NANOPARTICLES AND SUNSCREEN

Background Information

Nano-Link

NSF

Overview

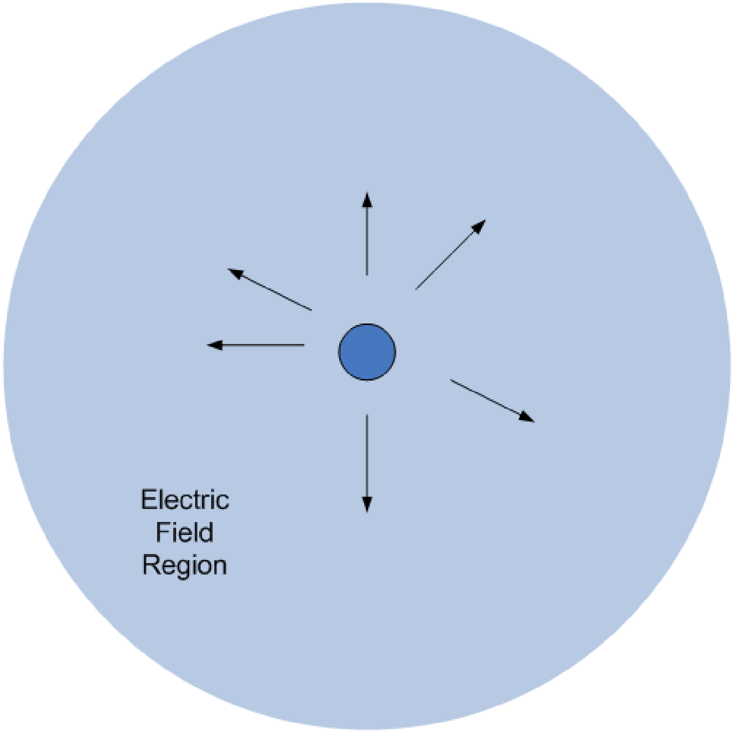
The following slides present background information on light and its interaction with matter. They may be presented as part of a lecture introducing the Nanoparticles and Sunscreen activity.

REVIEW OF LIGHT

Electromagnetic (EM) radiation encompasses a wide range of phenomena, including visible light, ultraviolet light, infrared light, radio waves, microwaves, X-rays, and gamma rays.

EM radiation shows both wave and particle characteristics. Light particles, or quanta, are known as photons.

LIGHT WAVES OCCUR THROUGH THE INTERPLAY OF ELECTRIC AND MAGNETIC FIELDS



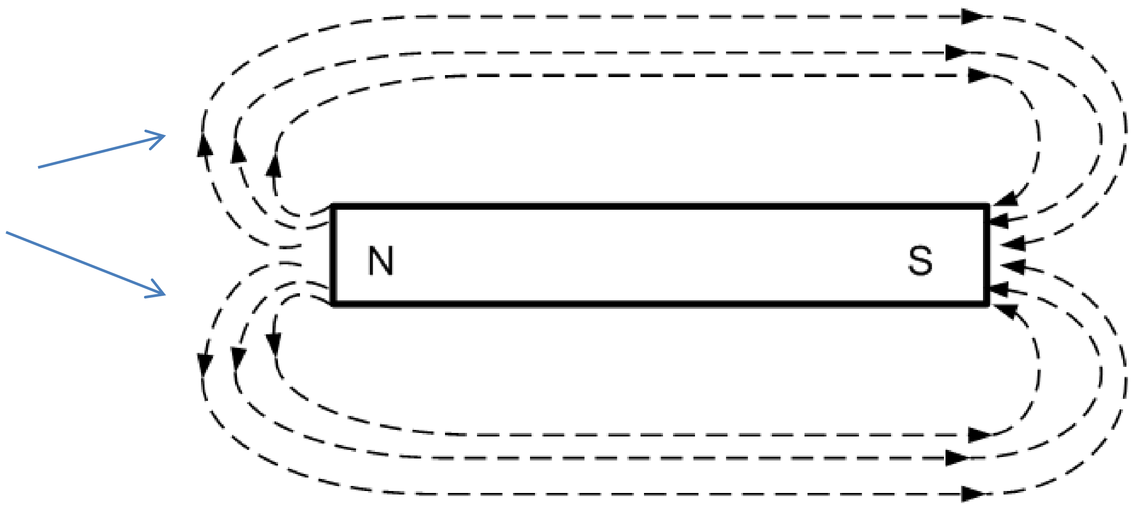
1. An electrostatic charge (for example, a positively-charged proton) sets up an electric field in the space around it. The electric field strength decreases with distance from the charge.

