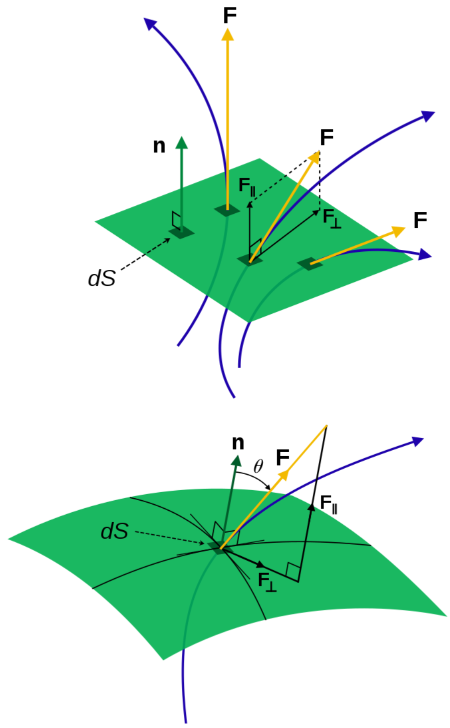
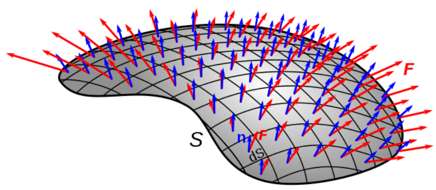
Flux

Flux describes any effect that appears to pass or travel (whether it actually moves or not) through a surface or substance. A flux is a concept in applied mathematics and vector calculus which has many applications to physics. For transport phenomena, flux is a vector quantity, describing the magnitude and direction of the flow of a substance or property. In vector calculus flux is a scalar quantity, defined as the surface integral of the perpendicular component of a vector field over a surface.[1]



The field lines of a vector field **F** through surfaces with unit normal **n**, the angle from **n** to **F** is θ. Flux is a measure of how much of the field passes through a given surface. **F** is decomposed into components perpendicular (⊥) and parallel (∥) to **n**. Only the parallel component contributes to flux because it is the maximum extent of the field passing through the surface at a point, the perpendicular component does not contribute. **Top:** Three field lines through a plane surface, one normal to the surface, one parallel, and one intermediate. **Bottom:** Field line through a curved surface, showing the setup of the unit normal and surface element to calculate flux.



To calculate the flux of a vector field $\mathbf{F}$ *(red arrows)* through a surface S the surface is divided into small patches dS. The flux through each patch is equal to the normal (perpendicular) component of the field, the dot product of $\mathbf{F}(\mathbf{x})$ with the unit normal vector $\mathbf{n}(\mathbf{x})$ *(blue arrows)* at the point $\mathbf{x}$ multiplied by the area dS. The sum of $\mathbf{F} \cdot \mathbf{n}dS$ for each patch on the surface is the flux through the surface

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Terminology

The word *flux* comes from Latin: *fluxus* means "flow", and *fluere* is "to flow".[2] As *fluxion*, this term was introduced into differential calculus by Isaac Newton.

The concept of heat flux was a key contribution of Joseph Fourier, in the analysis of heat transfer phenomena.[3] His seminal treatise *Théorie analytique de la chaleur* (*The Analytical Theory of Heat*),[4] defines *fluxion* as a central quantity and proceeds to derive the now well-known expressions of flux in terms of temperature differences across a slab, and then more generally in terms of temperature gradients or differentials of temperature, across other geometries. One could argue, based on the work of James Clerk Maxwell,[5] that the transport definition precedes the definition of flux used in electromagnetism. The specific quote from Maxwell is:

> In the case of fluxes, we have to take the integral, over a surface, of the flux through every element of the surface. The result of this operation is called the surface integral of the flux. It represents the quantity which passes through the surface.
>
> — James Clerk Maxwell

According to the transport definition, flux may be a single vector, or it may be a vector field / function of position. In the latter case flux can readily be integrated over a surface. By contrast, according to the electromagnetism definition, flux *is* the integral over a surface; it makes no sense to integrate a second-definition flux for one would be integrating over a surface twice. Thus, Maxwell's quote only makes sense if "flux" is being used according to the transport definition (and furthermore is a vector field rather than single vector). This is ironic because Maxwell was one of the major developers of what we now call "electric flux" and "magnetic flux" according to the electromagnetism definition. Their names in accordance with the quote (and transport definition) would be "surface integral of electric flux" and "surface integral of magnetic flux", in which case "electric flux" would instead be defined as "electric field" and "magnetic flux" defined as "magnetic field". This implies that Maxwell conceived of these fields as flows/fluxes of some sort.

