TEAM

BODENSTEIN, DANIEL JOESEPH
EWING, BROCK FITZGERALD
GRAHAM, JOSEPH MATTHEW
LONG, MICHAEL J
O LOUGHLIN, CHRISTOPHER E

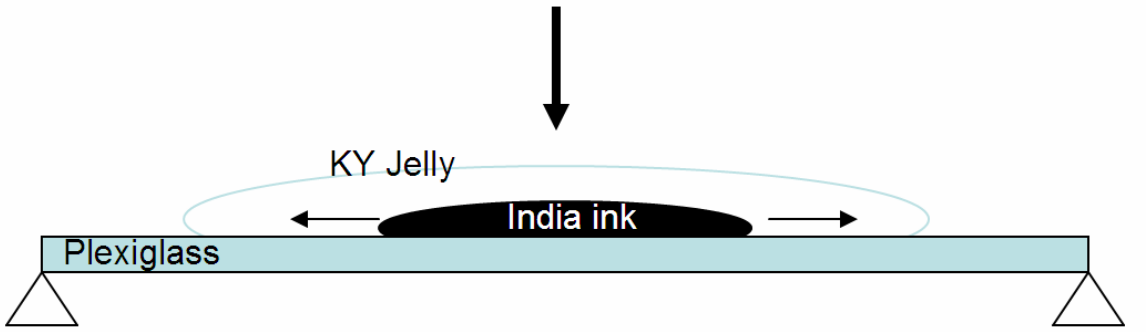
GROUP PROJECT ONE
Class: Flow Visualization
October 25, 2007

Objective

The purpose of our study was to capture a low Reynolds number interaction between multiple fluids. Black ink and a clear gel were used to enhance the interaction's visibility. Many different combinations of fluids were observed, changing both hue and surface tension effects. In the end the best captured images were obtained with only KY Jelly and India ink. The final picture was chosen for its stunning contrast and distinctly pictured flow.

Flow and Apparatus

The apparatus that was required for the image was an optically neutral clear plate with camera below which allowed for a mixture to be placed on the surface of the plate and photographed from below. The setup allowed for natural backlighting which alleviated any shadows that might appear in an indoor setup. The apparatus for the flow image is shown in the figure below:



The flow was created in such a manner that the relevant information that was created by the original flow was still able to be photographed long after it occurred. Using an India ink on the flat surface we poured a K-Y Jelly blob onto the stagnant ink, the actual size of the image is about 3 cm is diameter. During pouring we approximated a Reynolds number of 1.5, which put the flow well into the laminar region. One of the major factors of having a low Reynolds number is that the inertial terms in the Navier-Stokes equation are relatively unimportant; the flow pattern is determined by a balance of the viscous forces and the pressure gradients in the fluid (Purcell, 1976).

What we end up capturing in the image is the initial impact of the K-Y on the stagnant ink which trapped a large portion of the ink, in the center of the image, under the jelly. Outside of this trapped ink is the crater that began to force the rest of the ink away from the moving jelly. Due to the high viscosity of the jelly, rolls began to drop over the ink and capture fantastic ripples of ink underneath it as it moved out. After the initial ripples subsided we can see that the K-Y is clearly shearing with the ink and creating a viscous interaction that is creating symmetrical ripples and streaks in the ink as it very slowly creeps to stagnation. All of this motion was able to be captured in the image due to both the transparency of the K-Y and its high viscosity. The overall time for the phenomenon to be created and contained was approximately 2-3 minutes.

Visualization Technique
In order to visualize the interaction between two fluids of very different viscosities, we decided to have one of our fluids dyed, while keeping the other transparent. This allowed us to visually isolate one of the fluid flows so that we could better understand the physics involved in the interaction. Because we felt that the flow of the lighter, less viscous fluid would be more interesting than that of the heavy, dense, slow moving fluid, we chose undiluted India ink as our less-viscous fluid and transparent K-Y Jelly as our more-viscous fluid. The result of this visualization technique is a clear image with little distraction that allows the viewer to focus on the fluid flow. The photo was taken outside using bright sunlight to illuminate the image from behind. No flash was necessary as the sun was bright enough and a flash may have caused a glare off of the clear plate.

Photographic Technique
The front of the lens was placed 9.0 inches below the bottom surface of the 1/8" plexi-glass sheet. This image was captured after most motion had stopped and at $1/360^{th}$ of a second exposure time there is virtually no motion captured- less then one-pixel width of motion. A flare guard was placed one the front of the vertical lens to prevent the afternoon sun from adding artifacts to the image. The image is 3072 x 2040 pixels in size and the droplet is 1.10 inches in diameter in the vertical and 1.0 inches in the horizontal. The CRW (Canon Raw Format) was imported into Apple's Aperture program and the image was fully de-saturated in order to give the black and white contrast. This enhances and simplifies the image without any loss of data. No other manipulations were performed.

Photo Data:

Image Date:	10/19/07 4:41 PM MST
Camera Model:	Canon EOS 10D
Serial Number:	620312005
Shutter Speed:	1/360th second
Aperture:	F4
Exposure Bias:	0ev
Focal Length:	100mm
ISO Speed Rating:	ISO 200
Aspect Ratio:	3:2
Orientation:	Landscape
Depth:	16-bit
Color Profile:	Adobe RGB 1998

Artistic Expression
The scale of the image is ambiguous and could imply either a macro or micro dimension. The circular shape of the image and its mysterious imagery contained within it references both a telescopic view of a galaxy or a microscopic peering into a cell. Both of these

worlds represent a challenging realm and often inspire contemplation to the make-up and meaning of the universe. The duality represented in the work acts to challenge the viewer to make up his or her own mind about what the image depicts and acknowledges similarities in form existing in many scales within the universe.

A circular shape relating to the iris of an eye has universally been employed in artwork throughout history in many cultures. This form has inspired many through mythological and psychological discussion. Our image recalls the same iris-like inspiration. While looking at the image, it seems to look back, lending an engaging interplay with the viewer.

The original color image was converted to black and white in order to bring attention to the great range of values embodied in the work – it goes from white to black with many subtle shades of grey in between. This allows the photograph to appear to have a wonderful illusion of a deep perspective and certainly highlights the range of scientific reactions unfolding.

The numerous almost concentric circles in the piece imply a pulse, just as when a pebble is dropped into a still pond of water and waves continually expand outward. The middle "circles" are harder in value, nearing true black. They center the piece and give balance to the numerous implied textures that are visible throughout the photograph. The outer dark ring acts to contain or frame the image, giving the interior importance.

The almost pure white "background" causes the orb-like image to float – nothing anchors it – instilling the notion that the orb is dynamic and may move or spin at any moment.

References:

1. Purcell, E.M., *Life at Low Reynolds Number.* Retrieved 22 October 2007. June 1976. http://jilawww.colorado.edu/perkinsgroup/Purcell_life_at_low_reynolds_number.pdf

Misc. Info:

Inputs

Free-stream fluid velocity, *V*:	0.05	m/s
Characteristic distance (or pipe diameter), *D*:	3	cm
Fluid density, ρ:	1	kg/m^3
Fluid viscosity (dynamic), μ:	1	cP