Radiant flux

In radiometry, **radiant flux** or **radiant power** is the radiant energy emitted, reflected, transmitted, or received per unit time, and **spectral flux** or **spectral power** is the radiant flux per unit frequency or wavelength, depending on whether the spectrum is taken as a function of frequency or of wavelength. The SI unit of radiant flux is the watt (W), one joule per second (J/s), while that of spectral flux in frequency is the watt per hertz (W/Hz) and that of spectral flux in wavelength is the watt per metre (W/m)—commonly the watt per nanometre (W/nm).


A flow chart describing the relationship of various physical quantities, including radiant flux and exitance.

Mathematical definitions

Radiant flux

Radiant flux, denoted Φ_e ('e' for "energetic", to avoid confusion with photometric quantities), is defined as[1]

$$\Phi_\mathrm{e} = \frac{dQ_\mathrm{e}}{dt}$$

$$Q_\mathrm{e} = \int_\Sigma \mathbf{S} \cdot \hat{\mathbf{n}}\, dA$$

where

- t is the time;
- Q_e is the radiant energy flux of the field out of a closed surface Σ;
- **S** is the Poynting vector, representing the current density of radiant energy;
- **n** is the normal vector of a point on Σ;
- **A** represent the area of Σ.

But the time-average of the norm of the Poynting vector is used instead, because in radiometry it is the only quantity that radiation detectors are able to measure:

$$\Phi_\mathrm{e} \approx \int_\Sigma \langle|\mathbf{S}|\rangle \cos\alpha\ dA,$$

where ⟨-⟩ is the time-average, and α is the angle between **n** and $\langle|\mathbf{S}|\rangle$.

Spectral flux

Spectral flux in frequency, denoted $\Phi_{e,\nu}$, is defined as[1]

$$\Phi_{e,\nu} = \frac{\partial \Phi_e}{\partial \nu},$$

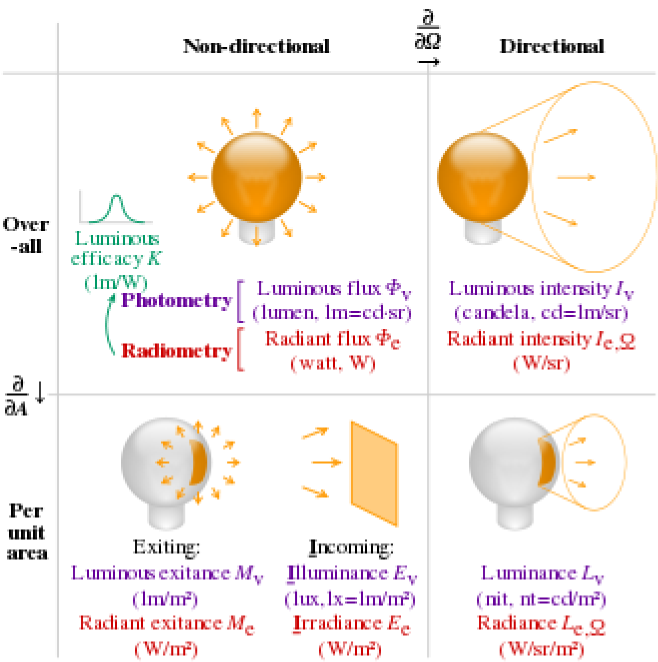
where ν is the frequency.

Spectral flux in wavelength, denoted $\Phi_{e,\lambda}$, is defined as[1]

$$\Phi_{e,\lambda} = \frac{\partial \Phi_e}{\partial \lambda},$$

where λ is the wavelength.