Given a flux according to the electromagnetism definition, the corresponding **flux density**, if that term is used, refers to its derivative along the surface that was integrated. By the Fundamental theorem of calculus, the corresponding **flux density** is a flux according to the transport definition. Given a **current** such as electric current—charge per time, **current density** would also be a flux according to the transport definition—charge per time per area. Due to the conflicting definitions of *flux*, and the interchangeability of *flux*, *flow*, and *current* in nontechnical English, all of the terms used in this paragraph are sometimes used interchangeably and ambiguously. Concrete fluxes in the rest of this article will be used in accordance to their broad acceptance in the literature, regardless of which definition of flux the term corresponds to.

Flux as flow rate per unit area

In transport phenomena (heat transfer, mass transfer and fluid dynamics), flux is defined as the *rate of flow of a property per unit area,* which has the dimensions [quantity]·[time]$^{-1}$·[area]$^{-1}$.[6] The area is of the surface the property is flowing "through" or "across". For example, the magnitude of a river's current, i.e. the amount of water that flows through a cross-section of the river each second, or the amount of sunlight energy that lands on a patch of ground each second, are kinds of flux.

General mathematical definition (transport)

Here are 3 definitions in increasing order of complexity. Each is a special case of the following. In all cases the frequent symbol *j*, (or *J*) is used for flux, *q* for the physical quantity that flows, *t* for time, and *A* for area. These identifiers will be written in bold when and only when they are vectors.

First, flux as a (single) scalar:

$$j = \frac{I}{A}$$

where:

$$I = \lim_{\Delta t \to 0} \frac{\Delta q}{\Delta t} = \frac{\mathrm{d}q}{\mathrm{d}t}$$

In this case the surface in which flux is being measured is fixed, and has area *A*. The surface is assumed to be flat, and the flow is assumed to be everywhere constant with respect to position, and perpendicular to the surface.

Second, flux as a scalar field defined along a surface, i.e. a function of points on the surface:

$$j(\mathbf{p}) = \frac{\partial I}{\partial A}(\mathbf{p})$$
$$I(A, \mathbf{p}) = \frac{\mathrm{d}q}{\mathrm{d}t}(A, \mathbf{p})$$

As before, the surface is assumed to be flat, and the flow is assumed to be everywhere perpendicular to it. However the flow need not be constant. *q* is now a function of **p**, a point on the surface, and *A*, an area. Rather than measure the total flow through the surface, q measures the flow through the disk with area *A* centered at *p* along the surface.

Finally, flux as a vector field:

$$\mathbf{j}(\mathbf{p}) = \frac{\partial \mathbf{I}}{\partial A}(\mathbf{p})$$
$$\mathbf{I}(A, \mathbf{p}) = \underset{\hat{\mathbf{n}}}{\arg\max}\, \hat{\mathbf{n}}_{\mathbf{p}} \frac{\mathrm{d}q}{\mathrm{d}t}(A, \mathbf{p}, \hat{\mathbf{n}})$$

In this case, there is no fixed surface we are measuring over. *q* is a function of a point, an area, and a direction (given by a unit vector, $\hat{\mathbf{n}}$), and measures the flow through the disk of area A perpendicular to that unit vector. *I* is defined picking the unit vector that maximizes the flow around the point, because the true flow is maximized across the disk that is perpendicular to it. The unit vector thus uniquely maximizes the function when it points in the "true direction" of the flow. [Strictly speaking, this is an abuse of notation because the "arg max" cannot directly compare vectors; we take the vector with the biggest norm instead.]

Properties

These direct definitions, especially the last, are rather unwieldy. For example, the argmax construction is artificial from the perspective of empirical measurements, when with a Weathervane or similar one can easily deduce the direction of flux at a point. Rather than defining the vector flux directly, it is often more intuitive to state some properties about it. Furthermore, from these properties the flux can uniquely be determined anyway.

