Indigo Renderer Manual

For Indigo Renderer version 1.0.x

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Contents

Indigo Overview

Indigo is a stand-alone application. Indigo renders one image at a time, reading the scene description from Indigo scene file (.igs), and writing the resulting image as a PNG file in the 'renders' directory. Indigo can be used in conjunction with a 3d-modelling package such as 3dsMax by using one of the exporters being coded by various people. The process in this case is

1. model scene in the 3d modelling package.
2. Use exporter script to export .3ds models and scene xml file to some directory.
3. Start indigo, specifying the path to the scene file to render.

Alternatively, the scene file can be hand-edited.

Running Indigo

There are two executable files included in the Indigo distribution. Indigo.exe is the graphical user-interface (GUI) version of Indigo. Indigo_console.exe is the command line, non-GUI version.

Running Indigo on Linux

Although Indigo doesn't have a native build for the Linux platform, it can be run through Wine.

The following is an example of how to get, install, and run Indigo on a Debian based distribution:

```
wget http://www.indogorenderer.com/latest_indigo_version.zip
apt-get install unzip
apt-get install wine
unzip latest_indigo_version.zip
cd latest_indigo_version
wine indigo_console.exe testscenes/simple_test.igs
```

You will need to replace the URI 'http://www.indogorenderer.com/latest_indigo_version.zip' with the correct URI for the Indigo version you want to download.

Network Rendering

Indigo supports distributed rendering over a TCP/IP network. One Indigo process is started as a network master. Mutiple Indigo processes (usually on other boxes) are then started as network slaves. The network slaves work on their own local version of the render, and periodically upload their buffer to the network master, where they are combined into the master render and saved to disk in the 'renders' directory as per usual.

The steps to run a network render are as follows:

1. Choose a scene to render, eg. somescene.xml.
2. Start the network master process like this:

   indigo.exe somescene.xml -n m

   The *-n m* switch tells the process to run as a network master

3. On another box, start a network slave process like this:

   indigo.exe -n s -h lust:7777

   The *-n s* switch runs indigo in network slave mode.

   The *-h lust:7777* switch tells the slave to connect to the network master running on the host 'lust' on port 7777 (the indigo port)

   You should of course substitute the host name running the network master for 'lust'.

   The *-h* switch is optional. If it is not present, the local network is scanned for any masters, and if one is found, the slave connects to the master automatically.

Synchronising the scene file

In the above network rendering example, the file 'somescene.xml' needs to be present on all boxes, so that all the slaves and the master can load it. This can cause problems if the scene is changed on one box but not others. One way to ensure that all Indigo processes are working on the same scene is to place the scene in a windows share. Then the master would be started like this, and analogously for the slaves.

indigo.exe \\lust\sceneshare\somescene.xml -n m

Progressive rendering

As a consequence of the unbiased nature of Indigo, the render will gradually converge over time to the correct solution. The longer you leave the render, the less noise will remain in the image. Indigo can be left to render a given scene for an arbitrary amount of time, and will never terminate by itself. Simply close Indigo when you are satisfied with the render (or you don't want to wait any longer).

Command line parameter Reference

indigo [scenepathname]

Starts Indigo. If *scenepathname* is present, then it will attemp to load that scene file.

-h hostname:port

Sets the hostname and port that a network slave indigo process will try and connect to, e.g.

indigo -n s -h masterhostname:7777

-halt halttime

Stops the Indigo process after *halttime* seconds. By default Indigo does not halt.

-haltspp X

Stops the Indigo process after X samples per pixel have been reached.

-n s

Start in network render slave mode.

-n m

Start in network render master mode.

-n wm

Start in network render working master mode. Working master mode is like master mode, except rendering work is done on the master as well as the slaves.

-o pathname

Writes the render to *pathname* instead of the usual generated pathname.

-p port

Instructs a network render master to listen on a particular port.

-r igi_path

Resume render using Indigo Image (.igi) found at *igi_path*.

-t numthreads

Runs the Indigo process with *numthreads* threads.

--ptest

Runs performance test for the given scene.

--dumpmetadata png_path

Dump PNG meta data from file at *png_path*

--pack scene.igs out.pigs

Pack Indigo scene *scene.igs* to *out.pigs*

Scene XML format

Indigo scene files are stored in an XML format. The filename extension is .igs, for 'Indigo Scene'.

Root element should be called 'scene'.

renderer_settings

This element provides a means of overriding various settings from inifile.xml. This element is optional, and so are each of its children. Any setting defined here overrides the respective setting from inifile.xml.

element status: optional

width

Sets the width (horizontal resolution) of the output image.

type: integer

restrictions*:* must be > 0

units*:* pixels

default value*:* 600

height

Sets the height (vertical resolution) of the output image.

type: integer

restrictions*:* must be > 0

units*:* pixels

default value*:* 450

bih_tri_threshold

If the number of triangles in a single mesh exceeds this threshold, then a BIH will be used for intersection accleration for that mesh, otherwise a Kd-tree is used.

type: integer

restrictions*:* must be > 0

units*:* number of triangles

default value*:* 1100000

metropolis

Enables or disables Metropolis-Hastings sampling

type: boolean

default value*:* true

large_mutation_prob

Probability of selecting a large mutation type. Only used if metropolis is true.

type: scalar real

restrictions*:* must in range [0, 1]

units*:* dimensionless

default value*:* 0.4

max_change

Radius of the perturbation mutation distribution.

type: scalar real

restrictions*:* must in range [0, 1]

units*:* dimensionless

default value*:* 0.01

max_depth

Maximum ray bounce depth.

type: integer

restrictions*:* must be > 0

units*:* number of bounces

default value*:* 10000

max_num_consec_rejections

Maximum number of consecutive rejection of tentative new samples when Metropolis-Hastings transport is used. Note that any non-infinite number technically causes biased sampling.

type: integer

restrictions*:* must be > 0

units*:* number of rejections

default value: 1000

logging

If true, a log of the console output is written to log.txt

type: boolean

default value: true

bidirectional

If true, bidirectional path tracing is used to construct paths. Otherwise, backwards path tracing is used.

type: boolean

default value: true

save_untonemapped_exr

If true, an untonemapped EXR image is saved in the renders directory.

type: boolean

default value: false

save_tonemapped_exr

If true, a tonemapped EXR image is saved in the renders directory.

type: boolean

default value: false

save_igi

If true, an untonemapped Indigo Image (.igi) file is saved in the renders directory.

type: boolean

default value: false

image_save_period

The rendered image(s) will be saved to the renders directory every *image_save_period* seconds.

type: scalar real

restrictions: must be > 0

units: seconds

default value: 10

halt_time

If positive, indigo will halt after *halt_time* seconds.

type: scalar real

restrictions:

units: seconds

default value: -1

halt_samples_per_pixel

If positive, indigo will halt after *halt_samples_per_pixel* samples per pixel have been reached.

type: scalar real

restrictions:

units: samples / pixel

default value: -1

hybrid

If true, direct illumination is sampled with QMC sampling, and indirect illumination with Metropolis-Hastings sampling.

type: boolean

default value: false

frame_upload_period

Period between uploads of the image buffer from slave to master when rendering in network mode.

type: scalar real

restrictions: must be > 0

units: seconds

default value: 40

auto_choose_num_threads

If true, the number of render threads used is set based on the number of logical cores detected.

type: boolean

default value: true

num_threads

Number of render threads used. This setting is only used if *auto_choose_num_threads* is false.

type: integer

restrictions: must be > 0

units: number of threads

default value: 1

super_sample_factor

If this factor is greater than 1, then the image is rendered at a higher resolution internally, then downsampled using the downsize filter before the render is saved to disk. This can help to reduce aliasing around high contrast edges.

Note that higher factors require more memory (RAM).

type: integer

restrictions: must be > 0

units: dimensionless

default value: 2

display_period

The internal HDR buffer is tonemapped and displayed on screen every *display_period* seconds.

type: scalar real

restrictions: must be > 0

units: seconds

default value: 10

ray_origin_nudge_distance

Ray origins are offset by this distance after intersection, in order to avoid false self-intersections.

type: scalar real

restrictions: must be >= 0

units: meters

default value: 1.0e-4

watermark

If true, an 'Indigo Renderer' logo is drawn on the bottom right hand corner of the output render.

type: boolean

default value: false

cache_trees

If true, kd-trees are cached to disk after construction, in the tree_cache directory.

type: boolean

default value: true

aperture_diffraction

If true, diffraction of light passing through the camera aperture is simulated.

type: boolean

default value: true

post_process_diffraction

If true, aperture_diffraction is simulated using a filter applied to the image buffer, instead of perturbation of rays. This technique is generally faster and less noisy, but slightly less accurate.

type: boolean

default value: true

render_region

If this element is present, only a certain region of the usual image is rendered.

Only pixels (x, y) such that x1 <= x < x2 and y1 <= y < y2 are rendered.

render_region::x1

X Coordinate of top left pixel of rendered region.

type: integer

restrictions: must be >= 0

units: pixels

render_region::y1

Y Coordinate of top left pixel of rendered region.

type: integer

restrictions: must be >= 0

units: pixels

render_region::x2

X Coordinate of pixel immediately to the right of rendered region.

type: integer

restrictions: x1 < x2 <= width

units: pixels

render_region::y2

Y Coordinate of pixel immediately below rendered region.

type: integer

restrictions: *y*1 < y2 <= height

units: pixels

render_foreground_alpha

If this is true, the output image is just a greyscale image, where the foreground is white, and the background (physical sky, env map, constant background, void background etc..) is black.

type: boolean

default value: false

splat_filter

Controls the filter used for splatting contributions to the image buffer.

Can be one of *box*, *gaussian,* or *mn_cubic*.

splat_filter::box

Box filter. Causes bad aliasing, don't use :)

splat_filter::gaussian

Gaussian filter with standard deviation of 0.35 pixels.

splat_filter::mn_cubic

Mitchell-Netravali cubic filter. Good all-round filter with little aliasing.