Nano-Link

LIGHT WAVES OCCUR THROUGH THE INTERPLAY OF ELECTRIC AND MAGNETIC FIELDS

2. A magnetic material (for example, a bar magnet) sets up a magnetic field in the space around it. Magnetic field strength also decreases with distance from the source.

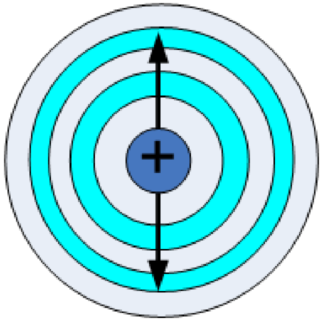
Region of magnetic field



3. In the 1830's, scientists (Oersted, Faraday, and others) observed that electric and magnetic fields were interrelated: a moving magnet induces (i.e., creates) an electric field without any charge being present, and a moving electric charge creates a magnetic field without any physical magnet.

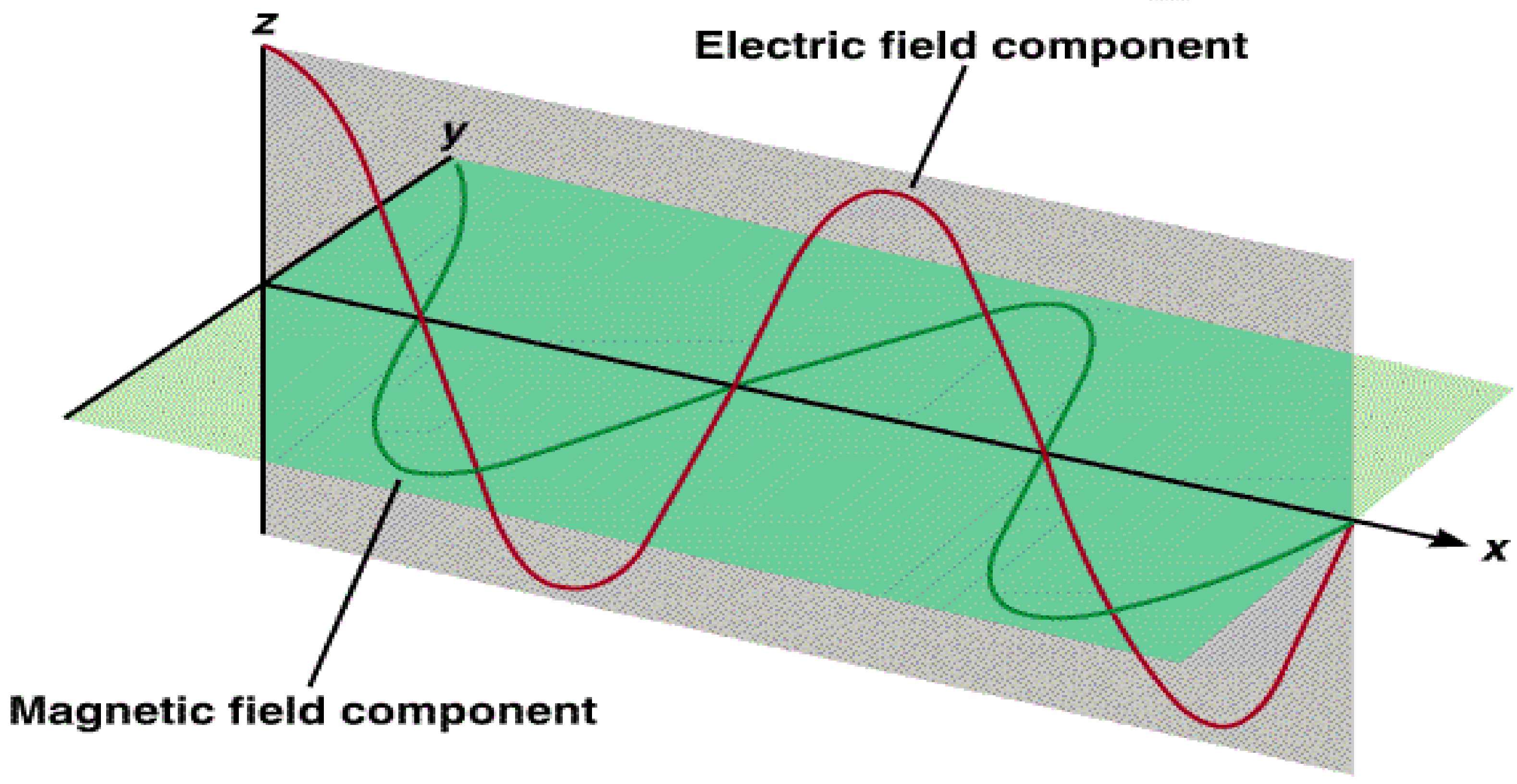
LIGHT WAVES OCCUR THROUGH THE INTERPLAY OF ELECTRIC AND MAGNETIC FIELDS

If a charge is accelerated (e.g., moved in a circle, or oscillated back and forth) its electric field will oscillate with time. An electric field that