Exhibit Design
Product Requirements Document
Rochester Museum and Science Center

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Document Number 00003

Revisions	Level	Date
	E	12-17-2016

Authentication Block

Revision History

Rev	Description	Date
A	Initial PRD	10/26/2016
B	Second draft	11/08/2016
C	Third draft	11/29/2016
D	Forth draft – Overhaul of formatting	12/07/2016
D.1	Intermediate Revision – Physical Explanation	12/13/2016
E	Final Revision	12/17/2016

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Vision

An interactive exhibit that engages kids of all ages (3-100) and can teach fundamentals about some optical phenomenon. Accompanying the exhibit will be a plaque elaborating on the phenomenon demonstrated. The plaque will explain the physical phenomenon at the level of technical sophistication which a child can understand, or at least which a non-technically educated adult can understand and engage with.

The focus will be on a single exhibit. Additional exhibits may be constructed if time permits.

- Plan A

<u>Background</u>
Certain materials exhibit birefringence when put under mechanical stress. This means that depending on the polarization of incoming light, the material will cause the light to slow down at different rates. As a consequence, the polarization is warped in a way representative of the spatial pattern of stress on the material. If you place the material between two polarizers with an external light source, the first polarizer will assert linear polarization on the light, the material will potentially modify the asserted polarization depending on the stress on the location of the object, and the second polarizer will block the component of light polarized in the direction of the first polarizer. If the material does not modify the polarization in a region do to a lack of internal stress, the light will be blocked and the region will appear dark. Thus, the light which shines through the system can be viewed as a map of the stress on a material.

<u>Design</u>
Our first priority will be to develop an exhibit which demonstrates stress induced birefringence in an interactive and exciting way. Specifically, we will develop a stress plate which, when stepped on, will exhibit a fringe pattern as a consequence of birefringence. This will be achieved using the configuration shown in *figures 1* and *2* by placing a uniform light source under a sheet, which is in turn between two crossed polarizers. The sheet must be constructed of a material which exhibits significant stress induced birefringence under the weight of a small child. Additionally, the structure must be able to function, or at least not break, under the weight of a large adult. The light source must be reasonably uniform and bright enough so that fringes induced by the material are clearly visible. The plate would ideally be of uniform brightness or darkness when no pressure is applied and only display complex patterns when stepped on. There may be an internal, spatially varying stress pattern permanently embedded in the birefringent medium causing a more intricate illumination pattern without external stress; however, and the static uniformity of the plate is not a strictly necessary condition so long as whatever light distribution is present on the panel when no pressure is applied changes in a highly visible way when pressure is applied. The entire optical apparatus would be about 2 ft. square in area and 1 ft. tall.

Figure #1

This is a representation of our final product as packaged. It will be approximately 2 ft. on a side and 1 ft. tall. The four side faces of the box will likely be wooden, and the top face will be glass or plastic.

