day: dule I Adams h exposure Juition			
(1) Shutter speed A slow $30 = 1/30 sec$ 60 -120 240 -480	4 ways to control pixel values 2 3 Aperture ISO big 4 5.6 800 -8 400 -11 200 16 100 low sensitivity f / 16	Deliberate over/under exposure Overexposed = More light, or more sensitive ISO EV = +1 Proper exposure = middle value on an average pixel Underexposed = Less light, less sensitive EV = -1	

Shutter speed: motion blur at slow speeds Aperture: low depth of field at large aperture ISO: Noise at high ISO Deliberate under/over: Camera will change one or more of the other three settings, with attendant side effects.

Any measurement requires 3 types of resolution: spatial, temporal, measurand (dynamic range) Making an image is equivalent to making a measurement of light (measurand)

	$\frac{1.0}{1.0}$ 1 $ 2$ $ 4$ $-$
Resolution: Spatial	≥ \\\// \\\ =
Can two adjacent things be resolved?	
	<u>1.4</u> <u>1.6</u>
Resolution = minimum distance between two	<u>1.8</u>
objects for them to be recognized as separate.	2.0
Applies to objects (spatial resolution)	5-line resolution test wedges: 1:2 ratio each Video Test Pattern John Beale 1999
and events (temporal or time resolution) and any quantity being measured (measurand)	"Large resolution" = meaningless "Fine resolution" or "Highly resol
Spatial resolution can be DEGRADED by • Bad focus	= well - resolved.
Rastering, pixelation	
Diffraction effects	
Low contrast	
 Compression artifact (in jpegs) 	
Motion blur	

	Bad focus: is circle of confusion > pixel?	
	sensor	
	$\wedge + -$	
\sim	pixel	
	• Diffraction effects if lens aperture or pixel size < λ wavelength of light	
λ < d	$\lambda > d$	
tweeters,	woofers, relatively	
Beamy effect, s	sharp focus small aperture	
	1/2	
	le : http://www.luminous-landscape.com/tutorials/understanding-series/u-	
	tion.shtml. Moral of the story: high f number has better depth of field, but sharpness	
can be	defeated by diffraction effects.	
Current	it sensor sizes range 35 - 3 mm. For 3k px wide, 1 pixel = 10 -1 μm.	
	= 0.7 μm. Pretty close!	
'E!	II Frame' DSLR: sensor size is ~35 mm	
	p://www.whatdigitalcamera.com/roundup/camera-	
	ndups/best-full-frame-dslrs-2016-9263.	
1001		
How much re	esolution is needed?	
Consider rang	ge of scales:	
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Time resolution

Other considerations of shutter speed:

Short enough to 'freeze' flow= TIME RESOLVED VS long enough to get desired particle tracks or long enough to be TIME AVERAGED. Calculate motion blur. If unacceptable, increase time resolution= shorter exposure time

Increase shutter speed

Max is 1/10,000? 0.1 msec, 100 µsec? At best. High speed camera 30,000 fps ~ 3 x 10-5 sec = 30 µsec

Freeze the flow with short light source (won't work for light emitting fluids, i.e. flames) Strobe, camera flash ~ 10-5 or -6 sec = 1-10 μsec Pulsed laser 3x10⁻⁹ sec = 3 nsec or less Good resource for high speed photography: http://www.hiviz.com/index.html

If long shutter is needed, might be too much light, even at low ISO. Try a NDF = Neutral Density Filter. Neutral = all wavelengths equally. Gray. NDF 1 = 1 /10 light transmission, 3 stops NDF 2 = 1/100 etc. Log scale. 7 stops <u>http://en.wikipedia.org/wiki/File:Strickland Falls Shadows Lifted.jpg</u> 30 seconds. NDF 8x = 1/100,000,000 = 27 stops

 $10^{8} = 2^{\times}$ $\ll \ln 10^{-} \times \ln 2$ $\chi = \% \frac{\ln 10}{\ln 2}$

= 26.6



Need a tripod for macros, or shutters > 1/30 sec Full size start at \$25. Highly recommended.

Several available for checkout.

Estimate motion blur *in pixels* to guide choice of shutter speed.

Resolution Homework for Monday: Write short answers and submit in Dropbox.

1) In your Get Wet image, are all the scales of interest in the flow wellresolved in the image?

Is there a sharp boundary in the flow that only takes up one or two pixels in the image? What was the major effect that degraded the resolution?

2) At what f/ does your lens produce the sharpest image? Take an object that you can easily focus on (a ruler?), and image it with a range of f/. Then zoom in and check the focus. Try to minimize the effects of motion blur and ISO noise so your testing is valid. Submit at least three images illustrating your results.