If the flux **j** passes through the area at an angle θ to the area normal $\hat{\mathbf{n}}$, then

$$\mathbf{j} \cdot \hat{\mathbf{n}} = j \cos\theta$$

where · is the dot product of the unit vectors. This is, the component of flux passing through the surface (i.e. normal to it) is *j* cos *θ*, while the component of flux passing tangential to the area is *j* sin *θ*, but there is *no* flux actually passing *through* the area in the tangential direction. The *only* component of flux passing normal to the area is the cosine component.

For vector flux, the surface integral of **j** over a surface *S*, gives the proper flowing per unit of time through the surface.

$$\frac{\mathrm{d}q}{\mathrm{d}t} = \iint_S \mathbf{j} \cdot \hat{\mathbf{n}}\, \mathrm{d}A = \iint_S \mathbf{j} \cdot \mathrm{d}\mathbf{A}$$

A (and its infinitesimal) is the vector area, combination of the magnitude of the area through which the property passes, *A*, and a unit vector normal to the area, $\hat{\mathbf{n}}$. The relation is $\mathbf{A} = A\hat{\mathbf{n}}$. Unlike in the second set of equations, the surface here need not be flat.

Finally, we can integrate again over the time duration t_1 to t_2, getting the total amount of the property flowing through the surface in that time ($t_2 - t_1$):

$$q = \int_{t_1}^{t_2} \iint_S \mathbf{j} \cdot \mathrm{d}\mathbf{A}\, \mathrm{d}t$$

Transport fluxes

Eight of the most common forms of flux from the transport phenomena literature are defined as follows:

1. Momentum flux, the rate of transfer of momentum across a unit area (N·s·m^{-2}·s^{-1}). (Newton's law of viscosity)[7]
2. Heat flux, the rate of heat flow across a unit area (J·m^{-2}·s^{-1}). (Fourier's law of conduction)[8] (This definition of heat flux fits Maxwell's original definition.)[5]
3. Diffusion flux, the rate of movement of molecules across a unit area (mol·m^{-2}·s^{-1}). (Fick's law of diffusion)[7]

4. Volumetric flux, the rate of volume flow across a unit area ($m^3 \cdot m^{-2} \cdot s^{-1}$). (Darcy's law of groundwater flow)
5. Mass flux, the rate of mass flow across a unit area ($kg \cdot m^{-2} \cdot s^{-1}$). (Either an alternate form of Fick's law that includes the molecular mass, or an alternate form of Darcy's law that includes the density.)
6. Radiative flux, the amount of energy transferred in the form of photons at a certain distance from the source per unit area per second ($J \cdot m^{-2} \cdot s^{-1}$). Used in astronomy to determine the magnitude and spectral class of a star. Also acts as a generalization of heat flux, which is equal to the radiative flux when restricted to the electromagnetic spectrum.
7. Energy flux, the rate of transfer of energy through a unit area ($J \cdot m^{-2} \cdot s^{-1}$). The radiative flux and heat flux are specific cases of energy flux.
8. Particle flux, the rate of transfer of particles through a unit area ([number of particles] $m^{-2} \cdot s^{-1}$)

These fluxes are vectors at each point in space, and have a definite magnitude and direction. Also, one can take the divergence of any of these fluxes to determine the accumulation rate of the quantity in a control volume around a given point in space. For incompressible flow, the divergence of the volume flux is zero.

Chemical diffusion

As mentioned above, chemical molar flux of a component A in an isothermal, isobaric system is defined in Fick's law of diffusion as:

$$\mathbf{J}_A = -D_{AB} \nabla c_A$$

where the nabla symbol ∇ denotes the gradient operator, D_{AB} is the diffusion coefficient ($m^2 \cdot s^{-1}$) of component A diffusing through component B, c_A is the concentration (mol/m^3) of component A.[9]

This flux has units of mol·$m^{-2} \cdot s^{-1}$, and fits Maxwell's original definition of flux.[5]

For dilute gases, kinetic molecular theory relates the diffusion coefficient D to the particle density $n = N/V$, the molecular mass m, the collision cross section σ, and the absolute temperature T by

$$D = \frac{2}{3n\sigma} \sqrt{\frac{kT}{\pi m}}$$

where the second factor is the mean free path and the square root (with Boltzmann's constant k) is the mean velocity of the particles.