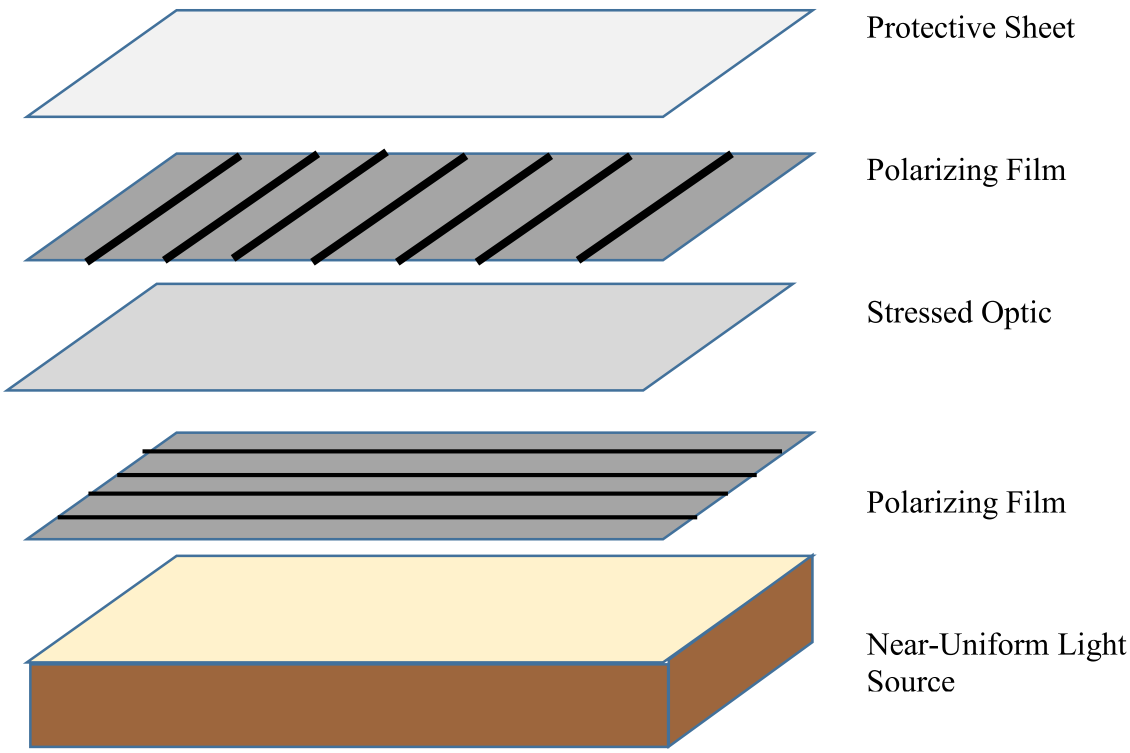

Figure #2

This is a representation of our final product unpackaged. At the base there will be a light source. The light emitted will travel through one polarizing film thus becoming polarized. It will then pass through the stressed optic which will distort the polarization then through a second polarizer which will only let through the light that has had its polarization distorted. A final protective sheet will be used to prevent the polarizing film from being damaged by particulates from people's shoes or cleaning agents.

- Plan A.1

If we are unable to construct a plate which meets the above constraints, we will attempt to construct an exhibit which demonstrates stress-induced birefringence in a more manageable way. This would present the same phenomena in an alternate way. It loses the theatrical intrigue of the original design, however, which is desired.

- Plan A.2

Alternatively, an alternative method of inducing fringe patterns on the floor is also possible. This may be in the form of an etalon where distorting the glass causes changes in the optical path length between two sheets of glass.

- Plan B

If we find that the constraints of *Plan A* are not achievable within the given time frame, or if we are able to finish *Plan A* with sufficient time in the semester, we will attempt to construct *Plan B*. The exhibit for *Plan B* will demonstrate the Pepper's Ghost technique (see figure 3). This demonstrates reflection and refraction through glass. We will be using a Kinect to remove the background of the live image feed, and a computer display pointing downward on top of the structure (see figure 4). The image is reflected in a 45 degree tilted glass plane.

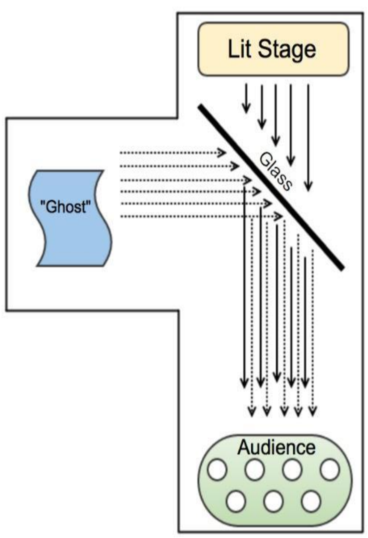

Figure #3

Ray trace analysis of the Pepper's Ghost effect. Some of the incident rays from the lit stage are refracted through the glass towards the audience, and some of the incident rays from the hidden room are reflected by the glass.