Please refer to the paper 'Reconstruction Filters in Computer Graphics' by Mitchell and Netravali, 1988, for more information.

splat_filter::mn_cubic::blur

The 'B' parameter from the paper. Higher blur values cause more blurring of the image

type: scalar real

restrictions*:* will give best results in range [0, 1]

units*:* dimensionless

default value*:* 0.6

splat_filter::mn_cubic::ring

The 'C' parameter from the paper. Higher ring values cause more 'ringing'. (alternating bands of black and white around high contrast edges).

Note that Mitchell and Netravali recommend choosing B and C such that 2C + B = 1.

type: scalar real

restrictions*:* will give best results in range [0, 1]

units*:* dimensionless

default value: 0.2

downsize_filter

Controls the filter used for downsizing super-sampled images.

Only used when super_sample_factor is greater than one.

Takes exactly the same parameters as *splat_filter*.

Example XML for renderer_settings:

```
<renderer_settings>
          <metropolis>true</metropolis>
          <bidirectional>true</bidirectional>

          <width>800</width>
          <height>600</height>

          <downsize_filter>
                    <mn_cubic>
                              <ring>0.2</ring>
                              <blur>0.6</blur>
                    </mn_cubic>
          </downsize_filter>
          <splat_filter>
                    <gaussian/>
          </splat_filter>

          <super_sample_factor>2</super_sample_factor>

          <aperture_diffraction>true</aperture_diffraction>
          <post_process_diffraction>true</post_process_diffraction>
</renderer_settings>
```

background

Illuminates scene with a uniform environment light.

element status: optional

Must have exactly one 'spectrum' child element.

example xml:

```
<background>
	<spectrum>
		<blackbody>
			<temperature>3500</temperature>
			<gain>1.0</gain>
		</blackbody>
	</spectrum>
</background>
```

skylight

Illuminates scene with sunlight and scattered skylight.

element status: optional

sundir

The *sundir* element defines the 3-vector direction towards the sun. the Z axis is up, e.g. (0,0,1) places the sun directly overhead. Need not be normalised

type: *real 3-vector*

restrictions: *z component must be > 0*

units: *dimensionless*

turbidity

The *turbidity* defines the haziness/clearness of the sky. Lower turbidity means a clearer sky. Should be set to something between 2 and ~5.

type: *scalar real*

restrictions: *> 0*

units: *dimensionless*

extra_atmospheric

If extra_atmospheric is true, then the skylight is computed as if it was outside the atmosphere.

This means that the sun spectrum is not attenuated by atmospheric scattering, and the sky will be black, since there is no atmospheric scattering.

Element status: optional

type: boolean

default:false

xml example:

```
<skylight>
        <sundir>0 0.6 1</sundir>
        <turbidity>2</turbidity>
</skylight>
```

env_map

element status: optional

Illuminates scene with a HDR environment map.

Currently Indigo can load two types of environment maps.

The first type is .exr maps in lat-long format:

env_map :: lat_long

env_map :: lat_long :: path

The path to the .exr file.

type: *string*

restrictions: *must be a valid path*

units:

env_map :: lat_long :: gain

The map is scaled by this factor when it is loaded.

type: *scalar real*

restrictions: *> 0*

units*: dimensionless*

The second type of Env map supported by Indigo is .float maps in spherical format. .float is a simple format exported by the HDR Shop program, with 3 32bit floats per pixel, one per colour channel, and no other information in the file.

env_map :: spherical

env_map :: spherical :: path

The path to the .exr file.

type*: string*

restrictions*: must be a valid path*

units*:*

env_map :: spherical :: width

The width of the map. Must be equal to the height

type*: scalar integer*

restrictions*: > 0*

units*: pixels*

env_map :: spherical :: gain

The map is scaled by this factor when it is loaded.

type*: scalar real*

restrictions*: > 0*

units*: dimensionless*

Example XML:

```
<env_map>
        <spherical>
            <path>probes/kitchen_probe.float</path>
            <width>640</width>
            <gain>0.9</gain>
        </spherical>
```

```
        <!--latlong>
            <path>probes/skylight-day.exr</path>
            <gain>1.0</gain>
        </latlong-->
</env_map>
```

Tonemapping

The tonemapping element should have one child element, either 'linear', 'reinhard', or 'camera'.

element status: required

tonemapping :: linear

tonemapping :: linear :: scale

A constant by which the pixel values are multiplied.

type: *scalar real*

restrictions: *>= 0*

units: *dimensionless*

tonemapping :: reinhard

tonemapping :: reinhard :: pre_scale

The pixel buffer is scaled by this factor before the non-linear stage of the tonemapping takes place. Stands in for the middle-grey luminance scaling in part 3.1 of Reinhard et. al.'s Photographic Tone Reproduction for Digital Images paper.

type: *scalar real*

restrictions: *>= 0*

units: *dimensionless*

tonemapping :: reinhard :: post_scale

This scaling factor is applied after the rest of the tone mapping stages. By default, the pixel with max luminance is mapped to white, so setting this scale to > 1 will result in pixels with less luminance being mapped to white. example:

type: *scalar real*

restrictions: *>= 0*

units: *dimensionless*

tonemapping :: reinhard :: burn

Determines the luminance at which clipping occurs.

A smaller value means more severe burn, no burn will occur in the limit as the value goes to infinity.

element status: optional

type*: scalar real*

restrictions*: > 1*

units*: dimensionless*

default value*: 10*

tonemapping :: camera

Camera tone mapping is an attempt to model the image generation process of a digital camera, and shares some parameters with a real camera.

The response function uses data from

http://www1.cs.columbia.edu/CAVE/software/softlib/dorf.php

, as such many cameras should be able to be modelled.

tonemapping :: camera :: response_function_path

Path to response function data file, e.g. 'data/camera_response_functions/dscs315.txt'

Path can be absolute or relative; if relative, it is taken relative to the Indigo executable base path.

type: string

restrictions*:*

units*:*

tonemapping :: camera :: ev_adjust

ev_adjust is exposure-value adjustment; increasing this value by 1 will effectively double the 'sensor output'.

type: real scalar

restrictions*:*

units*: dimensionless*

tonemapping :: camera :: film_iso

film speed (film ISO) has much the same effect as ev_adjust, except it's a linear factor. Doubling the film ISO will double the 'sensor output'.

type: real scalar

restrictions: *must be > 0*

units: *dimensionless*

xml example:

```
<tonemapping>
        <reinhard>
                <pre_scale>1.0</pre_scale>
                <post_scale>1.0</post_scale>
        </reinhard>
</tonemapping>
```

Camera

element status: required

pos

Defines the position of the camera.

type: real 3-vector

restrictions:

units: meters

up

Defines the up vector of the camera. This and the forwards vector uniquely determine the right vector. Need not be normalised.

type: real 3-vector

restrictions:

units: *dimensionless*

forwards

Defines the forwards vector of the camera, i.e. which direction it is facing. Need not be normalised.

type: real 3-vector

restrictions:

units: *dimensionless*

aperture_radius

Defines the radius of the camera aperture. Larger radius means more depth of field.

If a non-circular aperture is used, then aperture_radius defines the half-width of the rectangle in which the aperture shape is defined.

type: scalar real

restrictions: Must be greater than zero.

units: meters

focus_distance

Distance from the camera, along the camera forwards direction, to the focal plane. Objects lying on the focal plane will be in focus. Value not used if autofocus is set.

type: scalar real

restrictions: Must be greater than zero.

units: meters

aspect_ratio

Influences the directions in which rays are traced. Should be set to the image width divided by the image height.

type: scalar real

restrictions: Must be greater than zero.

units: dimensionless

sensor_width

Width of the sensor element of the camera. A reasonable default is 0.036. (36mm)

Determines the angle of view (FOV), together with the lens_sensor_dist.

type: scalar real

restrictions: Must be greater than zero.

units: meters

lens_sensor_dist

Distance from the camera sensor to the camera lens. A reasonable default is 0.02. (20mm)

type: scalar real

restrictions: Must be greater than zero.

units: meters

white_balance

Sets the white balance of the camera.

Possible values are D50, D55, D65 etc..
all the illuminants from **http://en.wikipedia.org/wiki/White_point** are supported.

What's this for?
Well lets say you're rendering a room illuminated by a 5000K blackbody emitter.
In real life, your eyes would adjust to the lighting conditions, and you would perceive the light as white.
The same would occur in a room lit by a 6500K blackbody emitter.
A whitebalance setting allows the camera to adjust in the same way that the eyes do.
So if you set the white balance to D50 and render the room with a 5000K emitter, the light should appear white.
If you set the white balance to D65 it will come out kinda orange.
The D65 white point is designed for outdoors and is a good general setting to use if you're not sure what to use.

type*:* string

restrictions*:* Must be one of 'D65', 'D50', 'E' etc..

exposure_duration

How long the exposure will be. The longer the exposure duration, the greater the light energy registered by the sensor.

type*:* scalar real

restrictions*:* Must be greater than zero.

units*:* seconds

autofocus

If this (empty) element is present, a ray will be traced from the camera position in the camera forwards direction. The camera focus distance will then be set to the distance the ray travels before striking an object, or to infinity if no object is hit.

Element status: optional

bloom (deprecated)

If this element is present, then a simple 'bloom' simulation will be computed.

bloom::weight (deprecated)

Controls the intensity of the bloom effect, as the fraction of the original image pixel values filtered and added back to the image.

type*:* scalar real

restrictions*:* Must be >= 0

units*:* dimensionless

bloom::radius (deprecated)

Standard deviation of the bloom filter kernel in pixels, as a fraction of the larger value of the image width and height.

type*:* scalar real

restrictions: Must be >= 0

units: dimensionless

obstacle_map

If this element is present, then an obstacle map texture is used when calculating the diffraction though the camera aperture.

An obstacle map will only have an effect if aperture_diffraction is enabled.

Path must be relative to the scene working directory.

Element status: optional

type*:* string

aperture_shape

This element allows a particular shape of camera aperture to be specified. The allowable shapes are *image, generated*, or *circular.*

If the aperture_shape element is not present, then a default circular aperture shape is used.

Note that a preview of the final aperture shape will be saved in the working directory as *aperture_preview.png*.

Element status: optional

aperture_shape::circular

Makes the camera use a circular shaped aperture.

aperture_shape::image

Allows the aperture shape to be loaded from an image file.

aperture_shape::image::path

The path to the aperture image file.

