BrianQ: well, I was thinking of Doos' problems with his gem microscope and how it was never going to match what can be done with a petrographic microscope
doos: ah
\Frank\: double ah
BrianQ: So I thought it might be fun to talk about resolution and NA
doos: yes please
Crystal2: what's that, Brian?
BrianQ: numerical aperture = NA
BrianQ: it is a term that describes what a microscope can and cannot do.
BrianQ: Let's form a mental image, shall we.... of a very long straight highway stretching miles off into the distance.
doos: route 69
Crystal2: lol
BrianQ: They have those sort of roads out in the western desert or plains in the US, yes Doos
BrianQ: Now it is dark... so all the cars have to have their headlights on.
BrianQ: A car pretty close to you, you can tell it is a car and not a motorcycle, because you see two lights separated horizontally
BrianQ: Y'all have that picture?
doos: yes
doos: reminds me of a joke .. later maybe
BrianQ: Now let's back that car up along the highway some distance... what happens to those two lights as you do that?
doos: they combine into one blur
BrianQ: or, what do you see...
DragonStek: dimmer and dimmer
BrianQ: yes, as the car gets further from you, the lights get dimmer and they appear to get closer together
doos: like a motorcycle
BrianQ: Eventually at some distance away they merge together and you can't tell if it is a car or a motorcycle
BrianQ: exactly, so y'all have the right picture in mind.
\Frank\: yes
BrianQ: At that specific distance, what happens is the "real" separation between the headlights has met the limits of your eyes' resolution
BrianQ: You can think of resolution as being able to distinguish between two objects close together
BrianQ: Now the physics for determining how far away the car can be, given a specific distance between the light sources, is pretty well documented.
BrianQ: As it turns out, we have an advantage at night... you can see the headlights as two separate objects a little further than you could at daytime.
BrianQ: Why?
doos: no light contaminations
DragonStek: too much light
BrianQ: nope, that isn't quite why... any other ideas?
BrianQ: Like, what changes in your eye when you try to see in low-light conditions,

compared to bright light conditions?
\Frank\: pupils are larger at night
DragonStek: lens on our eyes grow big or smaller
BrianQ: yes, pupils are larger at night!,
BrianQ: Pupils are like a little aperture behind the lens in our eye, and it gets bigger with less light and smaller with more light.
doos: or wider in the certain company
BrianQ: Also it gets bigger with using certain chemicals... so I've heard
BrianQ: :)
doos: heh
DragonStek: lol
Crystal2: lol
BrianQ: Anyways, the upshot is that the larger the pupil, the more light the eye can gather from an object
BrianQ: And the more light that can be gathered, the better the optics can pinpoint the location of the object
BrianQ: Let us recall what any object does... it emits light in ALL directions.
BrianQ: Your eyes, or some other optics system gathers a small fraction of that light.
BrianQ: In a way, that light is information... the more light you gather, the more information you have about the objects location
BrianQ: Thus, for example, telescopes are usually called "light buckets"
BrianQ: They gather a lot more light from stars and such than do our eyes.
BrianQ: This is because they use lenses or mirror that are much bigger than the lens in our eyes to gather the light... then they focus it down so it can be gathered by our eye or a camera, for example
BrianQ: The same is true of a microscope... the objective lens gathers much more light than our eye could alone...
BrianQ: Then the eyepiece takes that light and narrows it down into our eye.
BrianQ: The bottom line I am trying to promote here is that resolution is very dependent on how much light can be gathered.
doos: makes sense
BrianQ: This results from a mixture of geometry (which tells us how much light can be gathered) and wave theory (which tells us the limits of resolution for a given amount of light).
BrianQ: Can we call up the blackboard... because it would be best to see some of this in a drawing.
BrianQ: ?
doos: holdon .. go on while I put it up
BrianQ: Okay, here is the deal... if we think of a true point source of light, then we are talking about something infinitely small.
BrianQ: But even with the best optics in the world, with all possible abberations taken out...
doos: http://yey.be/chat/drawboard/blackboard.html (enabled)
BrianQ: we would never see a point... there would always be some apparent size or width to the object.
Sep 07 21:38:35 * guest1 (n=fn-javac@84.4.73.219) has joined #gemology

