

Ray Tracing

Use Ray-Tracing to model specular reflection, transmission and transmission/refraction.

Two separate Ray Tracing calculations are available in TMG. Automatic Ray-Tracing is performed if elements with defined solar specularity or solar transmissivity material properties have a direct view to a solar spectrum source either from *Diurnal Solar Heating*, *Orbit/Attitude Modeling* or *Radiative Heating*.

Ray Tracing for diffuse solar reflection and InfraRed flux is performed only if the *Ray Trace to Enhance Specular/Transparent Accuracy* option is toggled *ON* on the *Radiation Request* form.

Material Properties

Ray-Tracing calculations will be performed only if the model includes specular or transmissive elements. In TMG, elements can be specular and transmissive at the same time.

Transmissive and/or specular elements can reflect diffusely: if the addition of the absorptivity, transmissivity and specularity property values do not equal one, the remaining fraction is used to define diffuse reflection.

A material has a single value of transmissivity that applies to both the front and reverse sides. Since radiation will be transmitted through the element, it is implicit that its reverse side participates in the radiation process. A transmissive or partially transmissive element on the boundary of the model will create a leak unless the model is surrounded by a space element.

Automatic Ray-Tracing for Elements with Direct Solar View

In computing solar view factors, TMG automatically uses ray-tracing to model specular reflections and transmissions. The Ray-Tracing process is used to correct the direct solar view factors to account for specular images of the sun.

Collimated rays are launched from all specular or transmissive elements which have direct solar view factors greater than zero. The direction of these rays is controlled by the relative location of the elements to the sun.

To trace the rays through the enclosure, TMG uses the direction of the rays, accounting for any directional properties, and the view factors. TMG sends rays only to elements that can possibly have a view to the transmissive or specular elements.

The number of rays sent to an element is proportional to the view factor between the element and the transmissive and/or specular element. The ray density is controlled by the subdivision parameter (D); the number of rays launched between two quadrilateral elements is at least $16 \times D^4$. More rays are sent if the specular or transmissive element has a view factor with a large number of elements. When you are using the error criterion, TMG estimates a subdivision parameter based on the magnitude of the view factor.

A ray is traced through the enclosure until one of the following conditions is satisfied:

- it impinges a fully diffuse element
- its magnitude is reduced to less than 0.1% of its original value

- it has been traced through 100 reflections

Ray-Tracing for Diffuse Solar Reflection and IR

With this option toggled *ON* on the *Radiation Request* form, TMG will use ray tracing to compute the black body view factors resulting from specular reflection or transmission in the enclosure. Partially specular and diffuse surfaces are handled correctly and efficiently.

If the *Radiation Request* type is Enclosure, the ray tracing will be done only for the elements selected on the form.

Note that ray-tracing for diffuse solar reflection and IR can increase solve time substantially. With this option, when TMG computes black body view factors, it launches many rays from each surface element to every specular or transmissive surface which it sees; these rays are then traced throughout the enclosure. The ray density is controlled by the global subdivision parameter (*D*); the number of rays launched between two quadrilateral elements is equal to $16 \times D^4$.

When a ray intersects a specular surface element, its magnitude is reduced by the diffuse component of reflectivity. Rays are extinguished when one of the following conditions is satisfied:

- the ray impinges a fully diffuse element
- the ray's magnitude is reduced to less than 0.1% of its original value
- the ray has been traced through 100 reflections

Curved Surfaces and Ray-Tracing

For modeling systems which involve specular reflections from curved surfaces, either direct or diffuse solar or IR, you can use parabolic shell elements to get a more accurate simulation of the reflection patterns.

The mid-side nodes for parabolic shells are used to establish a shape function for the element. The resulting curved shape is accounted for in computing the intersection point and reflection direction for rays which impinge the element. The use of curved surface elements can be particularly important for accurate calculation of the focusing effects introduced by highly concave surfaces.

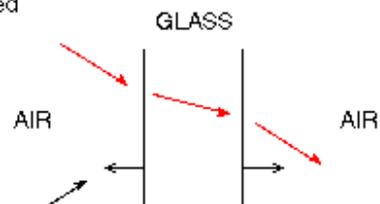
Refraction and Ray-Tracing

When modeling refraction, elements represent a transmissive surface, that is a change from one transmissive medium to another. For example, a meshed surface could represent the change from air to glass. A second meshed surface is needed to model the opposite surface of glass where the change is from glass to air.

The distance between the two meshed surfaces must be accurate.

Refraction Through a Glass Panel

Two meshed surfaces are required to model refraction through a glass panel



The element +Z triad direction is used to apply the correct index of refraction on each side of the elements.

The transmissivity specified in the material definition will be applied twice, so for values less than 1, the entered value must be adjusted to give the correct combined (effective) value. You should enter the square root of the total transmissivity.

You can model a transparent medium with solid elements. You must surface coat the solid elements with 2D elements that radiate from both sides. The solid elements will be ignored by TMG and radiation will pass through them. Remember though that the solid elements themselves will not absorb radiative energy. This energy is absorbed by the 2D surface coating elements and then transferred to the solid by conduction. Similarly, the solid elements cannot affect the transmissivity. For example, if the solid has a variable thickness and if this affects the transmissivity, the 2D surface coating elements must be created with the transmissivity that applies to their location on the solid. Solar transmissivity can be a function of the Angle of Incidence and/or of the Direction of Incidence in TMG.

The procedure shown here guides you through the steps needed to model refraction as light energy passes from a transparent material (air for example) through a second transparent material (glass for example) and back to the original transparent material:

1. Define the transmissivity of the second material as being the square root of the total transmissivity through the entire thickness of that material (e.g. thickness of the glass).
2. Specify two values for the index of refraction: one for the material on the front side (e.g. air) and one for the reverse side (e.g. glass).
3. Create a thin shell physical property. If you are surface coating solid elements, specify a null thickness. If you are meshing only the surfaces of your geometry, specify half of the total thickness.
4. Mesh each surface with shell elements.
5. Check the element +Z triad direction. The front side of the element should point toward the material for which the front side index of refraction applied.
6. If you do not mesh the solid, create a thermal coupling between the two surfaces to model conduction through the solid.

When modeling refraction through curved surfaces, you can use parabolic elements to increase the Ray-Tracing accuracy.