In turbulent flows, the transport by eddy motion can be expressed as a grossly increased diffusion coefficient.

Quantum mechanics

In quantum mechanics, particles of mass m in the quantum state $\psi(\mathbf{r}, t)$ have a probability density defined as

$$\rho = \psi^* \psi = |\psi|^2.$$

So the probability of finding a particle in a differential volume element $d^3\mathbf{r}$ is

$$dP = |\psi|^2 d^3\mathbf{r}.$$

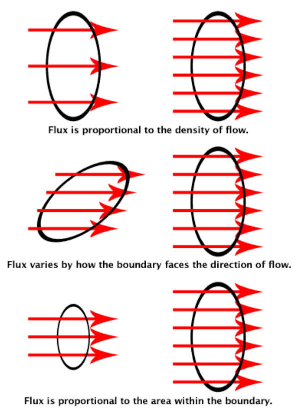
Then the number of particles passing perpendicularly through unit area of a cross-section per unit time is the probability flux;

$$\mathbf{J} = \frac{i\hbar}{2m} \left(\psi \nabla \psi^* - \psi^* \nabla \psi \right).$$

This is sometimes referred to as the probability current or current density,[10] or probability flux density.[11]

Flux as a surface integral

General mathematical definition (surface integral)



The flux visualized. The rings show the surface boundaries. The red arrows stand for the flow of charges, fluid particles, subatomic particles, photons, etc. The number of arrows that pass through each ring is the flux.

As a mathematical concept, flux is represented by the surface integral of a vector field,[12]

$$\Phi_F = \iint_A \mathbf{F} \cdot d\mathbf{A}$$

$$\Phi_F = \iint_A \mathbf{F} \cdot \mathbf{n} dA$$

where $\mathbf{F}$ is a vector field, and dA is the vector area of the surface A, directed as the surface normal. For the second, $\mathbf{n}$ is the outward pointed unit normal vector to the surface.

The surface has to be orientable, i.e. two sides can be distinguished: the surface does not fold back onto itself. Also, the surface has to be actually oriented, i.e. we use a convention as to flowing which way is counted positive; flowing backward is then counted negative.

The surface normal is usually directed by the right-hand rule.

Conversely, one can consider the flux the more fundamental quantity and call the vector field the flux density.

Often a vector field is drawn by curves (field lines) following the "flow"; the magnitude of the vector field is then the line density, and the flux through a surface is the number of lines. Lines originate from areas of positive divergence (sources) and end at areas of negative divergence (sinks).

See also the image at right: the number of red arrows passing through a unit area is the flux density, the curve encircling the red arrows denotes the boundary of the surface, and the orientation of the arrows with respect to the surface denotes the sign of the inner product of the vector field with the surface normals.

If the surface encloses a 3D region, usually the surface is oriented such that the **influx** is counted positive; the opposite is the **outflux**.

The divergence theorem states that the net outflux through a closed surface, in other words the net outflux from a 3D region, is found by adding the local net outflow from each point in the region (which is expressed by the divergence).

If the surface is not closed, it has an oriented curve as boundary. Stokes' theorem states that the flux of the curl of a vector field is the line integral of the vector field over this boundary. This path integral is also called circulation, especially in fluid dynamics. Thus the curl is the circulation density.

We can apply the flux and these theorems to many disciplines in which we see currents, forces, etc., applied through areas.

Electromagnetism

One way to better understand the concept of flux in electromagnetism is by comparing it to a butterfly net. The amount of air moving through the net at any given instant in time is the flux. If the wind speed is high, then the flux through the net is large. If the net is made bigger, then the flux is larger even though the wind speed is the same. For the most air to move through the net, the opening of the net must be facing the direction the wind is blowing. If the net is parallel to the wind, then no wind will be moving through the net. The simplest way to think of flux is "how much air goes through the net", where the air is a velocity field and the net is the boundary of an imaginary surface.