SI radiometry units



Comparison of photometric and radiometric quantities

SI radiometry units

Quantity		Unit		Dimension	Notes
Name	Symbol[nb 1]	Name	Symbol	Symbol	
Radiant energy	Q_e[nb 2]	joule	J	$\mathsf{M}{\cdot}\mathsf{L}^{2}{\cdot}\mathsf{T}^{-2}$	Energy of electromagnetic radiation.
Radiant energy density	w_e	joule per cubic metre	J/m^3	$\mathsf{M}{\cdot}\mathsf{L}^{-1}{\cdot}\mathsf{T}^{-2}$	Radiant energy per unit volume.
Radiant flux	Φ_e[nb 2]	watt	W = J/s	$\mathsf{M}{\cdot}\mathsf{L}^{2}{\cdot}\mathsf{T}^{-3}$	Radiant energy emitted, reflected, transmitted or received, per unit time. This is sometimes also called "radiant power", and called luminosity in Astronomy.
Spectral flux	$\Phi_{e,\nu}$[nb 3]	watt per hertz	W/Hz	$\mathsf{M}{\cdot}\mathsf{L}^{2}{\cdot}\mathsf{T}^{-2}$	Radiant flux per unit frequency or wavelength. The latter is commonly measured in $W{\cdot}nm^{-1}$.
	$\Phi_{e,\lambda}$[nb 4]	watt per metre	W/m	$\mathsf{M}{\cdot}\mathsf{L}{\cdot}\mathsf{T}^{-3}$	
Radiant intensity	$I_{e,\Omega}$[nb 5]	watt per steradian	W/sr	$\mathsf{M}{\cdot}\mathsf{L}^{2}{\cdot}\mathsf{T}^{-3}$	Radiant flux emitted, reflected, transmitted or received, per unit solid angle. This is a *directional* quantity.
Spectral intensity	$I_{e,\Omega,\nu}$[nb 3]	watt per steradian per hertz	$W{\cdot}sr^{-1}{\cdot}Hz^{-1}$	$\mathsf{M}{\cdot}\mathsf{L}^{2}{\cdot}\mathsf{T}^{-2}$	Radiant intensity per unit frequency or wavelength. The latter is commonly measured in $W{\cdot}sr^{-1}{\cdot}nm^{-1}$. This is a *directional* quantity.
	$I_{e,\Omega,\lambda}$[nb 4]	watt per steradian per metre	$W{\cdot}sr^{-1}{\cdot}m^{-1}$	$\mathsf{M}{\cdot}\mathsf{L}{\cdot}\mathsf{T}^{-3}$	
Radiance	$L_{e,\Omega}$[nb 5]	watt per steradian per square metre	$W{\cdot}sr^{-1}{\cdot}m^{-2}$	$\mathsf{M}{\cdot}\mathsf{T}^{-3}$	Radiant flux emitted, reflected, transmitted or received by a *surface*, per unit solid angle per unit projected area. This is a *directional* quantity. This is sometimes also confusingly called "intensity".
Spectral radiance Specific intensity	$L_{e,\Omega,\nu}$[nb 3]	watt per steradian per square metre per hertz	$W{\cdot}sr^{-1}{\cdot}m^{-2}{\cdot}Hz^{-1}$	$\mathsf{M}{\cdot}\mathsf{T}^{-2}$	Radiance of a *surface* per unit frequency or wavelength. The latter is commonly