is oscillating with time will induce an oscillating magnetic field. And in turn, a magnetic field that is oscillating with time will induce an electric field, oscillating at the same rate. This oscillating field induces an oscillating magnetic field, which induces an oscillating electric field, and so on.



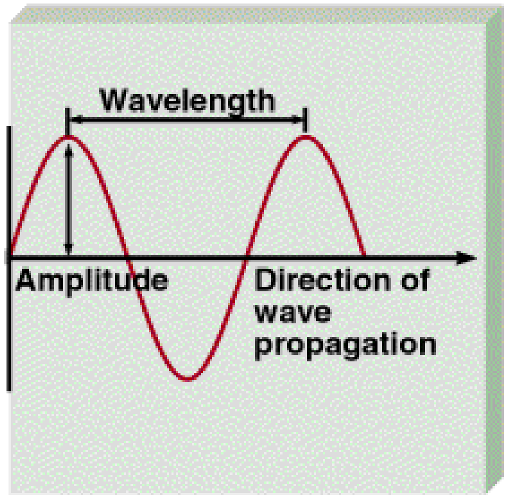
These coupled electric and magnetic fields propagate outward from the source, spreading out in a spherical shell from the source of the disturbance (the original oscillating charge). This is electromagnetic radiation.

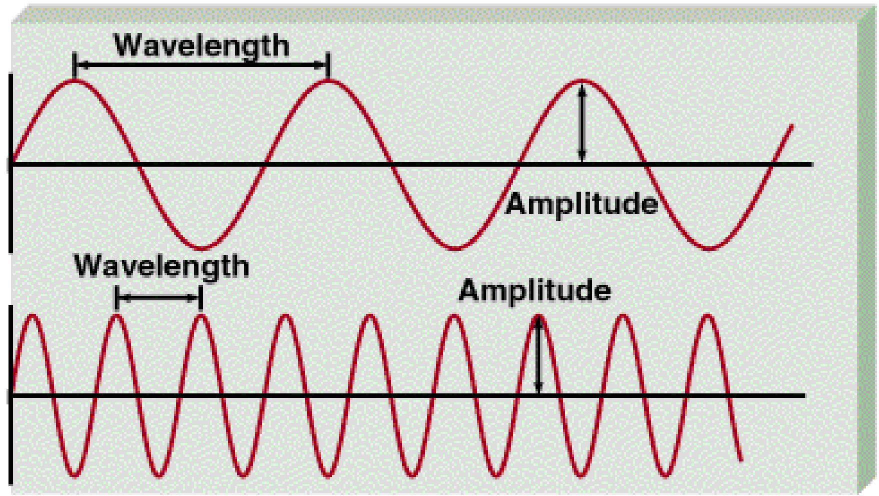
At any point in space, the coupled electric and magnetic fields move past as an undulation in the strengths of the electric and magnetic fields. This undulation is what an observer "sees", either with their eyes or with measuring instruments. This is light acting as a wave.