The image must be of PNG format.

The image is interpreted as a greyscale image.

The image must be square, and have power-of-two dimensions of at least 512 x 512.

White portions of the image are interpreted as transparent, and black parts of the image are interpreted as stopping light.

The white part of the aperture image should be as large as possible (i.e. It should just touch the edges of the square image), to allow for efficient sampling.

Path must be relative to the scene working directory.

type: string

aperture_shape::generated

Allows the aperture shape to be defined using a few parameters. See the attached digram for more information.

aperture_shape::generated::num_blades

Number of diaphragm blades.

type: integer

restrictions: Must be >= 3

units: dimensionless

aperture_shape::generated::start_angle

Initial angle of first diaphragm blade.

type: scalar real

restrictions:

units: radians

aperture_shape::generated::blade_offset

Distance from center of aperture shape to edge of diaphragm.

type: scalar real

restrictions: must be > 0

units: fraction of aperture shape width

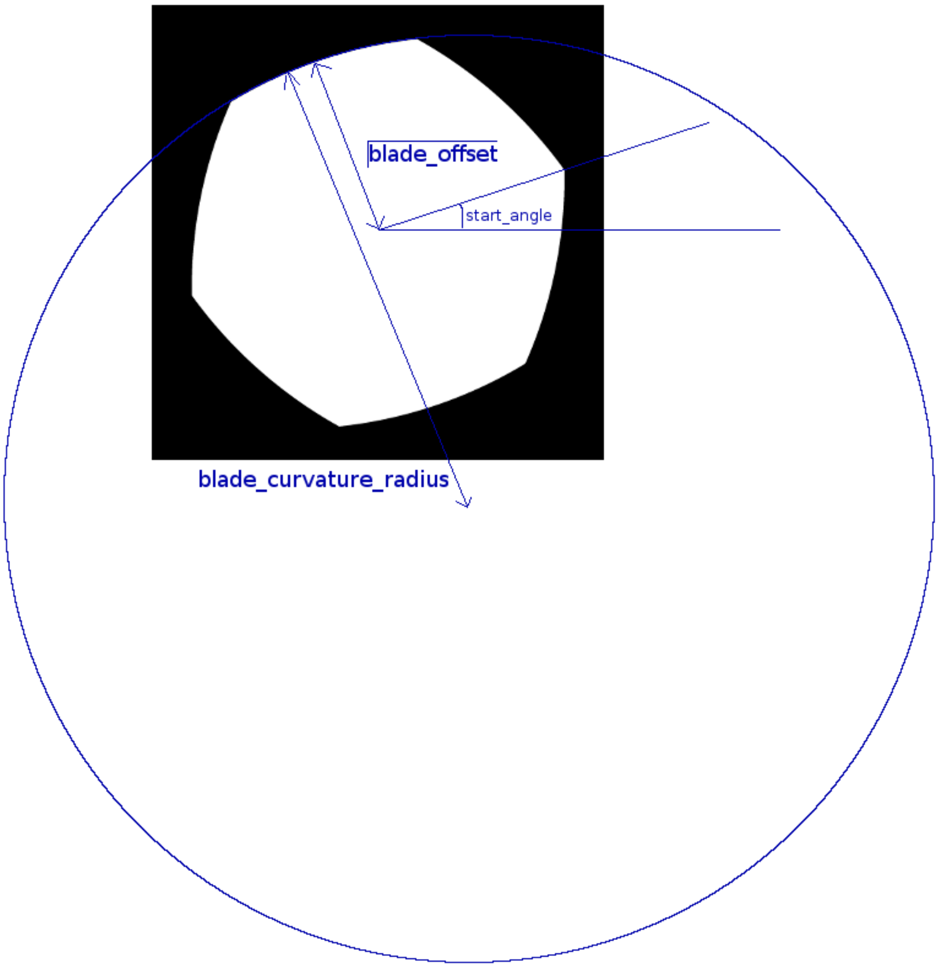
aperture_shape::generated::blade_curvature_radius

Distance from edge of diaphragm to effective center of diaphragm curvature circle.

type: scalar real

restrictions: must be > 0

units: fraction of aperture shape width



Camera element example XML:

```
<camera>
        <pos>0 -2 1</pos>
        <up>0 0 1</up>
        <forwards>0 1 0</forwards>
        <aperture_radius>0.001</aperture_radius>
        <focus_distance>3.0</focus_distance>
        <aspect_ratio>1.33</aspect_ratio>
        <sensor_width>0.036</sensor_width>
        <lens_sensor_dist>0.02</lens_sensor_dist>
        <white_balance>E</white_balance>

          <autofocus/>
          <bloom>
                    <weight>0.1</weight>
                    <radius>0.05</radius>
          </bloom>
</camera>
```

Materials

Texture

All maps used must be 3 component (RGB) maps.

The final, used value for each component is calculated like so:

$f(x) = a*g(x)^2 + b*g(x) + c$

and

$g(x) = x^{exponent}$

Where x is the colour component from the map (e.g. One of the R, G, B), normalised to [0, 1],

f(x) is the final used value, and *a*, *b*, *c*, and *exponent* are as described below.

In the case where are scalar value is required from the map, for example when using a bump map,

the final value is calculated as (f(r) + f(g) + f(b)) / 3

texture::uv_set

Name of the set of uv coordinates used for texture lookup.

type: string

restrictions: must be a uv set that has been exported by a mesh, if the material is used on that mesh.

units:

texture::path

Path to the texture on disk. Path must be relative to the scene working directory.

type: string

texture::exponent

Used for converting texture RGB values to display values. A typical value is thus 2.2.

type: scalar real

restrictions: must be > 0

units: dimensionless

texture::a

'a' coefficient for quadratic texture function.

Element status: optional

texture::b

'b' coefficient for quadratic texture function.

Element status: optional

texture::c

'c' coefficient for quadratic texture function.

Element status: optional

material

Defines a material.

A material element must have one child element called 'name', and another element which can be either 'specular', 'phong', or 'diffuse' etc..

material :: name

The name of the material

type: string

restrictions*:*

units*:*

example xml:

```
<material>
        <name>white</name>
        <diffuse>
            <colour>0.9 0.9 0.9</colour>
        </diffuse>
</material>
```

diffuse

Diffuse is a lambertian diffuse material.

albedo_spectrum

Sets the reflectance (albedo)

Values will be silently clamped to the range [0, 1].

Type: spectrum element

units: dimensionless

restrictions: Spectrum values should lie in the range [0, 1]

colour (deprecated as of v0.9)

Sets the RGB reflectance (albedo). All components should be in the range [0, 1)

Each component will be silently clamped to the range (after reverse gamma correction) [0, 0.9].

As of 0.7 test2, the RGB colour will be 'reverse gamma corrected' – all components will be converted to display values by raising to the power of 2.2.

type: real 3-vector

restrictions*: Each* component should be in the range [0, 1)

units*: dimensionless*

albedo_texture

Overrides the albedo (reflectance) of the material. If such a texture is present, the texture colour is used as the final diffuse colour.

element_status: optional

type: texture element

bump_map

The bump map is used to perturb the shading normal of the surface. Note that the b coefficient (gain) must often be set to a small value (e.g. 0.001) for realistic results.

element_status: optional

type: texture element

example xml:

```
<diffuse>
	<colour>0.8 0.8 0.8</colour>

	<albedo_texture>
		<uv_set>albedo</uv_set>
		<path>checker.jpg</path>
		<exponent>2.2</exponent>
	</albedo_texture>

	<bump_map>
		<uv_set>bump</uv_set>
		<path>bump_map.jpg</path>
		<b>0.0001</b>
		<exponent>1.0</exponent>
	</bump_map>
</diffuse>
```

specular

Specular is a material that can be both a perfect specular reflector and a perfect specular transmitter.

internal_medium_name

Should be the name of a medium already defined in the scene file.

type: string

unit:

restrictions:

transparent

true or false. If true, light can be transmitted, if not, only reflected light is simulated.

type: boolean

bump_map

The bump map is used to perturb the shading normal of the surface. Note that the b coefficient (gain) must often be set to a small value (e.g. 0.001) for realistic results.

element_status: optional

type: texture element

xml example:

```
<specular>
        <transparent>true</transparent>
        <internal_medium_name>glass</internal_medium_name>
</specular>
```

phong

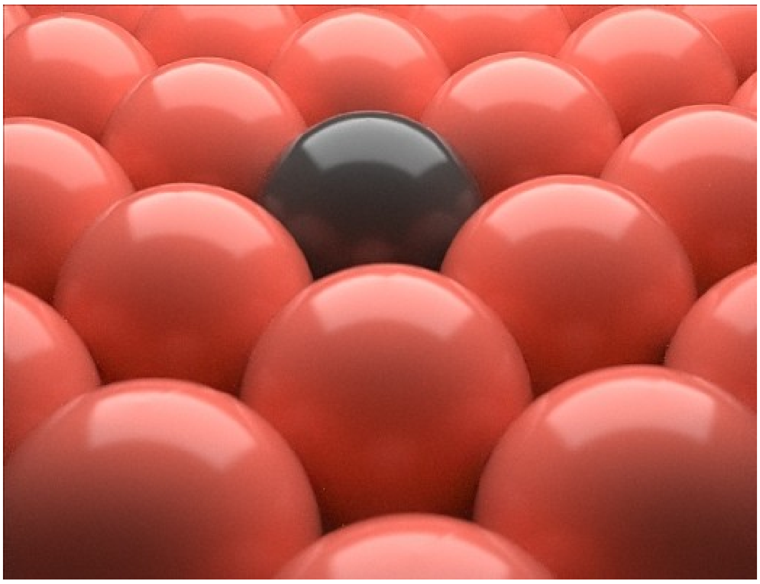


Image by Xman

Phong is a physically based glossy reflection model using a Phong lobe. Has a lambertian diffuse substrate.

diffuse_albedo_spectrum

The reflectance of the diffuse substrate. Note that the diffuse substrate can also be textured, in which case this element will have no effect.

Values will be silently clamped to the range [0, 1].

type: spectrum element

units*:* dimensionless

restrictions: Spectrum values should lie in the range [0, 1]

Diffuse (deprecated as of v0.9)

The RGB reflectance of the diffuse substrate. Note that the diffuse substrate can also be textured.