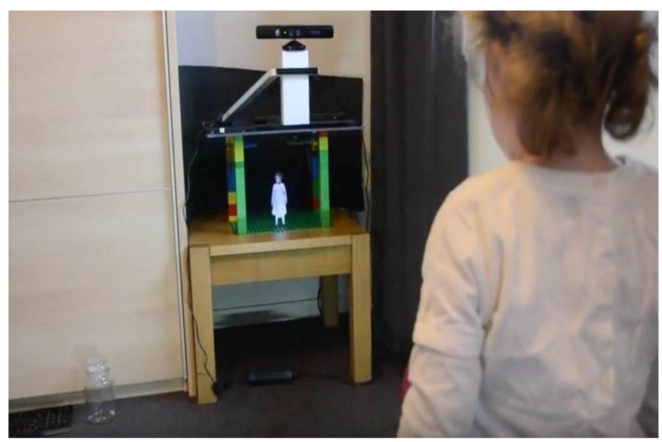

Figure #4

Setup of Plan B: demonstrating the Pepper's Ghost effect.

Environment

This exhibit would ideally be able to exist indoors during all seasons of Rochester. The exhibit is intended to be walked on and so should be easily cleaned when dirty.

Temperature
55-105 °F – operation range

Relative Humidity
Non-condensing – safe operation
>0% - meets specifications

Construction Restrictions & Safety Constraints

It should not be constantly consuming power, except for the light source. The light source would preferably draw sufficiently little power that it can be powered by a standard wall outlet, however this is not strictly necessary. The panel should be functional when stepped on with unclean shoes throughout a typical day of use. It should be cleanable with mop and water.

This product cannot have the ability to harm an unaccompanied child through proper use or misuse whether intentional or unintentional.

This product must be virtually indestructible.

Project Scope

We are responsible for:

- Designing and building one (1) final exhibit.
- Writing a concise explanation of the optical phenomenon for the layman visitor to understand.
- Detailed list of all materials used and vendors to get them from.
- Instruction manual for construction.
- Providing a document for how to clean exhibit if special method is required.

We are not responsible for:

- Installing the exhibit into the floor of the museum.

Budget

Materials	Price / unit	Quantity	Price	Vendor
Linear Polarizer (1ft x 1ft)	$35	4	$140	Polarization.com
Birefringent (Stress) Materials	~$200	1	$200	TBD
Plexiglass Protect Sheet (2ft x 2ft)	$34.52	2	$69.04	ProfessionalPlastics.com
Linear LED Bulb	$59.99	5	$299.95	Lumens.com
		SUM:	$708.99	

Computer Modeling of Design

To add technical depth to our project and more easily determine the sizes and materials needed, we will model our intended design. To do this, we will first use a finite element model software (e.g. Patran) followed by analysis using SigFit. These tools are capable of modeling the stress induced by any weight we instruct it to; the change in index of refraction due to this stress; and the portion of light that will pass through both polarizers. This will let us test various materials, thicknesses and weights without assembling a new apparatus each time.

After doing the finite element modeling above, we will model how various light sources work with the polarizers and stress plates. This will be necessary so that we do not purchase a light source that will not work with our product.

Other Project Resources

- Demonstration apparatus for visualizing stress in polarizers (through the ME department- Chris Pratt)
- Communicating with engineer James Meyer (who also builds exhibits for the RMSC), to help us develop a good set of constraints for our exhibit.

Spring Schedule

Jan 18 – 27	Model the design using Patran, SigFit, and LightTools
Jan 27	Finish prototype mark I design
Jan 28 – Feb 10	Build prototype mark I for museum floor
Feb 11 and/or 12	Supervise usage of prototype mark I on site
Feb 17	Finish prototype mark II design
Feb 18 – Mar 3	Build prototype mark II for museum floor.
Mar 4 and/or 5	Supervise usage of prototype mark II on site
Mar 10	Hopeful design freeze on product. If another round of prototyping is needed to troubleshoot, we will do so.
Mar 13 – 24	Build product
Mar 20 – 24	Write concise explanation for plaque
Mar 25 and/or 26	Supervise usage of product
Mar 31	Hard final design freeze
Apr 3 – 14	Apply any changes that need to be done to product
Apr 3 – 14	Compile information for museum (see Project Scope)