guest1: hi am i back?
BrianQ: Ok everyone try to call up the blackboard, and I'll get drawing on it.
BrianQ: yes Frank
guest1: bloody thing
Sep 07 21:39:38 * guest1 is now known as \\Frank\
Crystal2: got it
doos: frank: http://yey.be/chat/drawboard/blackboard.html
\\Frank\: Yes *I'm loading it now...what did I miss?
doos: let me past it to you in private frank
\\Frank\: ok
hi?
BrianQ: Ok, now my drawing starts off like a kid's drawing of the sun, a dot in the middle and rays of light leaving it.
BrianQ: Leaving in every direction.
BrianQ: yes?
DragonStek: YES
doos: yes
Crystal2: yes
BrianQ: Now I've drawn two yellow lines that are supposed to be the surfaces of two lenses. Which lens (if the other one isn't there) is going to collect more light?
BrianQ: from the dot
BrianQ: which collects more light rays?
doos: the bottom one
BrianQ: Yes, the one closer to the dot.
BrianQ: Both surfaces are supposed to have the same length, by the way. So the closer surface will intercept more rays.
BrianQ: Let's compare... see what region of rays each surface will collect... back to drawing.
doos: yes a much smaller cone of light
BrianQ: Yep, Doos is on it.
BrianQ: The closer surface intercepts a cone of light with a larger angle at the apex of the cone.
BrianQ: Y'all know what apex is? The dot source of light
doos: now I do
BrianQ: and the apex angle is the angle between the blue lines
BrianQ: or the red lines, for the other case
BrianQ: Everyone see this, what I'm talking about?
DragonStek: yeah
\\Frank\: yes
doos: yes about 40 degrees for the blue and about 30 degrees for the red
Crystal2: yes
BrianQ: The apex angle, then, is a measure of how much light the lens can gather... larger angle, more light gathered
BrianQ: Now if you want a copy of the current board, better do it now, because I'm going to erase.
doos: done .. not sure if I can save it for the chat though

BrianQ: What I want to do is set up the geometry a little more detailed, so we can see what happens as we change things.
BrianQ: That's ok, people will just have to imagine ;)
BrianQ: should've been here, haha
doos: indeed
doos: heh trying to draw "normal"
BrianQ: Here it isn't quite a normal, it is the central axis of revolution for the cone :0
BrianQ: Ok, the blue lines are two lenses with equal lengths for their surfaces
BrianQ: The object is the point, the apex of the triangles for which the blue lines form the base
BrianQ: The white lines show the cone of light accepted by each lens
BrianQ: All good so far?
doos: yes
DragonStek: yes
BrianQ: The yellow dashed line shows the central axis of the cone.
BrianQ: As we said, the lens closer to the source, closer to the apex, closer to bottom, accepts a larger cone of light, as measured by the apex angle.
BrianQ: Now for some reason, the proper way to measure the angle of a pointy cone is to measure it from the central axis to the edge.
BrianQ: rather than measure from edge to edge.
Sep 07 21:58:33 * \Frank\ has quit (Read error: 113 (No route to host))
doos: good riddance
BrianQ: One might call it the half angle, half the angle from edge-to-edge
BrianQ: heh
Crystal2: lol
BrianQ: I'm going to draw a curve (or at least try to) to show what angle I'm talking about.
BrianQ: do those teal, cyan, green-blue lines make sense?
doos: yes
DragonStek: yes
Crystal2: yes
BrianQ: That is the angle of importance, that is the angle that tells us how much light the lens is grabbing.
\\Frank\: yes
BrianQ: So, if we started moving a lens (as drawn) further and further away, what would happen to that angle?
doos: will get smaller
\\Frank\: it would decrease
Crystal2: ditto
BrianQ: And what value would it have when it stopped decreasing, and where would the lens be (relative to the source)?
doos: 0 at infinity
BrianQ: yes
\\Frank\: far away and angle theoretically at zero
BrianQ: yes, yes
\\Frank\: that doos is too smart and types too quickly for his own good