Each component will be silently clamped to the range (after reverse gamma correction) [0, 0.9].

As of 0.7 test2, the RGB colour will be 'reverse gamma corrected' – all components will be converted to display values by raising to the power of 2.2.

type: real 3-vector

units*:* dimensionless

restrictions: All components should be in the range [0, 1)

ior

Index of refraction of the dielectric coating or substance making up the material.

type*:* real scalar

units*:* dimensionless

restrictions: >= 1

exponent

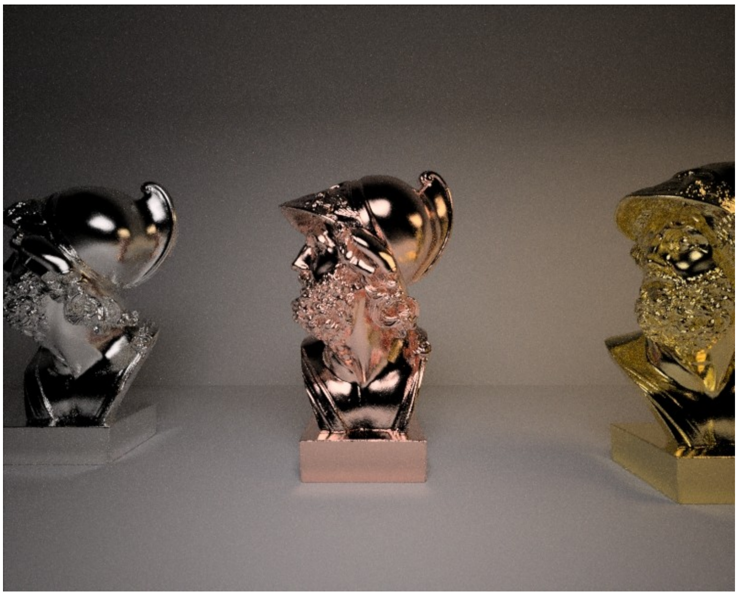
Sets the exponent of the Phong lobe controlling specular reflection. Higher exponent means more 'perfect' reflection, lower exponent leads to more glossy+diffuse highlights. Can range from ~1 to up to 10000 or more.

type: real scalar

units: dimensionless

restrictions: Must be greater than zero.

nk_data



The nk_data element specifies that the phong material should use measured complex IOR data to compute the reflection at various angles.

If nk_data is specified, then the diffuse and specular elements are not taken into account.

The value of the nk_data element should be a path to a .nk file, e.g. 'nkdata/au.nk'

element status: optional

type: string

units:

restrictions: Must be a valid path to a .nk file.

specular_reflectivity_spectrum

The specular reflectivity at normal incidence.

If this element is present, then the specular reflectivity at various angles is based on these values.

If this element is present, then the diffuse albedo of the material is set to zero, therefore, if this element is present, only metals can be simulated.

If this element is present, then the *ior* and *diffuse_albedo_spectrum* elements are ignored.

type: spectrum element

units*:* dimensionless

restrictions: Spectrum values should lie in the range [0, 1]

albedo_texture

Overrides the albedo (reflectance) of the diffuse substrate. If such a texture is present, the final diffuse colour is calculated as texture_colour.

element_status: optional

type: texture element

bump_map

The bump map is used to perturb the shading normal of the surface. Note that the b coefficient (gain) must often be set to a small value (e.g. 0.001) for realistic results.

element_status: optional

type: texture element

exponent_map

Used to vary the exponent of the phong material across the surface.

element_status: optional

type: texture element

xml example:

```
<phong>
        <diffuse>0.0 0.0 0.0</diffuse>
        <ior>1.5</ior>
        <exponent>10000</exponent>

</phong>

or

<phong>
        <nk_data>nkdata/au.nk</nk_data>
        <exponent>1000</exponent>
</phong>

or


<phong>
         <exponent>300</exponent>
         <specular_reflectivity_spectrum>
                  <rgb>
                           <rgb>0.8 0.3 0.6</rgb>
                           <gamma>1</gamma>
                  </rgb>
         </specular_reflectivity_spectrum>
</phong>
```

glossy_transparent

The glossy transparent is a material that simulates a rough surface of a transparent dielectric medium. It's good for simulating stuff like frosted glass, human skin etc...

internal_medium_name

Should be the name of a medium already defined in the scene file.

type: string

unit:

restrictions:

exponent

Sets the exponent of the Phong lobe controlling reflection and transmission. Higher exponent means more 'perfect' reflection, lower exponent leads to wider highlights. Can range from ~1 to up to 10000 or more.

type: real scalar

units: dimensionless

restrictions: *Must be greater than zero.*

bump_map

The bump map is used to perturb the shading normal of the surface. Note that the b coefficient (gain) must often be set to a small value (e.g. 0.001) for realistic results.

element_status: optional

type: texture element

xml example:

```
<material>
	<name>frosted_glass</name>

	<glossy_transparent>
		<internal_medium_name>glass</internal_medium_name>
		<exponent>1000</exponent>
	</glossy_transparent>
</material>
```

diffuse_transmitter

This material is a very simple BSDF that basically scatters incoming light into the opposite hemisphere, with a cosine weighted distrubution.
Although it doesn't really have any exact physical basis, it could be thought of as the limit of many sub-surface scatters inside a thin, highly scattering material. As such it should be useful for simulating such materials as curtains, lampshades etc..
It's meant to be used on single-layer geometry, and it does not have an associated internal medium (it's not an interface material).
It will probably be a good idea to blend this material with a normal diffuse material, so that some backscattered light is visible, not just transmitted light.

albedo_spectrum

Sets the transmission fraction (albedo)

Values will be silently clamped to the range [0, 1.0].

Type: spectrum element

units: dimensionless

restrictions: Spectrum values should lie in the range [0, 1]

Colour (deprecated as of v0.9)

Sets the RGB transmission (albedo). All components should be in the range [0, 1)

Each component will be silently clamped to the range (after reverse gamma correction) [0, 0.9].

As of 0.7 test2, the RGB colour will be 'reverse gamma corrected' – all components will be converted to display values by raising to the power of 2.2.

type: real 3-vector

restrictions: Each component should be in the range [0, 1)

units*:* dimensionless

albedo_texture

Overrides the albedo (transmission colour) of the material. If such a texture is present, the texture colour is used as the final diffuse colour.

element_status: optional

type: texture element

xml example:

```
<material>
	<name>diff_tran</name>

	<diffuse_transmitter>
		<colour>0 0 0</colour>

		<albedo_texture>
			<uv_set>albedo</uv_set>
			<path>../_peacock__by_darkbecky.jpg</path>
			<exponent>2.2</exponent>
		</albedo_texture>
	</diffuse_transmitter>
</material>
```

blend_material

The blend material allows two materials to be blended together, with the weighting factor a given constant, or controlled by an image map.

More than two materials can be blended, by using a hierarchical arrangement of blend materials.

There is one restriction that applies to what materials can be blended together (in the same blend tree composed of one or more blend materials) – At most one constituent material can be a BSDF containing a delta distribution. Materials with delta distributions are the specular and null_material material types.

blend_factor

Controls the fraction of each constituent material used.

A value of 0 means only material *a* is used, a value of 1 means only material *b* is used.

type: real scalar

restrictions: should be in the range [0, 1]

units*:* dimensionless

a_name

Name of constituent material *a*.

type: string

restrictions: must be the name of a material already defined.

b_name

Name of constituent material *b*.

type: string

restrictions: must be the name of a material already defined.

blend_map

If this element is present, then it specifies an image map that controls the blend factor in a per-pixel manner. If this element is present, then the value of the blend_factor is overriden by the map values. The map must be an RGB image.

element_status: optional

type: texture element

xml example:

```
<material>
          <name>mata</name>
          <phong>
                    <ior>3</ior>
                    <diffuse>1 0 0</diffuse>
                    <exponent>10000</exponent>

                    <bump_map>
                              <uv_set>bump</uv_set>
                              <path>indigo.jpg</path>
                              <b>0.003</b>
                              <exponent>1.0</exponent>
                    </bump_map>
          </phong>
</material>

<material>
          <name>matb</name>
          <diffuse>
                    <colour>0 1 0</colour>

                    <bump_map>
                              <uv_set>bump</uv_set>
                              <path>spherebump.jpg</path>
                              <b>0.1</b>
                              <exponent>1.0</exponent>
                    </bump_map>
          </diffuse>
</material>

<material>
          <name>blendmat</name>

          <blend>
                    <a_name>mata</a_name>
```

```
                    <b_name>matb</b_name>
                    <blend_factor>0.5</blend_factor>

                    <blend_map>
                              <uv_set>albedo</uv_set>
                              <path>checker.jpg</path>
                              <exponent>1.0</exponent>
                    </blend_map>
          </blend>
</material>
```

null_material

The null material is a very simple material that doesn't scatter light at all. It's effectively invisible.

The null material has no parameters.

Xml example:

```
<material>
		<name>b</name>
		<null_material/>
</material>
```

oren_nayar

The Oren-Nayar material models very rough surfaces that have no specular reflection.

It's appropriate for materials like clay, sprayed concrete, porous rock, Moon surface, etc..

See the paper 'Generalization of the Lambertian Model and Implications for Machine Vision' (1995) , Michael Oren, Shree K. Nayar, for more details.

Dependence of the Oren-Nayar material on the sigma parameter. Render by Zom-B, model from The Stanford 3D Scanning Repository

sigma

Controls the roughness of the material. A higher sigma gives a rougher material with more backscattering.

Standard deviation of the microfacet groove slope angles.

type: real scalar

restrictions: should be in the range [0, 1]

units: radians

albedo_spectrum

Sets the reflectance (albedo)

Values will be silently clamped to the range [0, 1].

