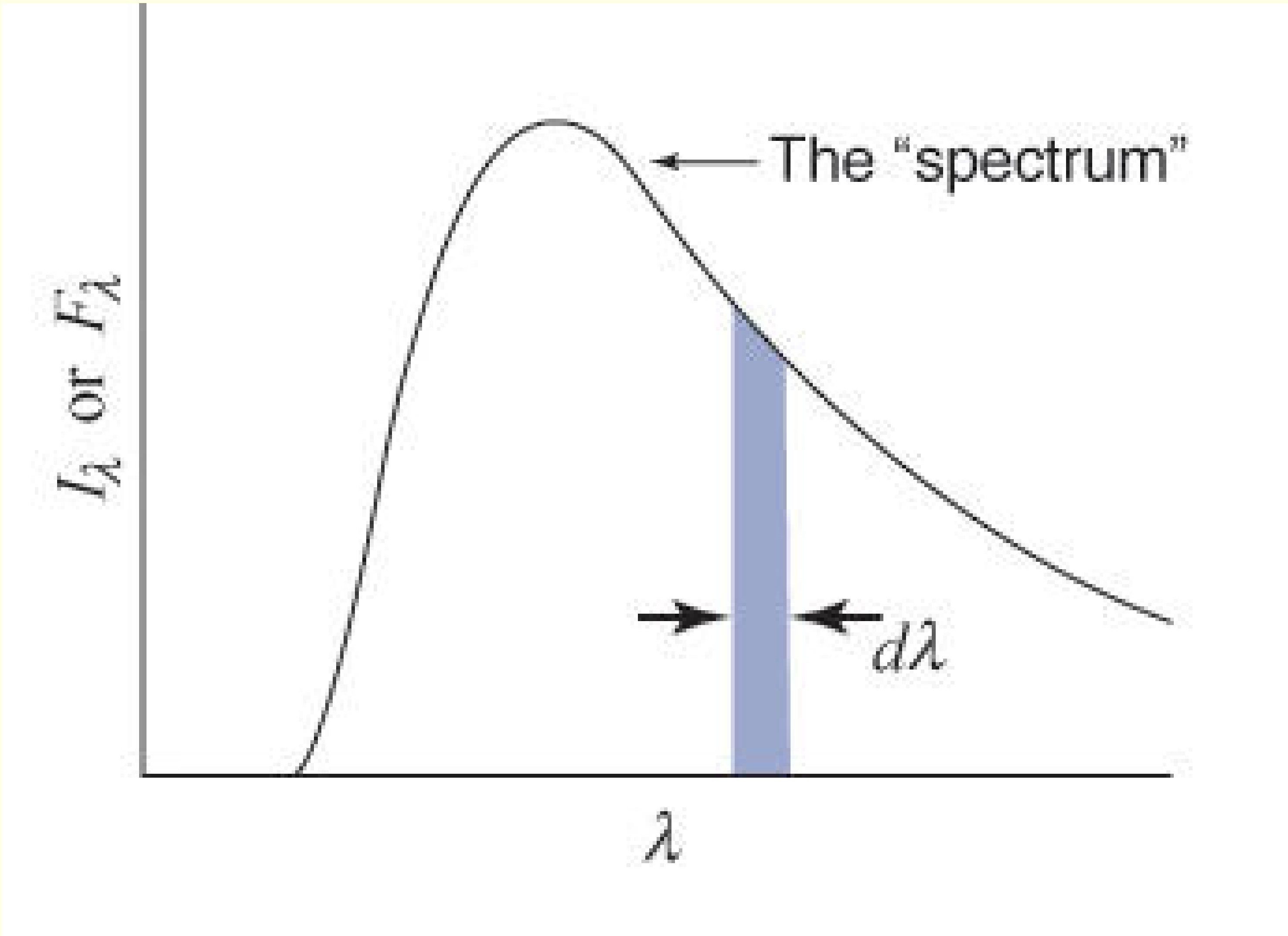
The flux F_λ at wavelength λ is called the *monochromatic flux*.



The curve represents a hypothetical spectrum of monochromatic flux. The area under the curve represents the flux associated with wavelengths ranging from λ_1 to λ_2.

The flux over the band of wavelengths $\lambda_1 < \lambda < \lambda_2$ is the integral

$$F(\lambda_1, \lambda_2) = \int_{\lambda_1}^{\lambda_2} F_\lambda \, d\lambda$$

representing the area under a finite segment of the the spectrum of monochromatic flux (i.e., the plot of F_λ as a function of λ).

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Solar radiation is parallel beam.
Terrestrial radiation is diffuse.

