3.1 RADIATION QUANTITIES

Solid angle

The geometric quantity of a **solid angle** Ω quantifies a part of an observer's visual field.

If we imagine an observer located at point *P*, his full visual field can be described by a sphere of arbitrary radius *r* (Fig. 3.1.1).

Then, a certain part of this full visual field defines an area *A* on the sphere's surface and the solid angle Ω is defined by

$$\Omega = \frac{A}{r^2}$$

As the area *A* is proportional to r^2, this fraction is independent of *r*.

If we want to calculate the solid angle determined by a cone, as shown in fig. 3.1.1 area *A* is the area of a spherical calotte.

However, as the solid angle is not only defined for conical parts of the full visual field, area *A* can be any arbitrary shape on the sphere's surface.

Although Ω is dimensionless, it is common to use the unit **steradian (sr)** . The observer's total visual field is described by the whole surface of the sphere, which is given by $4\pi r^2$, and thus covers the solid angle (Fig 3.1.1).

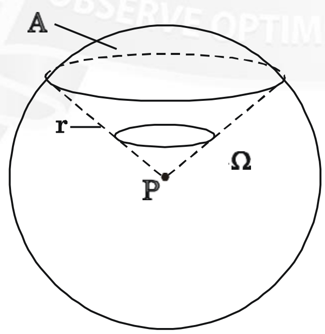

Fig. 3.1.1 Solid angle Ω quantifies a certain part of the visual field, seen by an observer located at P.

$$\Omega_{total} = 4\pi \text{ sr} = 12.57 \text{ sr}$$

Radiant power or radiant flux ϕ_e

It is defined by the total power or radiation emitted by a source (lamp, light emitting diode, etc.), transmitted through a surface or impinging upon a surface. **Radiant power is measured in watts** (W).

The definitions of all other radiometric quantities are based on radiant power.

If a light source emits uniformly in all directions, it is called an **isotropic light surface**. (Fig 3.1.2).

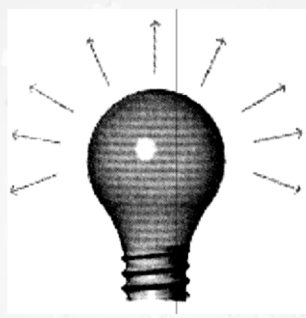

Fig. 3.1.2 The radiant power of ϕ_e of a light source is given by its total emitted radiation.

Radiant power characterizes the output of a source of electromagnetic radiation only by a single number and does not contain any information on the spectral distribution or the directional distribution of the lamp output.

Radiant intensity I_e

Radiant intensity I_e describes the radiant power of a source emitted in a certain direction. The source's (differential) radiant power $d\phi_e$ emitted in the direction of the (differential) solid angle element $d\,\Omega$ is given by (Fig. 3.3)

$$d\phi_e = I_e\, d\,\Omega$$

and thus

$$\Phi_e = \int I_e \, d\Omega$$

In general, radiant intensity depends on spatial direction.

The unit of radiant intensity is **W/sr**.

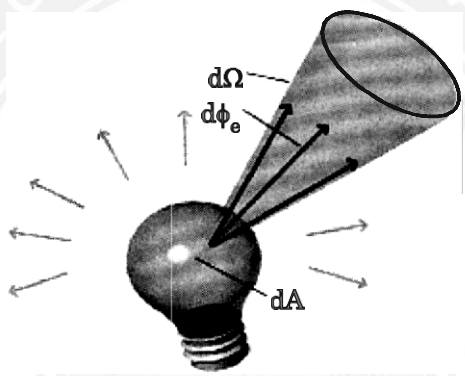

Fig. 3.1.3 Directional distribution of radiant intensity for an incandescent bulb

Radiance L_e

Radiance L_e describes the intensity of optical radiation emitted or reflected from a certain location on an emitting or reflecting surface in a particular direction. The radiant power $d\phi_e$ emitted by a surface element dA in the direction of the solid angle element $d\,\Omega$ is given by

$$d\phi_e = L_e \cos\theta \, dA \, d\Omega$$

In this relation, θ is the angle between the direction of the solid angle element $d\Omega$ and the normal of the emitting or reflecting surface element dA.

From the definition of radiant intensity I_e, it follows that the radiant intensity emitted by the area element dA in a certain direction is given by

$$dI_e = L_e \cos\theta \, dA$$

Thus,

$$I_e = \int_{\text{emitting}} L_e \cos\theta \, dA$$

The unit of radiance is $\mathbf{W/(m^2 \cdot sr)}$

Irradiance E_e

Irradiance E_e describes the amount of radiant power impinging upon a surface per unit area. In detail, the radiant power $d\phi_e$ upon the surface element dA is given by

$$d\phi_e = E_e \, dA$$

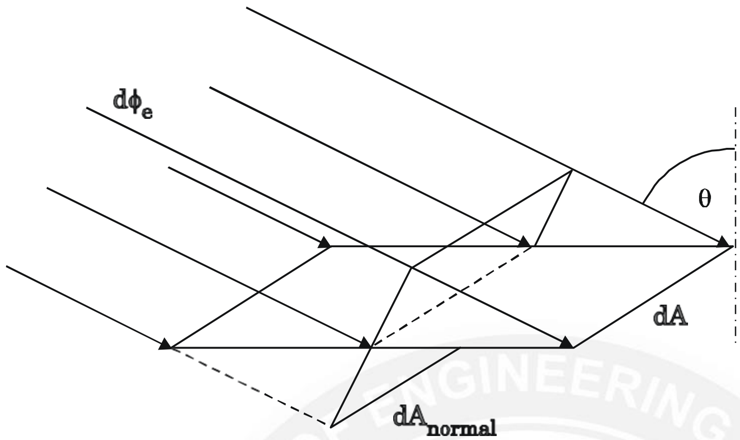

Fig. 3.1.4 Irradiance is defined as incident radiant power $d\phi_e$

per surface area element dA .

Generally, the surface element can be oriented at any angle towards the direction of the beam. However, irradiance is maximised when the surface element is perpendicular to the beam: (Fig. 3.1.4)

$$d\phi_e = E_{e,\,normal}\, dA_{normal}$$

Note that the corresponding area element dA_{normal}, which is oriented perpendicular to the incident beam, is given by

$$dA_{normal} = \cos\theta \, dA$$

with θ denoting the angle between the beam and the normal of *dA*, we get

$$E_e = E_{e,\,normal} \cos\theta$$

The unit of irradiance is **W/m²**.

Radiant exitance M_e

Radiant exitance M_e quantifies the radiant power per unit area, emitted or reflected from a certain location on a surface.

In detail, the (differential) radiant power $d\phi_e$ emitted or reflected by the surface element dA is given by

$$d\phi_e = M_e\, dA$$

From the definition of radiance follows that the (differential) amount radiant exitance dM_e emitted or reflected by a certain location on a surface in the direction of the (differential) solid angle element $d\,\Omega$ is given by

$$dM_e = L_e \cos\theta\, d\,\Omega$$

and consequently

$$M_e = \int L_e \cos\theta\, d\,\Omega$$

The integration is performed over the solid angle of 2π steradian corresponding to the directions on one side of the surface and θ denotes the angle between the respective direction and the surface's normal.

The unit of radiant exitance is **W/m²**. In some particular cases, $M_e = E_e$.