Type: spectrum element

units: dimensionless

restrictions: Spectrum values should lie in the range [0, 1]

albedo_texture

Overrides the albedo (reflectance) of the material. If such a texture is present, the texture colour is used as the final diffuse colour.

element_status: optional

type: texture element

bump_map

The bump map is used to perturb the shading normal of the surface. Note that the b coefficient (gain) must often be set to a small value (e.g. 0.001) for realistic results.

element_status: optional

type: texture element

Xml example:

```
<material>
	<name>mat</name>
	<oren_nayar>
		<albedo_spectrum>
			<uniform>
				<value>0.7</value>
			</uniform>
		</albedo_spectrum>

		<sigma>0.2</sigma>
	</oren_nayar>
</material>
```

Medium

medium

Defines a new medium. A medium has a type (much like material have types).

Media types include basic, epidermis, and dermis.

name

Name of the medium. Used when specifying the internal_medium_name in specular etc.. materials.

type: string

unit:

restrictions:

precedence

Precedence is used to determine which medium is considered to occupy a volume when two or more media occupy the volume. The medium with the highest precedence value is considered to occupy the medium, 'displacing' the other media.

The predefined and default scene medium, 'air', has precedence 1.

type: integer

unit:

restrictions: Should be > 1

medium::epidermis

Medium for simulating the outer layer of skin.

See Jensen and Donner's paper for more details and example values.

http://graphics.ucsd.edu/papers/egsr2006skin/egsr2006skin.pdf

melanin_fraction

Fraction of melanin present in tissue.

Typical range: 0 – 0.5

type: real scalar

unit: dimensionless

restrictions: Should be in range [0, 1]

melanin_type_blend

Controls the amount of eumelanin relative to pheomelanim in the tissue.

Typical range: 0 - 1

type: real scalar

unit: dimensionless

restrictions: Should be in range [0, 1]

medium::dermis

hemoglobin_fraction

Controls the amount of hemoglobin present.

Typical range: 0.001 – 0.1

type: real scalar

unit: dimensionless

restrictions: Should be in range [0, 1]

medium::basic

ior

Index of refraction. Should be >= 1.

Glass has an IOR (index of refraction) of about 1.5, water about 1.33.

The IOR of plastic varies, 1.5 would be a reasonable guess.

type: scalar real

unit: dimensionless

restrictions: >= 1

cauchy_b_coeff

Sets the 'b' coefficient in **Cauchy's equation**, which is used in Indigo to govern dispersive refraction. Units are micrometers squared. Setting to 0 disables dispersion. Note: the render can be slower to converge when dispersion is enabled, because each ray refracted through a dispersive medium can represent just one wavelength. So only set cauchy_b_coeff != 0 if you really want to see dispersion :)

Typical values for glass and water lie in the range 0.003 – 0.01

(see http://en.wikipedia.org/wiki/Cauchy%27s_equation for some coefficients)

type: scalar real

unit: micrometers^2

restrictions: Should be >= 0 for physical correctness

absorption_coefficient_spectrum

Controls the rate at which light is absorbed as it passes through the medium.

type: spectrum element

unit: meter^{-1}

restrictions: Should be >= 0 for physical correctness

subsurface_scattering

Use this element to make the medium scatter light as it passes through it.

element status: optional

subsurface_scattering::scattering_coefficient_spectrum

type: spectrum element

unit: meter^{-1}

restrictions: Should be >= 0 for physical correctness

subsurface_scattering:: phase_function

Chooses the phase function used for the scattering.

Should contain one phase_function element (see below).

type: phase function element

xml example:

```
<medium>
	<name>scattering_medium</name>

	<ior>1.5</ior>
	<cauchy_b_coeff>0.0</cauchy_b_coeff>
	<absorption_coefficient_spectrum>
		<rgb>
			<rgb>10000.0 5 5</rgb>
		</rgb>
	</absorption_coefficient_spectrum>

	<subsurface_scattering>
		<scattering_coefficient_spectrum>
			<uniform>
				<value>10</value>
			</uniform>
		</scattering_coefficient_spectrum>

		<phase_function>
			<uniform/>
		</phase_function>
	</subsurface_scattering>
</medium>
```

Phase Function

The phase function controls in what direction light is scattered, when a scattering event occurs.

Must be one of:

uniform

Takes no parameters

xml example:

```
<phase_function>
         <uniform/>
</phase_function>
```

henyey_greenstein

The Henyey-Greenstein phase function can be forwards or backwards scattering, depending on the 'g' parameter.

henyey_greenstein::g_spectrum

The g parameter may vary with wavelength, and is therefore specified using a spectrum element.

Spectrum values will be silently clamped to [-0.99, 0.99] .

type: spectrum element

units: dimensionless (average cosine of phase function scattering angle)

restrictions: spectrum values should lie in range [-1, 1]

xml example:

```
<phase_function>
 <henyey_greenstein>
 <g_spectrum>
 <uniform>
 <value>0.9</value>
 </uniform>
 </g_spectrum>
 </henyey_greenstein>
</phase_function>
```

Spectrum

Should have exactly one child, either *peak*, *blackbody*, *rgb,* or *uniform.*

spectrum::peak

spectrum::peak::peak_min

The wavelength in nm of the start of the spectrum peak.

type: real scalar

units: nanometers

restrictions: < peak_max

spectrum::peak::peak_width

The width of the spectrum peak, in nm.

type: real scalar

units: nanometers

restrictions: > 0

spectrum::peak::base_value

Exitant radiance for wavelengths outside the peak part of the spectrum.

type: real scalar

units: spectral radiance, W m^{-3} sr^{-1}

restrictions: >= 0

spectrum::peak::peak_value

Exitant radiance for wavelengths inside the peak part of the spectrum.

type: real scalar

units: spectral radiance, W m^{-3} sr^{-1}

restrictions: >= 0

spectrum::blackbody

spectum::blackbody::temperature

type: real scalar

units: Kelvin

restrictions: > 0

spectum::blackbody::gain

Exitant radiance is scaled by this

type: real scalar

units: dimensionless

restrictions: > 0

spectum::rgb

spectum::rgb::rgb

type: real 3-vector

units: spectral radiance, W m^{-3} sr^{-1}

restrictions: each component must be >= 0

spectum::rgb::gamma

The gamma value is used to convert rgb values from image values into intensity-linear display values.

The rgb components are raised by this exponent.

Use 2.2 as a suitable default.

type: real scalar

units: dimensionless

restrictions: must be > 0

spectum::uniform

spectum::uniform::value

type: real scalar

units: spectral radiance, W m^{-3} sr^{-1}

restrictions: must be >= 0

spectum::regular_tabulated

Allows nearly abitrary spectra to be defined. The spectrum value is given at regular wavelength intervals, and linear interpolation is used to sample at intermediate wavelengths.

spectum::regular_tabulated::start_wavelength

Wavelength of the first spectrum value.

type: real scalar

units: meters.

restrictions*:* must be >= 0

spectum::regular_tabulated::end_wavelength

Wavelength of the last spectrum value.

type: real scalar

units: meters.

restrictions*:* must be >= 0

spectum::regular_tabulated::num_values

Number of tabulated values

type: integer

units:

restrictions*:* must be >= 2

xml example:

```
<material>
    <name>mat1</name>
```

```
    <diffuse>
      <albedo_spectrum>
        <regular_tabulated>
          <start_wavelength>0.4E-06</start_wavelength>
          <end_wavelength>0.7E-06</end_wavelength>
          <num_values>10</num_values>
          <values>
            1 0.9 0.5 0.345 0 0 0 0 0 0
          </values>
        </regular_tabulated>
      </albedo_spectrum>
    </diffuse>
  </material>
```

rectanglelight

The rectangle light element defines a horizontal area light with normal (0,0,-1).

pos

The (x, y, z) position of the middle of the rectangle area light.

type: real 3-vector

units: meters

restrictions:

width

Width in x direction.

type: real scalar

units: meters

restrictions: > 0

height

Width in y direction.

type: real scalar

units: meters

restrictions: > 0

spectrum

Emission spectrum for the rectangle light; spectrum element is described above

type: spectrum element

efficacy_scale

The efficacy_scale element allows light sources of a given wattage and efficacy to be simulated.

The efficacy_scale element is optional, if it is used, it overrides the gain. Otherwise the gain works as normal.

The overall luminous efficiacy is the luminous flux per Watt of power drawn.
There are some values on the wikipedia page http://en.wikipedia.org/wiki/Luminous_efficacy

element status: optional

efficacy_scale::power_drawn

Power drawn by the light source, e.g. 100 Watts

type: real scalar

units: Watts

restrictions: > 0

efficacy_scale::overall_luminous_efficiacy

The overall luminous efficiacy is the luminous flux per Watt of power drawn.

type: real scalar

units: Lumens per Watt (lm/W)

restrictions: > 0

example xml:

```
<rectanglelight>
        <pos>0.0 0 1.9</pos>
        <width>0.2</width>
        <height>0.2</height>

        <spectrum>
                <peak>
                        <peak_min>300</peak_min>
                        <peak_width>550</peak_width>
                        <base_value>0</base_value>
                        <peak_value>200</peak_value>
                </peak>
          </spectrum>

          <efficiacy_scale>
                   <power_drawn>100</power_drawn>
                   <overall_luminous_efficiacy>17.5</overall_luminous_efficiacy>
          </efficiacy_scale>
</rectanglelight>
```

exit_portal

Exit portals are useful for speeding up the rate of convergence of interior renderings, when the interior is lit by an environmental light source, such as the sun/sky model.

Exit portals are placed over the openings between the interior and the exterior environment. These openings are the 'portals' in the scene.

Exit portals make the rendering process more efficient, because paths passing through such openings can be more efficiently sampled when explicity marked with an exit portal.

Requirements for exit portal usage:

- If exit portals are present in the scene, then all openings must be covered by exit portals. In other words, all possible paths that start on the camera, and then travel through space or a transparent object, and then escape out of the scene into the environment, must be blocked by one or more exit portals.
- The geometric normal (defined by triangle winding order) of an exit portal mesh triangle, where reachable by some path from the camera, must point into the interior of the scene. (i.e. The front side of the mesh faces should be visible by the camera)

pos

Translation applied to the mesh vertex positions, when transforming from object space into world space. This is also the origin of the object coordinated system in world coordinates.

type: real 3-vector

units: meters

restrictions:

scale

Uniform scale applied to the mesh vertex positions, when transforming from object space into world space.

type: real scalar

units: dimensionless

restrictions: > 0

rotation

Optional element that defines a linear transformation that is applied to the mesh vertex positions, when transforming from object space into world space.

