Science of Energy Frequently Asked Questions (V10.09)

<u>I've heard that there are other explanations about what makes the vanes in the radiometer spin.</u>
It's true that the reason for the rotation has historically been a cause of much scientific debate. The generally accepted explanation is the one that appears in the Science of Energy guide. It's called the thermodynamic explanation.

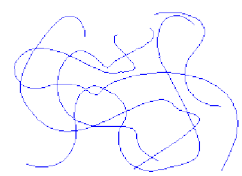
When a radiant energy source is directed at a radiometer, the radiometer becomes a heat engine. The operation of a heat engine is based on a difference in temperature that is converted to a mechanical output. In this case, the black side of the vane becomes hotter than the other side, as radiant energy from a light source warms the black side by black-body absorption faster than the silver or white side. The internal air molecules are "heated up" (i.e. experience an increase in their speed) when they touch the black side of the vane.

At least a partial explanation of how this makes the vanes spin is that gas molecules hitting the warmer side of the vane will pick up some of the heat, bouncing off the vane with increased speed. Giving the molecule this extra boost effectively means that a minute pressure is exerted on the vane. The imbalance of this effect between the warmer black side and the cooler silver side means the net pressure on the vane is equivalent to a push on the black side, and as a result the vanes spin round with the black side trailing.

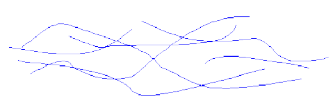
<u>Why isn't magnetism listed as a form of energy?</u>
Magnetism is due to electric charge and can be considered part of the Electricity category.

<u>If all forms of energy were formerly some other form of energy, what form of energy was solar nuclear fusion energy before?</u>
Gravitational forces create great heat and pressure. These forces "fuel" the nuclear fusion reaction.

<u>I don't understand rubber band effect.</u>
Simple answer: Rubber molecules are polymers shaped long chains. When the piece of rubber is just sitting there, the molecules are just tangled up in a random mess, like this:



When you pull on the rubber band, the polymer chains become align, like this:



When the chains align, something can happen. The chains can line up and pack together into extremely ordered arrangements called *crystals*. This is how the rubber molecules are arranged in a crystal:

When molecules, not just rubber molecules, but any molecules, form crystals, they give off heat. This is why the rubber band feels hot when it's stretched. When you let go of the rubber band, the polymer molecules break out of those crystals. Whenever molecules break out of crystals, they absorb heat. That's why the rubber band feels cold when you let go of it.

<u>There must be more to the happy/sad sphere explanation--explain it to me again or differently.</u>

There are two ways to explain the happy/sad sphere bouncing effect.

1. Polymer Structure

Everyone has played with balls that bounce, but few people truly understand the physics behind a bouncing ball. When you hold a ball above a surface, the ball has potential energy. Potential energy is the energy of position, and it depends on the mass of the ball and its height above the surface. As the ball falls through the air, the potential energy changes to kinetic energy. Kinetic energy is energy of motion.

As the ball falls through the air, the Law of Conservation of Energy is in effect and states that energy is neither gained nor lost, only transferred from one form to another. The total energy of the system remains the same; the potential energy changes to kinetic energy, but no energy is lost. When the ball collides with the floor, the ball becomes deformed. If the ball is elastic in nature, the ball will quickly return to its original form and spring up from the floor. This is Newton's Third Law of Motion- for every action there is an equal and opposite reaction. The ball pushes on the floor and the floor pushes back on the ball, causing it to rebound.

On a molecular level, the rubber is made from long chains of polymers. These polymers are tangled together and stretch upon impact. However, they only stretch for an instant before atomic interaction forces them back into their original, tangled shape and the ball shoots upward.

You may be wondering why the ball does not bounce back to its original height. Does this invalidate the Law of Conservation of Energy? Where did that energy go? The energy that is not being used to cause motion is changed to heat energy or sound energy. After playing a game of tennis or racquetball, you will notice that the ball is warmer at the end of the game than at the beginning because some of the motion energy has been changed to heat energy. Because bouncy balls have tightly linked polymer chains, most of the energy is transferred back to motion so little is lost to heat or sound energy, and the ball bounces well. This is the way the happy sphere behaves.

The sad sphere has different characteristics. When it is dropped from the same height onto the same surface, it does not bounce even though it has been given the same amount of potential energy as the happy sphere. It does not bounce because it is made up of a different material. Unlike the happy sphere, which is made of Neoprene, or common rubber, the sad sphere is made of Norsorex. On a molecular level, Norsorex is different from Neoprene because Norsorex's polymers are more loosely arranged and rub together more when the ball deforms. This additional movement, or rubbing together of polymer chains, results in motion being converted to heat energy; instead of the ball bouncing, it gets warm. There are several ways to make the sad sphere happy. One way is to change the temperature of the ball. When the happy sphere is cooled, its molecules are not as flexible, causing the ball to rebound a smaller distance. When the sad sphere is cooled, the Norsorex polymer does not deform as much, so less energy is converted to heat energy and the ball bounces. If the sad sphere is heated, the same process occurs and the ball bounces.