WAVE DEFINITIONS

Wavelength, often written as Greek letter λ: the distance between identical points on successive waves. Units of length: m, μm, nm, etc



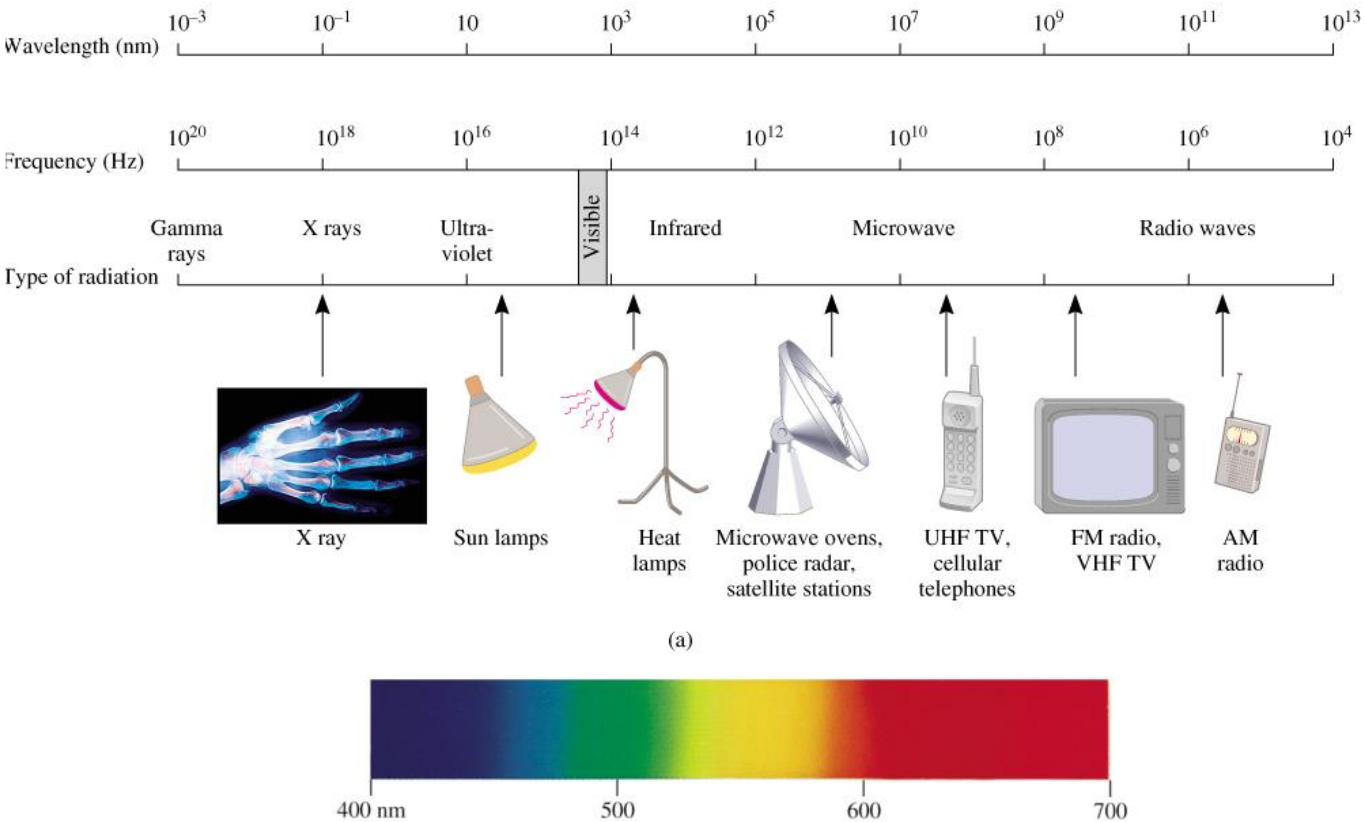


Frequency, written as Greek letter ν: the number of waves that pass through a particular point in one second. Units are cycles per second (abbreviated as *Hertz*, or Hz).