Note that position vectors in Indigo are considered to be column vectors.

As of Indigo 0.9, the orthogonality requirement on this matrix has been relaxed, the matrix now must merely be invertible.

rotation :: matrix

Defines a 3x3 matrix, in row-major format.

type: real 3x3 matrix

units: dimensionless

restrictions: Must be invertible.

mesh_name

Name of a mesh object already defined in the scene file.

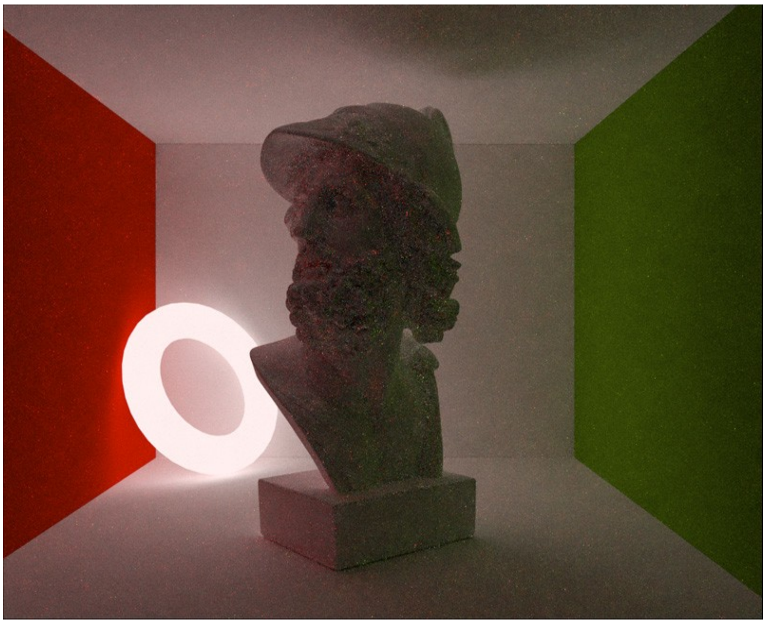
type: string

XML example:

```
<exit_portal>
   <pos>0.591146 0.361125 0.957886</pos>
   <scale>1</scale>
   <rotation>
     <matrix>
       1.000 0.000 0.000 0.000 1.0000 0.000 0.000 0.000 1.000
     </matrix>
   </rotation>
   <mesh_name>Plane.011</mesh_name>
 </exit_portal>
```

meshlight

A mesh light is an emitter that uses triangle mesh geometry. Any mesh that has already been defined can be used to define a mesh light.



pos

Translation applied to the mesh vertex positions, when transforming from object space into world space. This is also the origin of the object coordinated system in world coordinates.

type: real 3-vector

units: meters

restrictions:

scale

Uniform scale applied to the mesh vertex positions, when transforming from object space into world space.

type: real scalar

units: dimensionless

restrictions: > 0

rotation

Optional element that defines a linear transformation that is applied to the mesh vertex positions, when transforming from object space into world space.

Note that position vectors in Indigo are considered to be column vectors.

As of Indigo 0.9, the orthogonality requirement on this matrix has been relaxed, the matrix now must merely be invertible.

rotation :: matrix

Defines a 3x3 matrix, in row-major format.

type: real 3x3 matrix

units*:* dimensionless

restrictions: Must be invertible.

mesh_name

Name of a mesh object already defined in the scene file.

type: string

spectrum

Emission spectrum for the mesh light; spectrum element is described above

type: spectrum element

efficacy_scale

The efficacy_scale element allows light sources of a given wattage and efficacy to be simulated.

The efficacy_scale element is optional, if it is used, it overrides the gain. Otherwise the gain works as normal.

The overall luminous efficiacy is the luminous flux per Watt of power drawn.
There are some values on the wikipedia page http://en.wikipedia.org/wiki/Luminous_efficacy

element status: optional

efficacy_scale::power_drawn

Power drawn by the light source, e.g. 100 Watts

type: real scalar

units: Watts

restrictions: > 0

efficacy_scale::overall_luminous_efficiacy

The overall luminous efficiacy is the luminous flux per Watt of power drawn.

type: real scalar

units: Lumens per Watt (lm/W)

restrictions: > 0

texture

If this element is present, then the light emitted from the mesh light is modulated by an image map.

element_status: optional

type: texture element

ies_profile

If this element is present, then a directional distribution of light will be emitted from the emitter.

The directional distribution is loaded from a file satisfying the ANSI/IESNA LM-63-2002 data system (IES) for describing photometric light distributions.

If the ies_profile is present, then the spectral radiance of the emission spectrum will be scaled so that the light emits a luminous flux as defined in the IES file.

When using an IES profile, each triangle of the mesh light will emit light with a directional distibution determined by the IES data, using the normal of the triangle as the 'principle direction'.
So you can make the triangle face in any direction and it will work just fine.

When modelling a meshlight that will be used as an IES emitter, make sure it is completely flat, so that all triangle normals are the same.

Only IES files of photometric type 'C' are supported.

Only IES files with vertical angles starting at 0 degrees and ending at 90 degrees are supported.

element_status: optional

ies_profile :: path

Path to the IES file. Can be absolute or relative. If relative, the path is taken as relative to the scene base directory.

type: string

XML example:

```
<meshlight>
	<pos>0 0 2.4</pos>
	<scale>1</scale>
	<spectrum>
		<blackbody>
			<temperature>3500</temperature>
			<gain>1</gain>
		</blackbody>
	</spectrum>
	<mesh_name>prism</mesh_name>

	<efficacy_scale>
		<power_drawn>150</power_drawn>
		<overall_luminous_efficacy>20</overall_luminous_efficacy>
	</efficacy_scale>
</meshlight>
```

mesh

mesh :: name

Name of the mesh

mesh :: scale

Scales the vertex positions.

mesh :: path

The path to the .3ds mesh, eg 'prism\prism.3ds'. The path is relative to the deepest directory containing the scene file. Either backslashes or forward slashes can be used as directory separators.

mesh :: normal_smoothing

If this is set to false, normal smoothing will be disabled, and the geometric normal will always be used for this model.

mesh :: external

An external mesh type allows a mesh defined in another file to be loaded and used.

mesh :: external :: path

Path to mesh data file.

Path can be absolute or relative. If relative, it is take as relative to the scene file base path.

Allowed file types are .obj, .3ds, and .ply.

mesh :: embedded

An embedded mesh type allows the mesh to be defined directly in the .igs file.

mesh :: embedded :: expose_uv_set

Names a given index of uv (texture) coordinate information. Materials can then bind to the uv coordinates using the given name.

mesh :: embedded :: expose_uv_set :: index

Index of the uv coordinates as defined in the embedded mesh data.

type: integer

restrictions: must be >= 0, must be < than the total number of uv coordinates defined in the mesh data.

unit: dimensionless

mesh :: embedded :: expose_uv_set :: name

Name with which the uv set will be exposed to the materials.

type: string

restrictions:

unit:

mesh :: embedded :: vertex

Defines a single vertex.

mesh :: embedded :: vertex :: pos (attribute)

Position of the vertex, in the local coordinate system of the mesh

type: real 3-vector

restrictions:

unit: meters

mesh :: embedded :: vertex :: normal (attribute)

Normal of the vertex, in the local coordinate system of the mesh

type: real 3-vector

restrictions: vector must be normalised (have length ~= 1.0)

unit: meters

mesh :: embedded :: vertex :: uvN (attribute)

N-th uv coordinates. N must be >= 0 and <= 3.

type: real 2-vector

restrictions:

unit: normalised texture coordinates.

mesh :: embedded :: triangle_set

Defines a group of triangles sharing a common material.

mesh :: embedded :: triangle_set :: material_name

Name of the material triangles in this group will use.

type: string

restrictions: must be the name of an already-defined material.

Unit:

mesh :: embedded :: triangle_set :: tri

Defines a single triangle in terms of its constituent vertices, as a 3-vector of vertex indices.

The indices index into the vertices already defined in the current mesh.

type: integer 3-vector

restrictions: each vertex index must be >= 0 and < the total number of vertices already defined for the current mesh.

unit:

Xml example of an external mesh:

```
<mesh>
	<name>hand</name>
	<normal_smoothing>false</normal_smoothing>
	<scale>0.0005</scale>
	<external>
		<path>..\hand\gipshand2-273k.obj</path>
	</external>
</mesh>
```

An example of an internally defined mesh:

```
<mesh>
```

```
        <name>mesh1</name>

        <normal_smoothing>false</normal_smoothing>
        <embedded>
                <expose_uv_set>
                        <index>0</index>
                        <name>albedo</name>
                </expose_uv_set>

                <expose_uv_set>
                        <index>0</index>
                        <name>bump</name>
                </expose_uv_set>

                <vertex pos="-10 -10 0" normal="0 0 1" uv0="0 0" />
                <vertex pos="-10 10 0" normal="0 0 1" uv0="0 10" />
                <vertex pos="10 10 0" normal="0 0 1" uv0="10 10" />
                <vertex pos="10 -10 0" normal="0 0 1" uv0="10 0" />

                <triangle_set>
                        <material_name>white</material_name>
                        <tri>0 1 2</tri>
                        <tri>0 2 3</tri>
                </triangle_set>

                <vertex pos="-10 3 0" normal="0 -1 1" uv0="0 0" />
                <vertex pos="-10 3 20" normal="0 -1 1" uv0="0 10" />
                <vertex pos="10 3 20" normal="0 -1 1" uv0="10 10" />
                <vertex pos="10 3 0" normal="0 -1 1" uv0="10 0" />

                <triangle_set>
                        <material_name>checker</material_name>
                        <tri>4 5 6</tri>
                        <tri>4 6 7</tri>
                </triangle_set>
        </embedded>
</mesh>
```

model

Places a mesh instance into the scene.

pos

Translation applied to the model vertex positions, when transforming from object space into world space. This is also the origin of the object coordinated system in world coordinates.

type: real 3-vector

units: meters

restrictions:

scale

Uniform scale applied to the model vertex positions, when transforming from object space into world space.

type: real scalar

units: dimensionless

restrictions: > 0

rotation

Optional element that defines a linear transformation that is applied to the model vertex positions, when transforming from object space into world space.