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2. Physical Properties of the Two Spheres

The spheres are made of two different polymers, specifically developed to have special characteristics. The happy sphere is made of Neoprene®, the trade name for polymer polychloroprene. The sad sphere is made of Norsorex®, trade names for polymer polynorbornene.

While the two black spheres appear to be almost identical, they exhibit marked difference in their physical properties. The physical properties that affect their bounce include:

> *Low v. High Hysteresis*: Hysteresis is a measure of the retardation of the natural tendency of rubber to return to its original shape after deformation. Internal frictional forces resulting from the molecular structure of the rubber cause this retardation. The happy sphere has a low hysteresis due to its weaker molecular forces. This means the ball "wants" to get back to its original shape *now!* so it bounces right back into shape and into the air. The sad sphere exhibits high hysteresis as a result of its stronger molecular forces. Consequently, when you deform the sad sphere by dropping it against the floor, it only slowly returns to shape.
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> *Rate (Coefficient) of Restitution*: Restitution is the "desire" of a substance to return to its original shape, almost a molecular "memory". Hysteresis affects the rate of restitution. The sphere with low hysteresis (the happy sphere) exhibits a more rapid return to its original shape, resulting in its greater bounce because it has a high coefficient of restitution. The sphere with high hysteresis (the sad sphere) has a low coefficient of restitution resulting in very little bounce.

Surface Friction: The molecular structure of the two types of rubber is also responsible for discrepant qualities in the surface friction of the spheres. The happy sphere exhibits low surface friction, which allows it to bounce higher (less of its kinetic energy is dissipated as heat energy). The sad sphere has high surface friction that results in dissipated heat and therefore it doesn't bounce as high.

Resilience: Another physical property to consider is the resilience of the polymer. Resilience is a measure of the work required to deform the material. Neoprene (happy sphere) has extremely high resilience (it takes more of work to deform it) and dissipates little of its energy to sound and heat. Much of its original potential energy is converted into kinetic energy and therefore produces a good bounce. Norsorex (sad sphere) has low resilience (doesn't take as much work to deform it) and dissipates most of its original potential energy into heat and sound (characteristic "thud" sound) on impact and therefore has little kinetic energy to make it bounce. Its low resilience tends to dampen or absorb the kinetic energy.

Putting all of these factors together results in neoprene has excellent energy conservation properties (kinetic energy to mostly kinetic energy after it hits the surface), while Norsorex is able to absorb the kinetic energy and change it to heat energy. If a neoprene ball is dropped and bounces, most of the energy is conserved and contributes to a high bounce; little energy is dissipated through heat. A Norsorex ball absorbs the majority of the energy and bounces hardly at all, dissipating the energy through heat.

Why The Sad Sphere Bounces Higher After Being Heated

Polymers also have a rather unique property referred to as the glass transition temperature. This property is the temperature in which the material changes from a hard, glassy crystalline material to a soft, rubbery, amorphous material. Another way of saying this is that the glass transition temperature affects polymers elasticity. The two balls have different glass transition temperatures and that partially accounts for the reason they bounce at different levels.

With the happy sphere, its glass transition temperature of -42°C which makes it highly elastic at temperatures above its glass transition temperature and therefore has a higher level of rebound vs. bounce rate. The sad sphere has a glass transition temperature of 35°C and this makes it very non-elastic and therefore does not bounce very high. It actually is sometimes characterized as falling "like a rock" or making a thud-like sound. Heating the sad sphere in very hot water increases the spheres elasticity and will bounce to perhaps one-third that of the Happy sphere bounce.

Everyday Uses Of These Polymers

Norsorex - Because it is an impact-absorbing material it is used for things like shoe insoles, sports gloves and mitts, high-tech golf balls, tires, damping material in shock absorbers, and in industrial packing materials. Stereo speakers make use of Norsorex to minimize resonance and external vibration. Because it is 100% solid, it is far stiffer than foams and a large fraction of the peak impact force is still transmitted through the material. This type of polymer (polynorborene) is the only material suitable for making body armor because its density has the ability to spread impact forces over a wide area.

Neoprene – It has many uses besides bouncy balls. Neoprene is commonly used for wire and cable jacketing, automotive gaskets, seals, hoses and tubes, power transmission belts, latex gloves and balloons, as waterproof membranes, and for asphalt modification. Another important use for this product is that it is used for swimwear. If you are a swimmer, scuba diver, or water skier, it is used for wet suits because it tends to hold heat. Neoprene is flexible in its uses because it resists degradation from the sun, ozone, and weather. Doping of the Neoprene polymer allows for more versatility and optimal performance.