The Principles of Creating a Magnetic Mounting System: The physics every mount-maker needs to know

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Topography

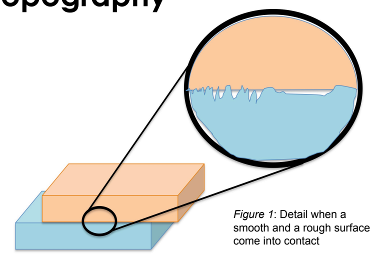


Figure 1: Detail when a smooth and a rough surface come into contact

The surfaces of all materials are irregular, if examined on a small enough scale. The surface texture of a selected material, whether rough or polished, determines the amount of contact between the two materials, an important aspect of creating friction

Friction

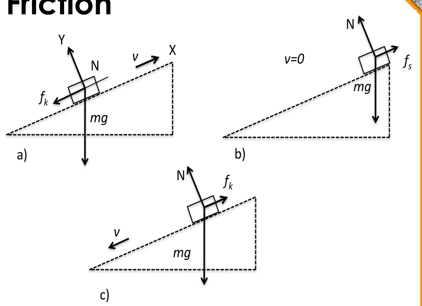


Figure 2: Forces on a block; a) Sliding up a rough slope; b) Resting at the highest point of a rough plane; c) Sliding down a rough plane.

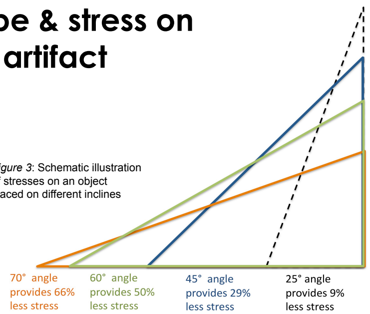
Frictional behavior of a material describes how difficult it is to move one surface across another. The frictional force of a surface depends on the downward force, a component of gravity, pressing the surfaces together.

Coefficient of friction

The coefficient of friction (μ) takes into account a material's surface quality to determine frictional force. Since the static coefficient of friction is greater than the kinetic coefficient of friction ($\mu_s > \mu_k$), it will take more energy to initiate motion than to maintain it at a constant speed. The rougher the surface, the greater the coefficient of friction will be (Figure 2b).

Slope & stress on the artifact

Figure 3: Schematic illustration of stresses on an object placed on different inclines



At a 45° angle to the vertical, the force of gravity is split equally into a slope component and a perpendicular component, the latter of which presses the artifact into the supporting surface. (As an aside, most museum professionals more often use the vertical angle. After all we are dealing with a vertical wall not a table.) Any mount with angles greater than 45° lessens the perpendicular component, or the downward pressure on the artifact, but at the cost of creating greater tension at the point of the along-slope fastener. This calculation, not widely used by museum professionals, comes from basic trigonometry (Barker 2005). Each increment of stress is not actually evenly distributed along a zero to 100% scale of stress (Figure 3). Increasing an angle from the vertical 0° to 25° reduces the strain on an object by only 9% at most. To achieve a reduction in strain of 29% or more one must increase the angle to 45°. At 60°, a reduction of 50% is achieved, and a 70° angle reduces stress on the object by 66%. The effect of gravitational pull is also impacted by both the mounting fastener and the static friction on the surface of the display fabric covering the support, the latter of which depends on the display fabric's surface quality

Static charge

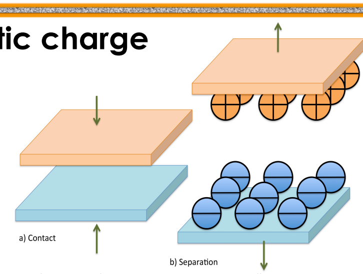


Figure 4: Schematic of electron exchange when two different materials are in contact and are then separated. The extent of this exchange is based on the materials placement on the Triboelectric series (Table 1).

Static charge occurs when materials are in contact and then separated without any apparent rubbing, or when materials are rubbed together. More static is created with rubbing than with simple contact and separation (Blythe 1974; Sello and Stevens 1984). When materials are in contact, electrical charges develop, which is usually avoided. Electrical charges occur when bonds between electrons, which are established when materials come into contact, are then broken upon separation (Carleton 1962).

All bodies are composed of both positive and negative charges equally (Sello and Stevens 1984). The basis of electrostatic charging is a surface phenomenon where the disruption of the condition of equilibrium is seen in the neutral atom (Commoner 1998). Electrons have a negative charge. When energy is applied to a material system, such as by friction or pressure, a small number of electrons can jump from one material to the other. The material whose atoms gain electrons will become negatively charged with static electricity, while the material that looses electrons will become positively charged. When two materials are in contact, a flow of electrons moves from one to the other; whether it is the same material or between two different types.

Tribo-electric series

Materials that can gain or lose electrons are called triboelectric materials. The order of propensity to gain or lose electrons is called the triboelectric series (Sello and Stevens 1984). The series is based on the conductivity of the individual material. The level of charge is linked to a material's placement in this series (Table 1). It is the distance of the two materials from one another on the series that increases the charge effect rather than the specific location in the series. Therefore, if two materials in contact are neighbors on the scale, there is less exchange, like cotton and steel. But if they are far apart, no matter where on the scale, exchange occurs. Table 1, compiled from many sources, shows the ranking of commonly used materials for mounting and in artifacts.