Note that position vectors in Indigo are considered to be column vectors.

As of Indigo 0.9, the orthogonality requirement on this matrix has been relaxed, the matrix now must merely be invertible.

rotation :: matrix

Defines a 3x3 matrix, in row-major format. For example, the identity matrix / null rotation can be defined like this:

```
<rotation>
        <matrix> 1 0 0 0 1 0 0 0 1 </matrix>
</rotation>
```

type: real 3x3 matrix

units: dimensionless

restrictions: Must be invertible.

mesh_name

Name of a mesh object already defined in the scene file.

type: string

xml example:

```
<model>
	<rotation>
		<matrix>
			1 0 0 0 0 -1 0 1 0
		</matrix>
	</rotation>
	<pos>0 0 0</pos>
	<scale>1</scale>

	<mesh_name>hand</mesh_name>
</model>
```

plane

'Plane' is an infinite plane.

Planes cannot be used in bidirectional tracing mode; use finite triangle meshes instead.

plane :: normal

type*:* real 3-vector

units*:* meters

restrictions: must have length 1

plane :: dist

Distance along plane normal from origin to plane.

type: real scalar

units*:* meters

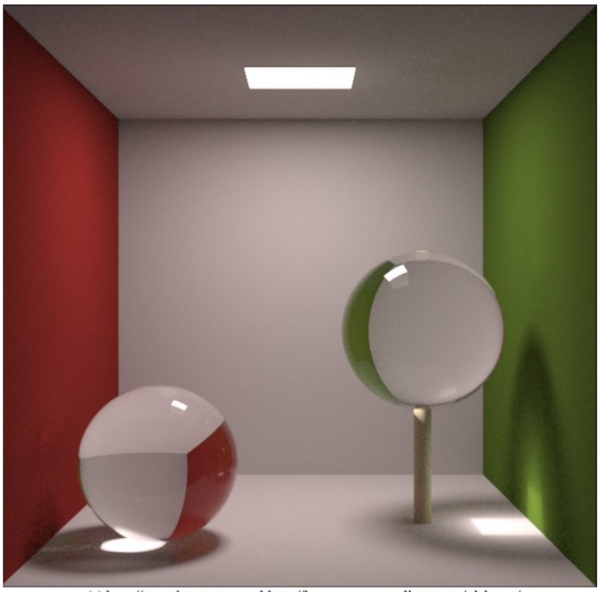
restrictions*:*

plane :: material_name

type: string

restrictions: must be the name of an already specified material.

sphere



(c) http://www.jotero.com and http://homepages.paradise.net.nz/nickamy/

sphere :: center

type: real 3-vector

units: meters

restrictions:

sphere :: radius

type: real scalar

units: meters

restrictions: > 0

sphere :: material_name

type: string

restrictions: must be the name of an already specified material.

Include

The *include* element allows a different .igs file to be loaded and processed during the processing of the main .igs file.

include :: pathname

Path to another .igs file to be processed. Path is absolute or taken as relative to the current scene file directory.

type: *string*

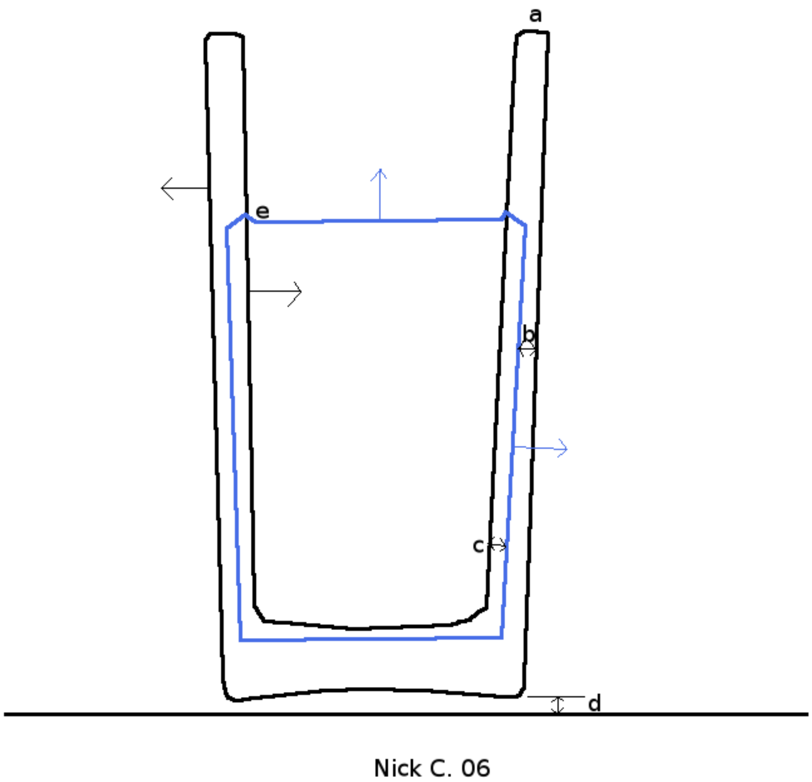
units:

restrictions:

Appendix A: Modelling a Liquid in a Glass For Indigo

If you want to create a realistic rendering of a liquid in a glass vessel in Indigo, you must model it in a rather particular way, to take advantage of the medium precedence system, so that all light scattering and transmission processes are simulated (reasonably) accurately.

In the requirements given below, a distance of 0.2mm is often mentioned. This distance is chosen because the default ray origin 'nudge distance' (used to avoid false self-intersection due to limited floating point precision) in Indigo is 0.1mm.



Modelling Requirements:

a) need sufficient polygonisation of the curve here because sharp edges cause shading normal artifacts. For example 10-20 points may be needed on piecewise curve.
b) distance should be > 0.2mm
c) distance should be > 0.2mm.
Note that while the distance between the glass and water surfaces in the walls of the glass needs only to be greater than 0.2mm, it should probably be about 1mm, depending on the width of the glass
d) distance between glass and ground plane should be in range [0.2mm, 1mm]
e) meniscus should be modelled

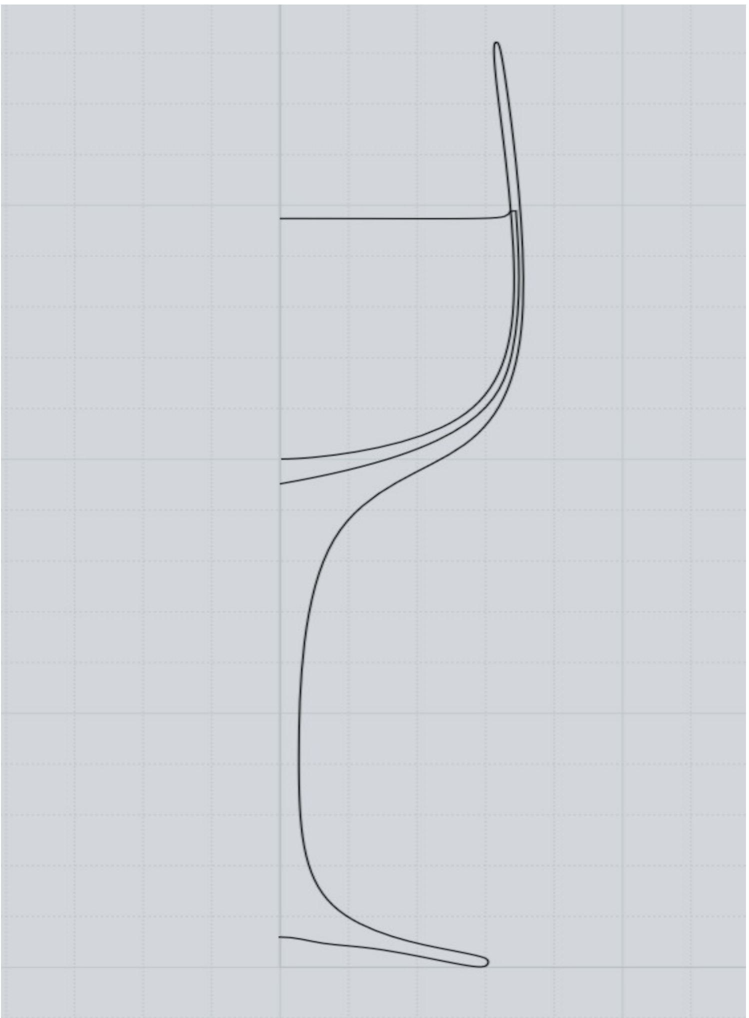
Addtionally:

f) all geometric (given by tri winding order) and smoothed normals should be as labelled.

g) total number of triangles is expected to be in range 10000-150000
h) surfaces should be two-manifold and closed (not self-intersecting).
i) **liquid** and glass should be assigned different materials.
j) part of the surface of the **liquid** component should lie inside the glass as shown.
k) The model should be created in units of meters.
l) The glass medium precedence should be greater than that of the **liquid** medium (because glass displaces water), which in turn should be greater than 1.

The following image shows a wine glass half-profile modelled in MoI, which can easily be turned into a complete 3d model using a lathe/revolve modifier.

Note how the lower and side edge of the wine volume lies inside the wall of the glass.



The wine glass rendered in Indigo:

Appendix B: Scattering Properties for Liquids

These values are from the paper *Acquiring Scattering Properties of Participating Media by Dilution* by Jensen et al. (http://graphics.ucsd.edu/~henrik/papers/acquiring_scattering_properties/)

Whaat has kindly converted the units from the paper into the SI units that Indigo uses.