Electric flux

An electric "charge," such as a single proton in space, has a magnitude defined in coulombs. Such a charge has an electric field surrounding it. In pictorial form, the electric field from a positive point charge can be visualized as a dot radiating electric field lines (sometimes also called "lines of force"). Conceptually, electric flux can be thought of as "the number of field lines" passing through a given area. Mathematically, electric flux is the integral of the normal component of the electric field over a given area. Hence, units of electric flux are, in the MKS system, newtons per coulomb times meters squared , or N m²/C. (Electric flux density is the electric flux per unit area, and is a measure of strength of the normal component of the electric field averaged over the area of integration. Its units are N/C, the same as the electric field in MKS units.)

Two forms of electric flux are used, one for the **E**-field:[13][14]

$$\Phi_E = \oiint_A \mathbf{E} \cdot \mathrm{d}\mathbf{A}$$

and one for the **D**-field (called the electric displacement):

$$\Phi_D = \oiint_A \mathbf{D} \cdot \mathrm{d}\mathbf{A}$$

This quantity arises in Gauss's law – which states that the flux of the electric field **E** out of a closed surface is proportional to the electric charge Q_A enclosed in the surface (independent of how that charge is distributed), the integral form is:

$$\oiint_A \mathbf{E} \cdot \mathrm{d}\mathbf{A} = \frac{Q_A}{\varepsilon_0}$$

where ε_0 is the permittivity of free space.

If one considers the flux of the electric field vector, **E**, for a tube near a point charge in the field of the charge but not containing it with sides formed by lines tangent to the field, the flux for the sides is zero and there is an equal and opposite flux at both ends of the tube. This is a consequence of Gauss's Law applied to an inverse square field. The flux for any cross-sectional surface of the tube will be the same. The total flux for any surface surrounding a charge q is q/ε_0.[15]

In free space the electric displacement is given by the constitutive relation $\mathbf{D} = \varepsilon_0 \mathbf{E}$, so for any bounding surface the **D**-field flux equals the charge Q_A within it. Here the expression "flux of" indicates a mathematical operation and, as can be seen, the result is not necessarily a "flow", since nothing actually flows along electric field lines.

Magnetic flux

The magnetic flux density (magnetic field) having the unit Wb/m² (Tesla) is denoted by **B**, and magnetic flux is defined analogously:[13][14]

$$\Phi_B = \oiint_A \mathbf{B} \cdot \mathrm{d}\mathbf{A}$$

with the same notation above. The quantity arises in Faraday's law of induction, where the magnetic flux is time-dependent either because the boundary is time-dependent or magnetic field is time-dependent. In integral form:

$$-\frac{\mathrm{d}\Phi_B}{\mathrm{d}t} = \oint_{\partial A} \mathbf{E} \cdot d\boldsymbol{\ell}$$

where $d\ell$ is an infinitesimal vector line element of the closed curve ∂A, with magnitude equal to the length of the infinitesimal line element, and direction given by the tangent to the curve ∂A, with the sign determined by the integration direction.

The time-rate of change of the magnetic flux through a loop of wire is minus the electromotive force created in that wire. The direction is such that if current is allowed to pass through the wire, the electromotive force will cause a current which "opposes" the change in magnetic field by itself producing a magnetic field opposite to the change. This is the basis for inductors and many electric generators.

Poynting flux

Using this definition, the flux of the Poynting vector **S** over a specified surface is the rate at which electromagnetic energy flows through that surface, defined like before:[14]

$$\Phi_S = \oiint_A \mathbf{S} \cdot \mathrm{d}\mathbf{A}$$

The flux of the Poynting vector through a surface is the electromagnetic power, or energy per unit time, passing through that surface. This is commonly used in analysis of electromagnetic radiation, but has application to other electromagnetic systems as well.

Confusingly, the Poynting vector is sometimes called the *power flux*, which is an example of the first usage of flux, above.[16] It has units of watts per square metre (W/m^2).