Amplitude - vertical distance from the midline of a wave to the peak or trough. Top and bottom example above have different wavelengths but the same amplitude. Units will vary.

Nano-Link

THE ELECTROMAGNETIC SPECTRUM



Beyond the blue end of the visible spectrum lie even shorter wavelengths associated with ultraviolet (UV) light. Our sun's energy output peaks in the visible range, which is why our eyes (and plants' photosynthesis) have evolved to use this portion of the EM spectrum. But the sun also produces shorter wavelengths in the UV range.

WAVELENGTH, FREQUENCY, VELOCITY

For any wave, wavelength x frequency = wave velocity in the medium

$$\lambda \nu = V$$

For EM radiation, velocity in vacuum (c) = 3.0×10^8 m/s

$$\lambda \nu = c$$

ELECTROMAGNETIC ENERGY

When thinking about EM radiation as a particle (photon)

$$E = h\nu = \frac{hc}{\lambda}$$

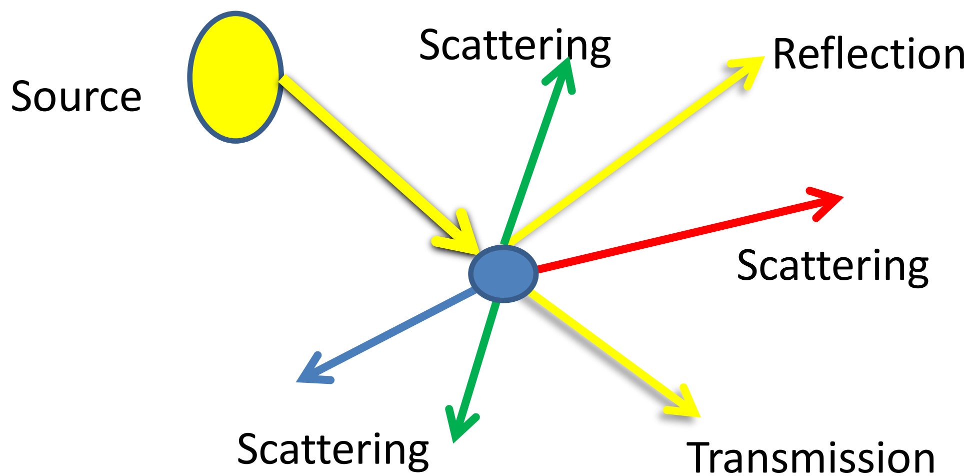
Where *h* = **Planck's constant.**

Longer wavelength = lower energy; shorter wavelength = higher energy.

Nano-Link

When light strikes matter, it may be

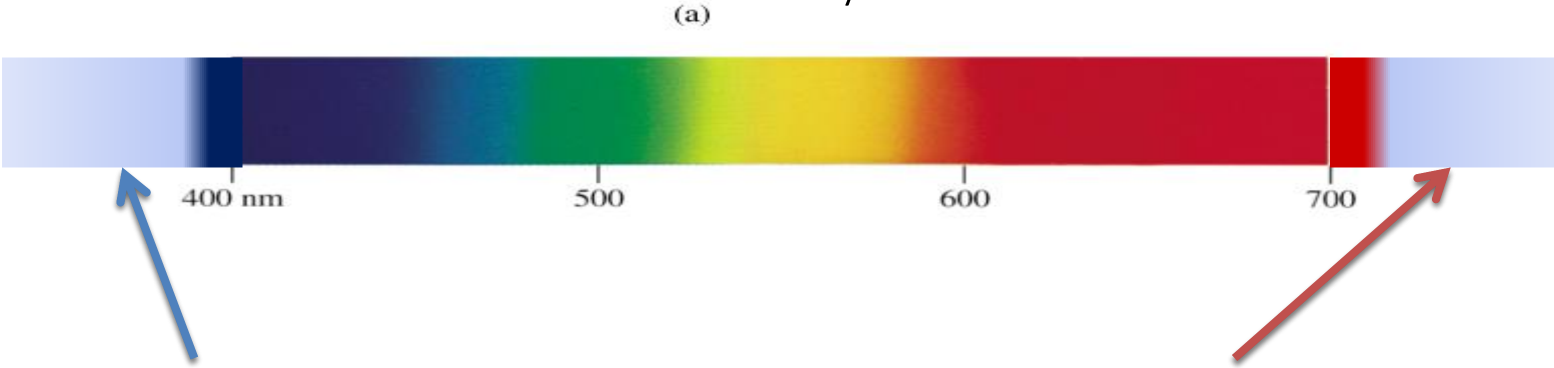
- *Reflected*, as from a mirror or smooth surface. The light may be thought of as a linear ray that approaches the surface at a given angle (the *angle of incidence),* and reflects from the surface at the same angle. The full light path lies in the same geometric plane.
- *Transmitted or absorbed:* If not all the light is reflected, the portion of light not reflected may be *transmitted* light if it leaves the material, or it may be *absorbed* by the material.
- *Re-emitted (scattered).* Light energy that is absorbed will be generally be re-emitted. This re-emission may be at a wavelength different from the incoming light, and may be re-emitted in all directions (i.e., not in the same plane as the incoming light ray). This re-emission over a broad area is called light *scattering*.