BrianQ: far away is a good approximation to infinity
doos: heh
BrianQ: Now... we move the lens the other way... toward the source... how big can the angle possibly get?
\\Frank\: almost 180 degrees
BrianQ: nope
BrianQ: we are looking at the "half-angle"
\\Frank\: ah 90
DragonStek: 90 degree
\\Frank\: degrees
BrianQ: yes, indeed
BrianQ: somewhere close to 90 degrees, at which point the object gets embedded into the lens
BrianQ: So now we know the allowed range of the cone's angle. Hmmm, anyone have a calculator handy?
doos: yes
\\Frank\: yes
BrianQ: IN AIR... we can figure out a lens's numerical aperture by calculating the sine of the angle.
BrianQ: NA (in air) = sin(cone "half angle")
doos: so between 0 and 1?
BrianQ: Yes... 0 means no light and 1 means all the light
BrianQ: um.. all the light sent in the forward direction
BrianQ: So in air, the largest amount of light that can be gathered is NA=1.
BrianQ: The reverse can be done... if you know the NA of the lens, you can figure out the half angle of the cone of light
BrianQ: cone "half angle" = arcsin (NA)
BrianQ: where arcsin on a calculator is usually the "2nd" button followed by the "sin" button
\\Frank\: question
BrianQ: yes?
\\Frank\: are these all assuming a single point source of light ?
doos: so a NA=0.5 = half angle of 30 degrees
doos: was one of my questions as well frank .. what if you want to focus on a circle
BrianQ: Yes, it does Frank... but all surfaces are composed from individual points.
BrianQ: For example you have some length line... the line is composed of point.
BrianQ: um... points
\\Frank\: yes true
BrianQ: Now as I mentioned, an infinitesimal point is never going to be viewed as infinitesimal.
\\Frank\: so we are talking about the particular point which is perpindicular to the lens?
BrianQ: it is going to be viewed with some minimum size.
doos: 400nm?
BrianQ: No actually... if the point is not along the central axis of the lens, for the most part, the lens still accepts the same cone of light.
BrianQ: As a very effective first approximation it doesn't matter where the point is in the

plane perpendicular to the lenses central axis.
BrianQ: But we'll show this some more when I erase the current drawing... so we'll get back to it
\\Frank\: ok
BrianQ: maybe Doos, but it really depends on the numerical aperture (NA) of the lens how wide the point will appear.
BrianQ: Let's take as a quick example a microscope objective lens that I just pulled off the internet... magnification 10x and NA = 0.25
BrianQ: What is the angle of the cone of light it accepts?
doos: ~15 degrees
doos: 14.5
\\Frank\: arcsin .25
BrianQ: yep... 14.47 degrees
BrianQ: Not a very big cone, compared to my sketches on the blackboard, eh?
doos: no
\\Frank\: but sthat is the half angle so the cone would be almost 30 degrees ?...right?
BrianQ: Yes, indeed, but 15 degrees is much smaller than the maximum possible angle.
\\Frank\: yes
BrianQ: Now here is a pretty good objective lens, with magnification of 80x and NA=.90
BrianQ: What is its cone half-angle?
doos: 64.15 degrees
doos: 64.16 degrees
doos: sawwy
BrianQ: Yep, and you aren't going to do much better than that.... Pressing microscope objectives to the utmost limits
BrianQ: you maybe can get a cone of 70 degrees, but that is extreme
BrianQ: Why can't we get closer to the maximum 90 degrees?
\\Frank\: does the higher more desirable NA have a much shorter distance between the lens and the object?
BrianQ: Absolutely, that is why indeed Frank
doos: that is probably the answer to the question frank
doos: lol
BrianQ: heh
BrianQ: Usually you have things in the way of the objective lens and object, like a coverslip or something
BrianQ: that limit the angle
\\Frank\: gem stereoscopes have a lot of working space...so I guess a pretty low NA
doos: yes must be
BrianQ: AND THAT IS THE POINT!
BrianQ: YAY
doos: crap
doos: here we go buying the stuff for "large working space"
BrianQ: a gem stereoscope has huge working distance, the objective is so far away from the viewed object, that they probably don't even write the NA on the barrel of the objective
BrianQ: because it is so embarrasingly small