SI radiometry units

SI radiometry units

Quantity		Unit		Dimension	Notes
Name	Symbol[nb 1]	Name	Symbol	Symbol	
Radiant energy	Q_e[nb 2]	joule	J	$\mathbf{M} \cdot \mathbf{L}^2 \cdot \mathbf{T}^{-2}$	Energy of electromagnetic radiation.
Radiant energy density	w_e	joule per cubic metre	J/m^3	$\mathbf{M} \cdot \mathbf{L}^{-1} \cdot \mathbf{T}^{-2}$	Radiant energy per unit volume.
Radiant flux	Φ_e[nb 2]	watt	W = J/s	$\mathbf{M} \cdot \mathbf{L}^2 \cdot \mathbf{T}^{-3}$	Radiant energy emitted, reflected, transmitted or received, per unit time. This is sometimes also called "radiant power".
Spectral flux	$\Phi_{e,\nu}$[nb 3]	watt per hertz	W/Hz	$\mathbf{M} \cdot \mathbf{L}^2 \cdot \mathbf{T}^{-2}$	Radiant flux per unit frequency or wavelength. The latter is commonly measured in W⋅nm^{-1}.
	$\Phi_{e,\lambda}$[nb 4]	watt per metre	W/m	$\mathbf{M} \cdot \mathbf{L} \cdot \mathbf{T}^{-3}$	
Radiant intensity	$I_{e,\Omega}$[nb 5]	watt per steradian	W/sr	$\mathbf{M} \cdot \mathbf{L}^2 \cdot \mathbf{T}^{-3}$	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⋅sr^{-1}⋅Hz^{-1}	$\mathbf{M} \cdot \mathbf{L}^2 \cdot \mathbf{T}^{-2}$	Radiant intensity per unit frequency or wavelength. The latter is commonly measured in W⋅sr^{-1}⋅nm^{-1}. This is a *directional* quantity.
	$I_{e,\Omega,\lambda}$[nb 4]	watt per steradian per metre	W⋅sr^{-1}⋅m^{-1}	$\mathbf{M} \cdot \mathbf{L} \cdot \mathbf{T}^{-3}$	
Radiance	$L_{e,\Omega}$[nb 5]	watt per steradian per square metre	W⋅sr^{-1}⋅m^{-2}	$\mathbf{M} \cdot \mathbf{T}^{-3}$	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	$L_{e,\Omega,\nu}$[nb 3]	watt per steradian per square metre per hertz	W⋅sr^{-1}⋅m^{-2}⋅Hz^{-1}	$\mathbf{M} \cdot \mathbf{T}^{-2}$	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}	$\mathbf{M} \cdot \mathbf{L}^{-1} \cdot \mathbf{T}^{-3}$	
Irradiance Flux density	E_e[nb 2]	watt per square metre	W/m^2	$\mathbf{M} \cdot \mathbf{T}^{-3}$	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}	$\mathbf{M} \cdot \mathbf{T}^{-2}$	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	$\mathbf{M} \cdot \mathbf{L}^{-1} \cdot \mathbf{T}^{-3}$	
Radiosity	J_e[nb 2]	watt per square metre	W/m^2	$\mathbf{M} \cdot \mathbf{T}^{-3}$	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}	$\mathbf{M} \cdot \mathbf{T}^{-2}$	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	$\mathbf{M} \cdot \mathbf{L}^{-1} \cdot \mathbf{T}^{-3}$	
Radiant exitance	M_e[nb 2]	watt per square metre	W/m^2	$\mathbf{M} \cdot \mathbf{T}^{-3}$	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}	$\mathbf{M} \cdot \mathbf{T}^{-2}$	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	$\mathbf{M} \cdot \mathbf{L}^{-1} \cdot \mathbf{T}^{-3}$	
Radiant exposure	H_e	joule per square metre	J/m^2	$\mathbf{M} \cdot \mathbf{T}^{-2}$	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}	$\mathbf{M} \cdot \mathbf{T}^{-1}$	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	$\mathbf{M} \cdot \mathbf{L}^{-1} \cdot \mathbf{T}^{-2}$	
Hemispherical emissivity	ε	N/A		**1**	Radiant exitance of a *surface*, divided by that of a *black body* at the same temperature as that surface.
Spectral hemispherical emissivity	ε_ν *or* ε_λ	N/A		**1**	Spectral exitance of a *surface*, divided by that of a *black body* at the same temperature as that surface.
Directional emissivity	ε_Ω	N/A		**1**	Radiance *emitted* by a *surface*, divided by that emitted by a *black body* at the same temperature as that surface.
Spectral directional emissivity	$\varepsilon_{\Omega,\nu}$ *or* $\varepsilon_{\Omega,\lambda}$	N/A		**1**	Spectral radiance *emitted* by a *surface*, divided by that of a *black body* at the same temperature as that surface.
Hemispherical absorptance	A	N/A		**1**	Radiant flux *absorbed* by a *surface*, divided by that received by that surface. This should not be confused with "absorbance".
Spectral hemispherical absorptance	A_ν *or* A_λ	N/A		**1**	Spectral flux *absorbed* by a *surface*, divided by that received by that surface. This should not be confused with "spectral absorbance".
Directional absorptance	A_Ω	N/A		**1**	Radiance *absorbed* by a *surface*, divided by the radiance incident onto that surface. This should not be confused with "absorbance".
Spectral directional absorptance	$A_{\Omega,\nu}$ *or* $A_{\Omega,\lambda}$	N/A		**1**	Spectral radiance *absorbed* by a *surface*, divided by the spectral radiance incident onto that surface. This should not be confused with "spectral absorbance".
Hemispherical reflectance	R	N/A		**1**	Radiant flux *reflected* by a *surface*, divided by that received by that surface.
Spectral hemispherical reflectance	R_ν *or* R_λ	N/A		**1**	Spectral flux *reflected* by a *surface*, divided by that received by that surface.
Directional reflectance	R_Ω	N/A		**1**	Radiance *reflected* by a *surface*, divided by that received by that surface.