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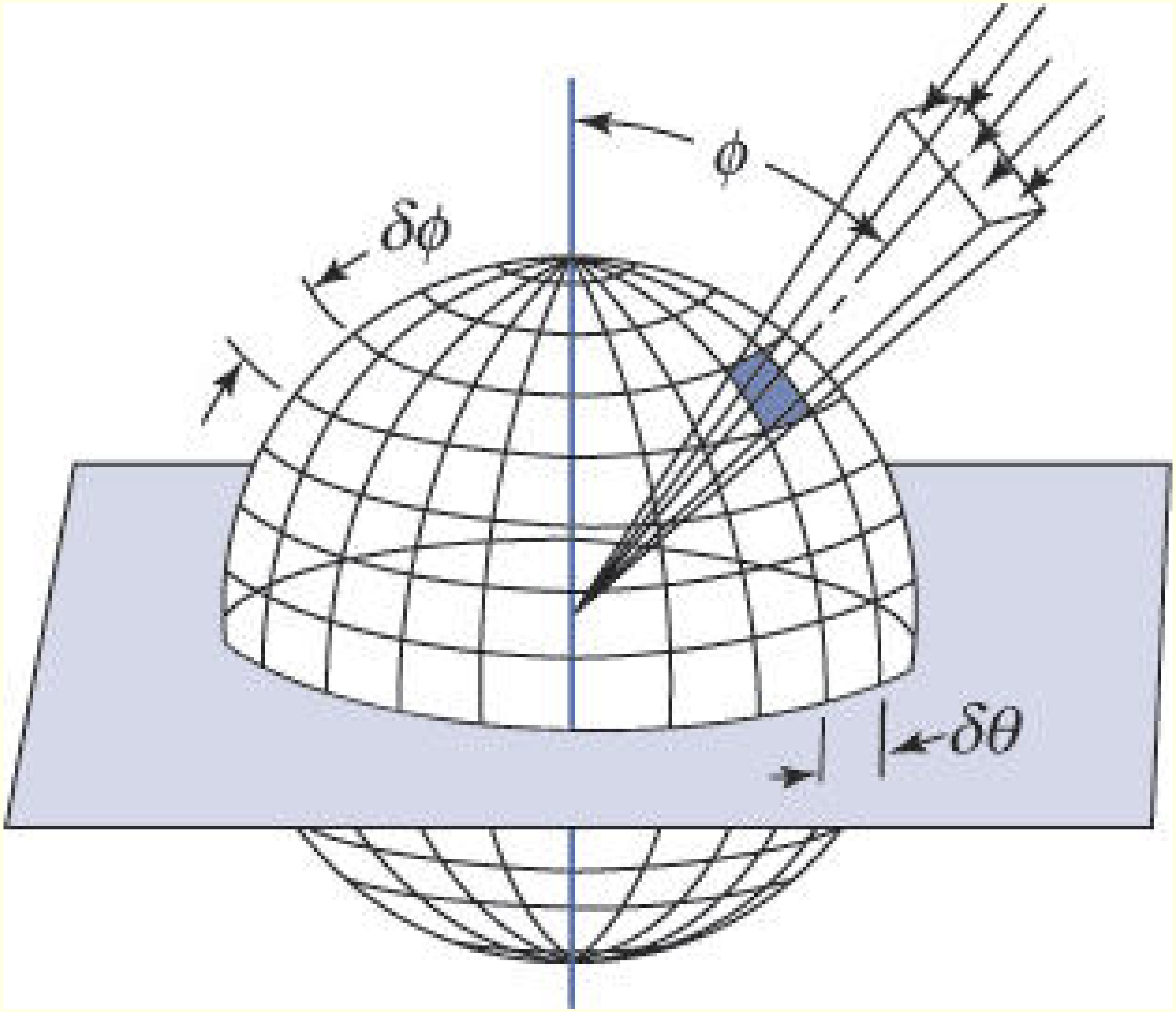
The integral of the monochromatic intensity over the entire electromagnetic spectrum is called the *intensity* (or radiance) I, which has units of $\mathrm{W\,m^{-2}}$ per unit arc of solid angle

$$I = \int_0^\infty I_\lambda \, d\lambda$$



Integration over solid angles.
The hemisphere covers 2π steradians.

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A full hemisphere corresponds to a solid angle of 2π steradians, the area of a hemisphere on the unit sphere.

Thus,

$$F_\lambda = \int_{2\pi} I_\lambda \cos\phi \, d\omega$$

where $d\omega$ represents an element of solid angle and $\cos\phi$ is the angle between the incident radiation and the direction normal to the surface element.

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Again, integrating over all wavelengths, we get the flux

$$F = \int F_\lambda \, d\lambda$$

End of §4.1