					measured in W·sr^{-1}·m^{-2}·nm^{-1}. This is a *directional* quantity. This is sometimes also confusingly called "spectral intensity".
	$L_{e,\Omega,\lambda}$[nb 4]	watt per steradian per square metre, per metre	W·sr^{-1}·m^{-3}	**M**·**L**$^{-1}$·**T**$^{-3}$	
Irradiance Flux density	E_e[nb 2]	watt per square metre	W/m^2	**M**·**T**$^{-3}$	Radiant flux *received* by a *surface* per unit area. This is sometimes also confusingly called "intensity".
Spectral irradiance Spectral flux density	$E_{e,\nu}$[nb 3]	watt per square metre per hertz	W·m^{-2}·Hz^{-1}	**M**·**T**$^{-2}$	Irradiance of a *surface* per unit frequency or wavelength. This is sometimes also confusingly called "spectral intensity". Non-SI units of spectral flux density include jansky (1 Jy = 10^{-26} W·m^{-2}·Hz^{-1}) and solar flux unit (1 sfu = 10^{-22} W·m^{-2}·Hz^{-1} = 10^4 Jy).
	$E_{e,\lambda}$[nb 4]	watt per square metre, per metre	W/m^3	**M**·**L**$^{-1}$·**T**$^{-3}$	
Radiosity	J_e[nb 2]	watt per square metre	W/m^2	**M**·**T**$^{-3}$	Radiant flux *leaving* (emitted, reflected and transmitted by) a *surface* per unit area. This is sometimes also confusingly called "intensity".
Spectral radiosity	$J_{e,\nu}$[nb 3]	watt per square metre per hertz	W·m^{-2}·Hz^{-1}	**M**·**T**$^{-2}$	Radiosity of a *surface* per unit frequency or wavelength. The latter is commonly measured in W·m^{-2}·nm^{-1}. This is sometimes also confusingly called "spectral intensity".
	$J_{e,\lambda}$[nb 4]	watt per square metre, per metre	W/m^3	**M**·**L**$^{-1}$·**T**$^{-3}$	
Radiant exitance	M_e[nb 2]	watt per square metre	W/m^2	**M**·**T**$^{-3}$	Radiant flux *emitted* by a *surface* per unit area. This is the emitted component of radiosity. "Radiant emittance" is an old term for this

					quantity. This is sometimes also confusingly called "intensity".
Spectral exitance	$M_{e,\nu}$[nb 3]	watt per square metre per hertz	W⋅m^{-2}⋅Hz^{-1}	**M**⋅$\mathbf{T}^{-2}$	Radiant exitance of a *surface* per unit frequency or wavelength. The latter is commonly measured in W⋅m^{-2}⋅nm^{-1}. "Spectral emittance" is an old term for this quantity. This is sometimes also confusingly called "spectral intensity".
	$M_{e,\lambda}$[nb 4]	watt per square metre, per metre	W/m^3	**M**⋅$\mathbf{L}^{-1}$⋅$\mathbf{T}^{-3}$	
Radiant exposure	H_e	joule per square metre	J/m^2	**M**⋅$\mathbf{T}^{-2}$	Radiant energy received by a *surface* per unit area, or equivalently irradiance of a *surface* integrated over time of irradiation. This is sometimes also called "radiant fluence".
Spectral exposure	$H_{e,\nu}$[nb 3]	joule per square metre per hertz	J⋅m^{-2}⋅Hz^{-1}	**M**⋅$\mathbf{T}^{-1}$	Radiant exposure of a *surface* per unit frequency or wavelength. The latter is commonly measured in J⋅m^{-2}⋅nm^{-1}. This is sometimes also called "spectral fluence".
	$H_{e,\lambda}$[nb 4]	joule per square metre, per metre	J/m^3	**M**⋅$\mathbf{L}^{-1}$⋅$\mathbf{T}^{-2}$	
See also: SI · Radiometry · Photometry					

1. Standards organizations recommend that radiometric quantities should be denoted with suffix "e" (for "energetic") to avoid confusion with photometric or photon quantities.
2. Alternative symbols sometimes seen: *W* or *E* for radiant energy, *P* or *F* for radiant flux, *I* for irradiance, *W* for radiant exitance.
3. Spectral quantities given per unit frequency are denoted with suffix "*ν*" (Greek letter nu, not to be confused with a letter "v", indicating a photometric quantity.)
4. Spectral quantities given per unit wavelength are denoted with suffix "*λ*".
5. Directional quantities are denoted with suffix "Ω".

See also

- Luminous flux
- Heat flux
- Power (physics)

- Radiosity (heat transfer)

References

1. "Thermal insulation — Heat transfer by radiation — Physical quantities and definitions" (http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=16943). *ISO 9288:1989*. ISO catalogue. 1989. Retrieved 2015-03-15.

Further reading

- Boyd, Robert (1983). *Radiometry and the Detection of Optical Radiation (Pure & Applied Optics Series)*. Wiley-Interscience. ISBN 978-0-471-86188-1.