Nano-Link

VISIBLE AND INVISIBLE PORTIONS OF THE SOLAR SPECTRUM

The visible spectrum. This corresponds to the peak light output of our local star, and it is the region to which our eyes have evolved to have maximum sensitivity.



Beyond the blue (short wavelength) end of the visible spectrum lie even shorter wavelengths associated with ultraviolet (UV) light. These shorter wavelengths in the UV range are energetic enough to damage living cells. They are responsible for sunburns in human skin, as well as contributing to skin cancers and cataracts. The very short wavelength UV rays are absorbed by Earth's ozone layer.

Beyond the red (long wavelength) end of the visible spectrum lie longer infrared wavelengths, associated with the physical sensation of heat. The vision of many predatory animal species is attuned to these longer IR wavelengths to enable night hunting.

Nano-Link

THE ULTRAVIOLET PORTION OF THE SOLAR SPECTRUM

Ultraviolet radiation is classified into three types, based on wavelength.

- UV-A: The longest wavelength UV radiation (closest to the visible range). It is not absorbed by Earth’s ozone. This type of UV radiation penetrates the skin and can cause cancer and premature aging of the skin.
- UV-B: Shorter wavelength UV. Although UV-B does not penetrate into the skin as deeply as UV-A, it’s higher energy is responsible for sunburns. It is partially blocked by the ozone layer.
- UV-C: This very short wavelength (highest energy) UV radiation is totally absorbed by the earth's atmosphere. It is typically encountered only from artificial radiation sources.

UV EFFECTS

Overexposure of human skin to solar UV can cause serious illness, including

- Skin cancer, specifically basal cell carcinoma, squamous cell carcinoma, and melanoma
- Pre-cancerous skin lesions

Too much exposure can also lead to

- Benign tumors
- Fine and coarse wrinkles
- Freckles
- Discolored areas of the skin, called mottled pigmentation

The best protection against solar overexposure is clothing to block the sun's UV rays. For cases when this is not practical or desirable, sunscreen lotions have been developed to block the solar UV radiation, at least partially.

HOW DO SUNSCREENS WORK?

Sunscreens combining *organic* and *inorganic* active ingredients.

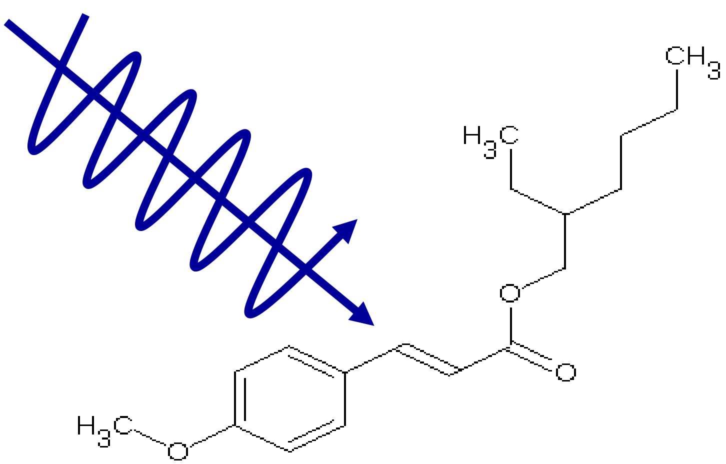
- Organic compounds used in sunscreen include octyl methoxycinnamate (OMC) or oxybenzone They absorb the UV radiation and dissipate it as heat.
- Inorganic ingredients like zinc oxide or titanium oxide reflect or scatter ultraviolet (UV) radiation.