Scattering Properties for Liquids

			Properties for media diluted in 23-V Liters of Water										Indigo Values									
			Extinction ($\times 10^{-2}$ mm^{-1})			Scattering ($\times 10^{-2}$ mm^{-1})			Average Cosine				Absorption (m^{-1})			Scattering (m^{-1})			G Spectrum		
Material	Volume (V) for Single Scattering (L)	Concentration (c1)	R	G	B	R	G	B	R	G	B	Concentration (c2)	R	G	B	R	G	B	R	G	B
Milk (lowfat)	0.02	0.07%	0.9126	1.0748	1.2500	0.9124	1.0744	1.2492	0.9320	0.9020	0.8590	100%	2.875	5.750	11.500	13115.750	15444.500	17957.250	0.932	0.902	0.859
Milk (reduced)	0.02	0.08%	1.0750	1.2213	1.3941	1.0748	1.2209	1.3931	0.8190	0.7970	0.7460	100%	2.556	5.111	12.778	13733.556	15600.389	17800.722	0.819	0.797	0.746
Milk (regular)	0.02	0.07%	1.1874	1.3296	1.4602	1.1873	1.3293	1.4589	0.7500	0.7140	0.6810	100%	1.533	4.600	19.933	18205.267	20382.600	22369.800	0.750	0.714	0.681
Coffee (espresso)	0.01	0.03%	0.4376	0.5115	0.6048	0.2707	0.2828	0.2970	0.9070	0.8960	0.8800	100%	4798.375	6575.125	8849.250	7782.625	8130.500	8538.750	0.907	0.896	0.880
Coffee (mint mocha)	0.01	0.03%	0.1900	0.2600	0.3500	0.0916	0.1081	0.1460	0.9100	0.9070	0.9140	100%	3772.000	5822.833	7820.000	3511.333	4143.833	5596.667	0.910	0.907	0.914
Soy Milk (lowfat)	0.02	0.07%	0.1419	0.1625	0.2740	0.1418	0.1620	0.2715	0.8500	0.8530	0.8420	100%	1.437	7.188	35.938	2038.375	2328.750	3902.813	0.850	0.853	0.842
Soy Milk (regular)	0.01	0.05%	0.2434	0.2719	0.4597	0.2433	0.2714	0.4563	0.8730	0.8580	0.8320	100%	1.917	9.583	65.167	4663.250	5201.833	8745.750	0.873	0.858	0.832
Choc. Milk (lowfat)	0.01	0.04%	0.4282	0.5014	0.5791	0.4277	0.4998	0.5723	0.9340	0.9270	0.9160	100%	11.500	36.800	156.400	9837.100	11495.400	13162.900	0.934	0.927	0.916
Choc. Milk (regular)	0.02	0.07%	0.7359	0.9172	1.0688	0.7352	0.9142	1.0588	0.8620	0.8380	0.8060	100%	10.062	43.125	143.750	10568.500	13141.625	15220.250	0.862	0.838	0.806
Soda (coke)	1.6	6.96%	0.7143	1.1688	1.7169	0.0177	0.0208	0.0000	0.9650	0.9720		100%	100.136	165.025	246.804	2.544	2.990	0.000	0.965	0.972	0.000
Soda (pepsi)	1.6	6.96%	0.6433	0.9990	1.4420	0.0058	0.0141	0.0000	0.9260	0.9790		100%	91.641	141.579	207.288	0.834	2.027	0.000	0.926	0.979	0.000
Soda (sprite)	15	65.22%	0.1299	0.1283	0.1395	0.0069	0.0089	0.0089	0.9430	0.9530	0.9520	100%	1.886	1.831	2.003	0.106	0.136	0.136	0.943	0.953	0.952
Sports Gatorade	1.5	6.52%	0.4009	0.4185	0.4324	0.2392	0.2927	0.3745	0.9330	0.9330	0.9350	100%	24.794	19.289	8.878	36.677	44.881	57.423	0.933	0.933	0.935
Wine (chardonnay)	3.3	14.35%	0.1577	0.1748	0.3512	0.0030	0.0047	0.0069	0.9140	0.9580	0.9750	100%	10.782	11.855	23.997	0.209	0.328	0.481	0.914	0.958	0.975
Wine (white zinfandel)	3.3	14.35%	0.1763	0.2370	0.2913	0.0031	0.0048	0.0066	0.9190	0.9430	0.9720	100%	12.072	16.184	19.843	0.216	0.335	0.460	0.919	0.943	0.972
Wine (merlot)	1.5	6.52%	0.7639	1.6429	1.9196	0.0053	0.0000	0.0000	0.9740			100%	116.319	251.911	294.339	0.813	0.000	0.000	0.974	0.000	0.000
Beer (budweiser)	2.9	12.61%	0.1486	0.3210	0.7360	0.0037	0.0069	0.0074	0.9170	0.9560	0.9820	100%	11.492	24.911	57.786	0.293	0.547	0.587	0.917	0.956	0.982
Beer (coorslight)	1	4.35%	0.0295	0.0663	0.1521	0.0027	0.0055	0.0000	0.9180	0.9660		100%	6.164	13.984	34.983	0.621	1.265	0.000	0.918	0.966	0.000
Beer (yuengling)	2.9	12.61%	0.1535	0.3322	0.7452	0.0495	0.0521	0.0597	0.9690	0.9690	0.9750	100%	8.248	22.215	54.367	3.926	4.132	4.735	0.969	0.969	0.975
Detergent (clorox)	1.2	5.22%	0.1600	0.2500	0.3300	0.1425	0.1723	0.1928	0.9120	0.9050	0.8920	100%	3.354	14.893	26.297	27.313	33.024	36.953	0.912	0.905	0.892
Detergent (era)	2.3	10.00%	0.7987	0.5746	0.2849	0.0553	0.0586	0.0906	0.9490	0.9500	0.9710	100%	74.340	51.600	19.430	5.530	5.860	9.060	0.949	0.950	0.971
Apple Juice	1.8	7.83%	0.1215	0.2101	0.4407	0.0201	0.0243	0.0323	0.9470	0.9490	0.9450	100%	12.957	23.741	52.184	2.568	3.105	4.127	0.947	0.949	0.945
Cranberry Juice	1.5	6.52%	0.2700	0.6300	0.8300	0.0128	0.0155	0.0196	0.9470	0.9510	0.9740	100%	39.437	94.223	124.261	1.963	2.377	3.005	0.947	0.951	0.974
Grape Juice	1.2	5.22%	0.5500	1.2500	1.5300	0.0072	0.0000	0.0000	0.9610			100%	104.037	239.583	293.250	1.380	0.000	0.000	0.961	0.000	0.000
Ruby Grapefruit Juice	0.24	1.04%	0.2513	0.3517	0.4305	0.1617	0.1606	0.1669	0.9290	0.9290	0.9310	100%	85.867	183.138	252.617	154.963	153.908	159.946	0.929	0.929	0.931
White Grapefruit Juice	0.16	0.70%	0.3609	0.3800	0.5632	0.3513	0.3669	0.5237	0.5480	0.5450	0.5650	100%	13.800	18.831	56.781	504.994	527.419	752.819	0.548	0.545	0.565
Shampoo (balancing)	0.3	1.30%	0.0288	0.0710	0.0952	0.0104	0.0114	0.0147	0.9100	0.9050	0.9200	100%	14.107	45.693	61.717	7.973	8.740	11.270	0.910	0.905	0.920
Shampoo (strawberry)	0.3	1.30%	0.0217	0.0788	0.1022	0.0028	0.0032	0.0033	0.9270	0.9350	0.9940	100%	14.490	57.960	75.823	2.147	2.453	2.530	0.927	0.935	0.994
Head & Shoulders	0.24	1.04%	0.3674	0.4527	0.5211	0.2791	0.2890	0.3086	0.9110	0.8960	0.8840	100%	84.621	156.879	203.646	267.471	276.958	295.742	0.911	0.896	0.884
Lemon Tea Powder		5tsp	0.3400	0.5800	0.8800	0.0798	0.0898	0.1073	0.9460	0.9460	0.9490	5tsp	2.602	4.902	7.727	0.798	0.898	1.073	0.946	0.946	0.949
Orange Powder		4tbsp	0.3377	0.5573	1.0122	0.1928	0.2132	0.2259	0.9190	0.9180	0.9220	4tbsp	1.449	3.441	7.863	1.928	2.132	2.259	0.919	0.918	0.922
Pink Lemonade Powder		5tbsp	0.2400	0.3700	0.4500	0.1235	0.1334	0.1305	0.9020	0.9020	0.9040	5tbsp	1.165	2.366	3.195	1.235	1.334	1.305	0.902	0.902	0.904
Cappuccino Powder		0.25tsp	0.2574	0.3536	0.4840	0.0654	0.0882	0.1568	0.8490	0.8430	0.9260	0.25tsp	1.920	2.654	3.272	0.654	0.882	1.568	0.849	0.843	0.926
Salt Powder		1.75cup	0.7600	0.8685	0.9363	0.2485	0.2822	0.3216	0.8020	0.7930	0.8210	1.75cup	5.115	5.863	6.147	2.485	2.822	3.216	0.802	0.793	0.821
Sugar Powder		5cup	0.0795	0.1759	0.2780	0.0145	0.0162	0.0202	0.9210	0.9190	0.9310	5cup	0.650	1.597	2.578	0.145	0.162	0.202	0.921	0.919	0.931
Suisse Mocha Powder		0.5tsp	0.5098	0.6476	0.7944	0.3223	0.3583	0.4148	0.9070	0.8940	0.8880	0.5tsp	1.875	2.893	3.796	3.223	3.583	4.148	0.907	0.894	0.888
Mission Bay Surface (1-2) hours		100.00%	3.3623	3.2929	3.2193	0.2415	0.2765	0.3256	0.8420	0.8650	0.9120	100%	31.208	30.164	28.937	2.415	2.765	3.256	0.842	0.865	0.912
Pacific Ocean Surface (1 hour)		100.00%	3.36	3.32	3.24	0.18	0.18	0.23	0.9	0.83	0.91	100%	31.85	31.32	30.15	1.8	1.83	2.28	0.9	0.83	0.91
Mission Bay 10ft Deep (30 min)		100.00%	3.41	3.34	3.28	0.1	0.13	0.19	0.73	0.82	0.92	100%	33.07	32.14	30.94	0.99	1.27	1.88	0.73	0.82	0.92
Mission Bay 10ft deep (8 hours)		100.00%	3.4	3.35	3.29	0.1	0.1	0.16	0.93	0.91	0.95	100%	32.98	32.42	31.32	1.02	1.03	1.61	0.93	0.91	0.95