doos: they dont indeed
BrianQ: Whereas biological and petrographic objectives always have the NA written on the barrel
\\Frank\: are these also stereo scopes or monaculers?
doos: objective lenses make no distinction
BrianQ: Stereo as well as mono... but the objective is so very close to the viewed object
BrianQ: When you get up to 80x magnification, the objective is around 0.2 inches from what you are viewing.
BrianQ: oops, sorry...
BrianQ: 0.2 mm
BrianQ: from what you are looking at
DragonStek: which ends up crushing the gem
BrianQ: how thick is a sheet of typing paper?
\\Frank\: scratching the lens more like
doos: about the same or over Brian
\\Frank\: about 1000nm?
BrianQ: Usually, the objective lens is spring-loaded, so there is some flex as it crashes into the slide
\\Frank\: guess thats why minerologists study thin slices
BrianQ: Yes, Doos, about 0.2 mm, about 20,000 nm
BrianQ: That is exactly why they study thin slices
BrianQ: They can't see down any further than the thickness of a sheet of paper, so why have all that additional rock in the way?
BrianQ: Besides, things ordinarily opaque become transparent at that thickness
BrianQ: except metals which are opaque at all scales
\\Frank\: yes you mentioned that in the past...except metals
BrianQ: so can use transmitted light easily for observation
BrianQ: So that's the story, morning glories, on what you traded off in using a gem microscope
\\Frank\: If they are capturing a larger angle does this make it possible for them to see both halves od a biref optic character more easily than a gemmo scope?
BrianQ: yes
BrianQ: um... what
BrianQ: um.. wait
BrianQ: no... not necessarily
doos: http://gemologyproject.com/wiki/images/9/98/Biaxial_45degrees.jpg
doos: like that image
BrianQ: that is the "window" of the microscope
BrianQ: and that is set by some other features
BrianQ: What it does allow is to see more closely, more finely, the fringes being produced
BrianQ: And this is the problem Doos was having, I think.
doos: yes
\\Frank\: so the optical resolution is better?
BrianQ: Not being able to see the details clearly
BrianQ: yes, for the gemmo 'scope, resolution is not one of its selling features

doos: well if you look at the image .. you see two "melatopes" .. that is a rare occasion
doos: or two isogyres
BrianQ: ok, let me finish off one last bit... and next time we'll connect NA to resolution.
doos: ok
BrianQ: Recall all I've said so far is more NA means better resolution, but not been specific
\\Frank\: doesn't this extra fine resolution cause problems when trying to view depth?...is the focus sharper on the perticular plane being viewed or is depth enhanced as well?
\\Frank\: sorry I'll save that question till later
BrianQ: Next time maybe we'll be able to figure out exactly how far that car needs to be away before its headlights merge
BrianQ: You are correct Frank, about your question
\\Frank\: :)
BrianQ: But in my experiment, I don't actually need any depth view at all, since what I'm looking at are circles with no width
doos: transform plane
BrianQ: supposedly... like the picture in my icon... no it is a regular image
BrianQ: not a transform interference image
BrianQ: What I DO need is an NA bigger than one!
BrianQ: How to get that?!?!...
doos: inverse it?
\\Frank\: convex lens?
BrianQ: Here's how it is done.... fill the region between the objective lens and the object with material of higher refractive index than air
doos: ah yes
\\Frank\: oil
BrianQ: Virtually anything will do, but water and oil are the two favorites
BrianQ: water is useful for biology, because most that stuff is already IN water
\\Frank\: so the objective lens is immersed along with the object?
BrianQ: But oil has higher refractive index, and so it is better.... and yes, absolutely Frank
BrianQ: I hate it, this gloppy oil on my objective
\\Frank\: how high above 1 can you stretch th NA to?
BrianQ: Let me give you the formula first
BrianQ: NA = n * sin (cone half angle)
BrianQ: where n is refractive index of the medium
BrianQ: Now my objective gives an NA = 1.4
doos: so a ri of about 1.6
BrianQ: and that is about as close to the theoretical limit as you can purchase
doos: n = 1.4 in that case
BrianQ: The oil has index of refraction n=1.5
doos: half angle of 90
\\Frank\: why not use higher RI liquids?
BrianQ: actually 1.515 to be specific (you guys seem to like 3 decimal places)
doos: toxic probably
BrianQ: yes toxic
doos: heh