Some (but not all) sunscreens are formulated to protect against the two types of damaging UV radiation, UV-A and UV-B.

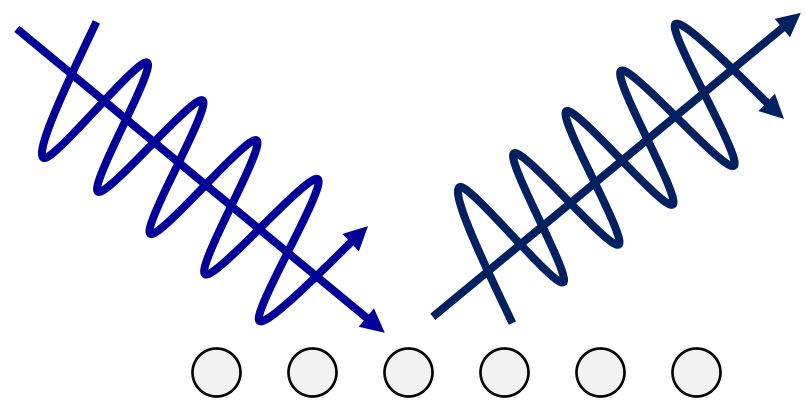
HOW ARE NANOPARTICLE SUNSCREENS DIFFERENT?

Organic compounds absorb incoming energy, resulting in molecular vibrations. This is dissipated as heat.

Inorganic particles scatter the incoming UV rays away from the skin.



2 - Ethylhexyl p - methoxycinnamate



Zinc oxide or titanium dioxide

WHAT DOES SPF MEAN?

- **SPF stands for Sun Protection Factor.** It can help determine how long one can stay in the sun before getting a sunburn. Since sunburns are caused by UV-B radiation, SPF does not indicate protection from UV-A.
- **Human skin has a natural SPF**, partially determined by the level of melanin, that is, how darkly pigmented the skin is.
- **The SPF is a multiplication factor**. If you can stay out in the sun 15 minutes before burning, using a sunscreen with an SPF of 10 would allow you to resist the burn for 10x longer or 150 minutes.
- Although the SPF only applies to UV-B, the labels of most products indicate if they offer broad spectrum protection, which is some indication of whether or not they work against UV-A radiation.
- The particles in nanoparticle-based sunscreens scatter both UV-A and UV-B radiation.

From: About.com (http://chemistry.about.com/od/howthingsworkfaqs/f/sunscreen.htm)

Nano-Link

ARE THERE CONCERNS OVER USING NANOPARTICLE SUNSCREENS

Some people have expressed concerns about potential hazards of the nanoparticles used in sunscreens. These hazard may affect the individual user (personal) or the larger ecosystem (environmental).

- Personal hazards. Where do the nanoparticle go once they are rubbed into the skin?
- Environmental. What is the fate of the nanoparticles once the sunscreen is washed off into the lake or down the shower drain?

Nano-Link

ARE THERE CONCERNS OVER USING NANOPARTICLE SUNSCREENS

Research into these potential problems is ongoing. Early results suggest that the personal exposure is not a significant hazard.

- Where do the nanoparticle go once they are rubbed into the skin? The ydo not appear to penetrate into the blood stream. The skin is a very effective organ at keeping materials outside the body.
- Research into the environmental fate of nanoparticles is continuing. Researchers are particularly interested in the uptake of titania and zinc oxide nanoparticles by aquatic organisms, from plankton to fish.