Types of materials & their location on the series

In general, proteins tend to be located at the upper part of the series, with metals in the lower part; lead and aluminum are exceptions to this rule. Synthetics tend to be located at both far ends, and both glass and acrylic are together at the upper end of the series.

A few observations about the location of materials in the series:

- Cellulosic plant fibers are in the neutral section, located in the middle of the table, along with wool and are very close together in the series.
- When mounting paper items, consider using a synthetic material to strengthen the holding power.
- Proteins, such as animal fibers, are located exclusively in the upper, positive section of the table, perhaps because amino acids tend to donate electrons.
- Synthetics are at opposing ends, with nylon and acrylic at the most positive end and polyester, polyethylene, and silicone at the most negative end.
- The topography of materials matters; the more surface area in contact between materials, the higher chance they will exchange electrons.
- Environmental conditions matter; hydrophilic materials at low relative humidity exchange charge more readily than at high relative humidity, while hydrophobic materials are less likely to exchange a charge.

Adhesion & Cohesion

The triboelectric effect is considered to be very similar to the phenomenon of adhesion, in which two materials composed of different molecules tend to stick together on contact as a result of a chemical reaction. Adhesion is very similar to a chemical bond in which adjacent yet dissimilar atoms exchange electrons. When one material is physically moved away from the other, the bonding forces appear to the human eye as 'friction.' One material gains electrons, thereby creating excess electrons, while the other material loses them, thereby creating a deficit of electrons.

Other features of the series relate to the preservation of collections and clearly would benefit from more study and attention. For instance, note that the phenomena involving electron exchange are related to light fastness and the pH of materials (Commoner 1998).

Figure 5: Polyester fibers attached to wool fabric of a military uniform.

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Table 1: Tribroelectric series

Charge	*Material*	*Notes*
+	Air	
	Polyurethane foam	
	Hair	
	Nylon, Dry skin	Dry skin has the greatest tendency to give up electrons and becoming highly positive in charge. [Resiliency 9 out of 11]
	Glass	Why TV screens collect dust on their surfaces.
	Acrylic, Lucite	
	Leather	
	Rabbit's fur	Fur is often used to create static electricity.
	Quartz	
	Mica	
	Lead	Surprisingly close to cat fur.
	Cat's fur	
	Silk	[Resiliency 5 out of 11]
	Aluminum	
	Paper	
	Cotton	Best for non-static clothes. [Resiliency 3 out of 11]
	Wool	
NEUTRAL		
	Steel	Not useful for static electrisity
	Wood	Attracts some electrons, but is almost neutral
	Amber	
	Sealing wax	
	Polystyrene	
	Rubber balloon	
	Resins	
	Hard rubber	
	Nickel, Copper	
	Sulfur	
	Brass, Silver	
	Gold, Platinum	
	Acetate, Rayon	[Resiliency 2 out of 11]
	Synthetic rubber	
	Polyester	[High resiliency (11 out of 11)] Higher friction than cotton
	Stryrene & Polystyrene	Why packing peanuts seems to stick to everything.
	Plastic wrap	
	Polyethylene	
	Polypropylene	
	Vinyl, PVC	
	Silicon	
	Teflon	Teflon has the greatest endency of gathering electrons on its surface and becoming highly negative in charge.
	Silicone rubber	
-	Ebonite	

Table 2: Summary of materials

Material Properties	**A lower potential to aid to the Magnetic System**	**A higher potential to aid to the Magnetic System**
Textile Issues		
Fiber type	Cotton fibers have a lower friction	Polyester fibers have a higher friction
Weave density	Tighter weaves have a lower friction	Courser weaves have a higher friction
Twill direction	Twill in warp direction has a lower friction	Twill in weft direction has a higher friction
Surface Issues		
Surface characteristics	Smooth surface has a lower friction	Rough surface has a higher friction
Static charge	Material with a low static charge	Material with a high static charge
Other Issues		
Triboelectric series	Materials that are neighbors	Materials that are far apart
Slope	Vertical and shear directional mounts	More than 45 degrees
Friction	With increased relative humidity	With decreased relative humidity
Elastic deformation	Stiffer, less deformation on the fibers will create less contact	The more deformation, the more contact
Relative humidity	Wetter environment	Drier environment

Conclusion

The intention is to help guide museum professional and other practitioners in selecting materials. Incorporating ideas relevant to a particular situation is likely to make one's magnetic system more successful (see Table 2 'Summary of material properties that effect a magnetic system'). Friction, and its relation to slope, plays a significant role in determining the strength of a magnetic system. The slope of a mounted artifact may need to be 45° or more to adequately to alleviate stress on an artifact. This is a good argument for increasing the footprint of display areas, especially those with important artifacts. Display cases may need to be deeper to accommodate this necessary angle.

By using synthetic materials, it is also possible to reduce the number of magnets needed for the system, thereby limiting the chances an artifact is damaged by compression. Pull force applies the pressure required to lock the fibers together, and thus reduces slippage (Wood 2012a). Using synthetic materials may also reduce the compression of an artifact by reducing how strong a magnet must be; by encouraging cohesion and 'grab' between layers, less pull force is necessary. Using a weaker magnet will reduce the chance that low-resiliency materials become compressed and therefore reduce the chances an artifact is damaged. Finally, this poster has also outlined how the materials one selects can help strengthen the overall magnetic system.