doos: but having the objective outside the liquid would have no effect?
BrianQ: so... calculating the cone halfangle from the formula: cone halfangle = arcsin (NA/n)
BrianQ: I get a cone of light 67.53, which I am sure must be about the limit that can be done and still give myself 0.2 mm of space between lens and object
BrianQ: 67.53 degrees
BrianQ: Outside the liquid, you get an image, just not as sharp
doos: ty
BrianQ: I didn't know anything about microscopy once upon a time, so I did look to see what i could see...
doos: you are a pretty good teach, should do that for a living
BrianQ: The difference was amazing
BrianQ: heh
\\Frank\: sounds messy to me
BrianQ: Here is an interesting thing.... of course the objective begins its position not looking at anything, out in the air
BrianQ: And so you see something like a white television screen of a certain brightness
BrianQ: Moving the objective toward the specimen, eventually it comes into contact with the oil and what do you think happens?
doos: you get blinded
BrianQ: You still don't have what you are looking at in place yet, so you still see a white screen except (what?)..
\\Frank\: it's a much clearer white screen
BrianQ: actually Doos is pretty close
BrianQ: it becomes much brighter
BrianQ: MUCH BRIGHTER
\\Frank\: it gets brighter?
doos: yes higher NA = more light
BrianQ: Yes, because it is grabbing more light.... the higher NA
\\Frank\: of course
BrianQ: Now recall you have to position this close, so when the objective is out of the oil, you spin the know to position it
BrianQ: rather fast, until you see the screen really brighten up
BrianQ: and then you slow, slow down to position what you want
BrianQ: interesting, eh?
Crystal2: you spin the "know"?
doos: heh .. what is the know?
BrianQ: the knob, sorry
Crystal2: heh, like minds
doos: oh ok
DragonStek: LOL GOOD IT NOT ONLY ME
Crystal2: ok thanks
BrianQ: :)
doos: good stuff
Crystal2: yes
doos: but troubling as well

DragonStek: yes THANKS Brian
BrianQ: ok, now... I have had students spin the knob and crash the objective never seeing the brightness kick in
BrianQ: What did they do wrong?
doos: too low magnification
Crystal2: turned it to far too fast?
DragonStek: didnt take the lens cover off lol
Crystal2: lol
BrianQ: They put the slide in upside down, so the oil faced away from the objective
doos: doesnt it run out then?
\\Frank\: is the oil just a film then...no immersion cells etc?
BrianQ: actually I mount my slides vertically, not on a horizontal table... so I use high-viscosity oil
doos: ah sirop
BrianQ: but it slowly drips, drips, drips off the slide
\\Frank\: yuch
BrianQ: yep, immersion oil is yucky, yucky
BrianQ: I just put some wipes down to catch the drips
doos: or a sandwitch
Crystal2: lol
BrianQ: it is a thick film, by the way, Frank
\\Frank\: or a student
DragonStek: lol ewww
DragonStek: failing student for extra credit
doos: dont plant ideas in his heas
doos: head*
BrianQ: Well guys gotta go :(
Crystal2: thanks Brian!
doos: ok Brian, thanks a lot!
BrianQ: next time, how NA relates to resolution.
\\Frank\: me too...Thanks Brian good chat again :)
DragonStek: hehe night brian thanks again
BrianQ: Hope you'll log and send to Barbra, Doos
BrianQ: ciao ciao
doos: I'm off as well .. will do Brian
Crystal2: bye
Sep 07 23:03:10 * BrianQ has quit ("Java user signed off")