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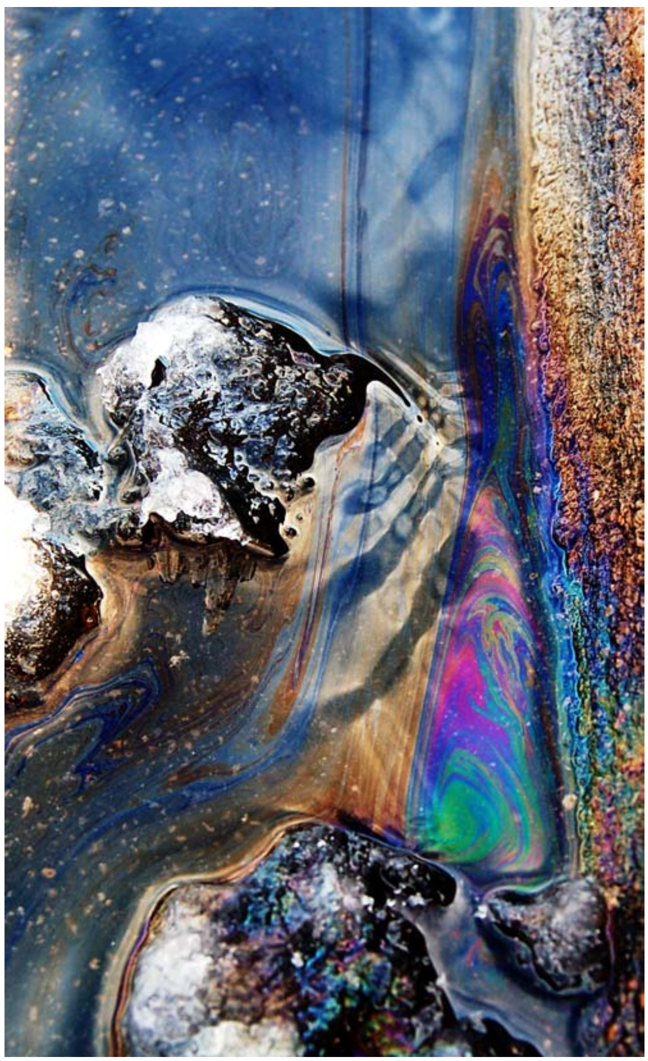
Thin Film Interference of Motor Oil on Water

The intent of this project was to capture some beautiful images from fairly ordinary and mundane sources, while displaying several fluid phenomena. The result is the following photograph, taken the 10th of February, 2006, of motor oil floating on water runoff from a street after a snowstorm. The brilliant colors shown are the result of thin film interference, and serve well to demonstrate vorticity in the water, and add an appealing aesthetic.



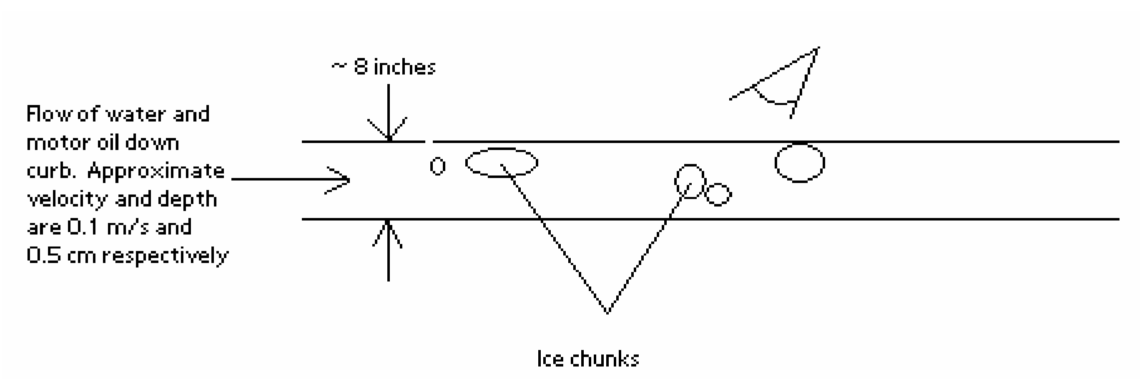
Thin film interference occurs when a very thin layer (thickness on the order of the wavelength of light) of fluid rests on top of another fluid with a different index of refraction. When light encounters a fluid with a different index of refraction, some of the light is transmitted through the layer, while another portion is reflected. In the thin film shown, light travels through the air and encounters the oil that has spread over the surface of the water. Some of this light is reflected back to our eyes. At the same time, the light transmitted through the oil encounters the water a very short distance below the oil. Again, some of this light is reflected back to our eyes. However, on the way to our eye, the light beams interfere with each other. This interference can be either constructive or destructive. Destructive interference will show up as a dark spot, whereas constructive interference will appear as a brilliant spot of color. The reason we see one color is that the light interferes in such a way to amplify one wavelength of light, and this wavelength determines the color that we see.

The water forms a vortex as it flows past the chunk of ice. Some of the flow is trapped by the curb of the street, and is forced back upstream as more water pushes in behind it. As the water continues further upstream, some of the water begins to be dragged back downstream by the free flow. This cycle causes the eddie in the flow, which is familiar to any who have spent much time along rivers and streams.

Many fluid phenomena can be seen in this photograph, though they can not be gone into in depth with this short report. The wake from flow over the ice chunk in the center of the picture, as well as the creep of the motor oil up the face of the curb, are some examples that could be investigated further.

This photograph was taken at a range of 3 feet with a digital Nikon D50 (6 Megapixel) camera. Lighting was from ambient sunshine with no flash. The exposure time was 1/160th of a second, with a focal length of 38mm and f-number f/7.1. The original photograph was then cropped to a size of 1000 X 1640 pixels (new resolution of 1.6 Mpx) and edited using Adobe Photoshop. Modifications made were to eliminate unused spectra by altering the red, green, and blue color levels, as well as to increase the contrast by adjusting the curves.

Below is a basic schematic of the setup used to create the photograph:



The field of view in this experiment is small, being only about 2” wide by 3” long. The flow rate of the water is estimated to be 0.1 meters per second, and the depth of the water/oil is about half a centimeter. With the consideration of the velocity of the fluid and the shutter speed of the camera, the fluid would have moved a distance of 0.625 millimeters. When compared to the field of view, this movement is very small, and so the time resolution is good. The velocity of the water over the concrete curb generates a Reynolds number of approximately 260,000. This means that the flow along the bottom of the water, in the boundary layer, is experiencing some turbulence, but is not quite fully turbulent. The surface water and oil seem to be flowing very smoothly, while the water beneath has quite a bit of motion and mixing occurring.

References:

http://physics.bu.edu/~duffy/PY106/Diffraction.html