Spectral directional reflectance	$R_{\Omega,\nu}$ *or* $R_{\Omega,\lambda}$	N/A		**1**	Spectral radiance *reflected* by a *surface*, divided by that received by that surface.
Hemispherical transmittance	T	N/A		**1**	Radiant flux *transmitted* by a *surface*, divided by that received by that surface.
Spectral hemispherical transmittance	T_ν *or* T_λ	N/A		**1**	Spectral flux *transmitted* by a *surface*, divided by that received by that surface.
Directional transmittance	T_Ω	N/A		**1**	Radiance *transmitted* by a *surface*, divided by that received by that surface.
Spectral directional transmittance	$T_{\Omega,\nu}$ *or* $T_{\Omega,\lambda}$	N/A		**1**	Spectral radiance *transmitted* by a *surface*, divided by that received by that surface.
Hemispherical attenuation coefficient	μ	reciprocal metre	m^{-1}	$\mathbf{L}^{-1}$	Radiant flux *absorbed* and *scattered* by a *volume* per unit length, divided by that received by that volume.
Spectral hemispherical attenuation coefficient	μ_ν *or* μ_λ	reciprocal metre	m^{-1}	$\mathbf{L}^{-1}$	Spectral radiant flux *absorbed* and *scattered* by a *volume* per unit length, divided by that received by that volume.
Directional attenuation coefficient	μ_Ω	reciprocal metre	m^{-1}	$\mathbf{L}^{-1}$	Radiance *absorbed* and *scattered* by a *volume* per unit length, divided by that received by that volume.
Spectral directional attenuation coefficient	$\mu_{\Omega,\nu}$ *or* $\mu_{\Omega,\lambda}$	reciprocal metre	m^{-1}	$\mathbf{L}^{-1}$	Spectral radiance *absorbed* and *scattered* by a *volume* per unit length, divided by that received by that volume.
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)—not to be confused with suffix "v" (for "visual") indicating a photometric quantity.
4. Spectral quantities given per unit wavelength are denoted with suffix "λ" (Greek).
5. Directional quantities are denoted with suffix "Ω" (Greek).

See also

- AB magnitude
- Explosively pumped flux compression generator
- Eddy covariance flux (aka, eddy correlation, eddy flux)
- Fast Flux Test Facility
- Fluence (flux of the first sort for particle beams)
- Fluid dynamics
- Flux footprint
- Flux pinning
- Flux quantization
- Gauss's law
- Inverse-square law
- Jansky (non SI unit of spectral flux density)
- Latent heat flux
- Luminous flux
- Magnetic flux
- Magnetic flux quantum
- Neutron flux
- Poynting flux
- Poynting theorem
- Radiant flux
- Rapid single flux quantum
- Sound energy flux
- Volumetric flux (flux of the first sort for fluids)
- Volumetric flow rate (flux of the second sort for fluids)

Notes

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Further reading

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External links

- The dictionary definition of *flux* at Wiktionary