Under - stand magnifiers: what's going on below the lens

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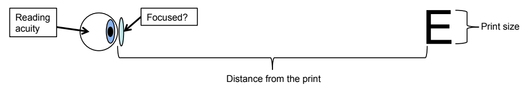
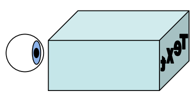
Predicting what patients can read

- What do you need to know?
  - Patient's reading acuity
  - Size of the print
  - Distance from the print
  - Is the print in focus?
    - Via accommodation or an add

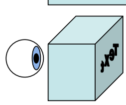


Predicting if a patient can read text



A patient is able to read 2 M print at 25 cm. Will the patient be able to read this text that is 3.2 M in a display case that is 32 cm deep?

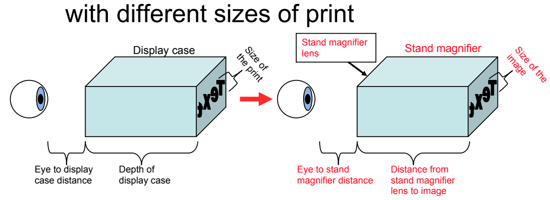
A patient is able to read 1.25 M print at 20 cm. Will the patient be able to read this text that is 2.5 M in a display case that is 50 cm deep?



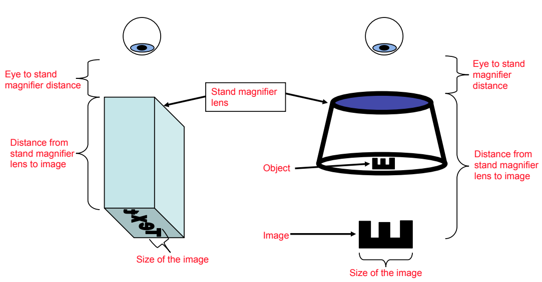
A patient is able to read 4 M print at 32 cm. Will the patient be able to read this text that is 2.5 M in a display case that is 25 cm deep?

Welcome to the world of stand magnifiers

- Stand magnifiers are just like display cases that are of different depths and with different sizes of print



Stand magnifier



Basics of stand magnifiers

- Object is NOT at the focal point of the lens
  - Object is always closer than the focal length of the lens
  - As a result, the image is virtual and located at a finite distance rather than optical infinity
- Image is enlarged
  - But is farther away than the original object

What do you need to know about a stand magnifier?

- Image location
  - Distance below the lens
- Image size
  - Or more accurately, image enlargement

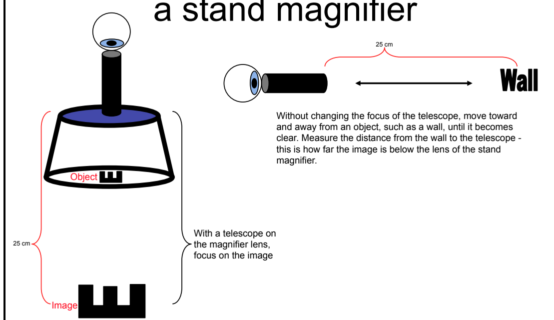
What do you need to know about the patient?

- Reading acuity
  - Not letter chart acuity
  - Not distance acuity (unless you have a distance reading chart)
  - Smallest print easily read when in reasonably good focus
- Distance from patient to stand magnifier lens

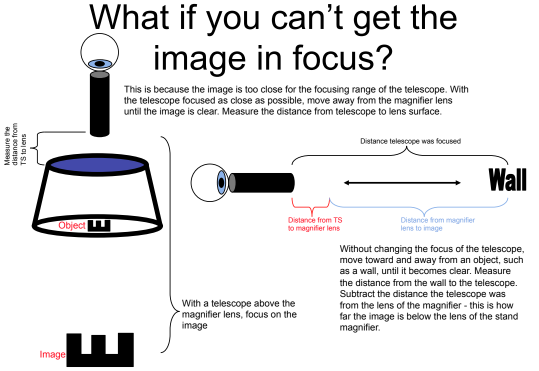
How do you measure image location of a stand mag?

- Most manufacturers don't supply this information
  - Eschenbach provides the information in a round about way
    - On the magnifier is the distance (in mm) that the patient needs to be above the magnifier in order to be 400 mm (40 cm) away from the image

Measuring image distance of a stand magnifier



What if you can't get the image in focus?



Calculating image enlargement

- Can't directly measure the image size clinically
- "Easiest" clinical method uses measurements and calculations to arrive at the image enlargement
  - Awkward, a bit convoluted but reasonably accurate

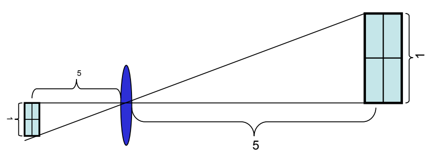
Calculating image enlargement

- Image enlargement = entering vergence/exiting vergence (U/V)
  - Or image distance/object distance (v/u)
    - Problems with this ratio
- Measure the equivalent power (P_e) of the stand magnifier lens
  - Not front or back vertex and not the power the manufacturer states on the magnifier

Calculating image enlargement (cont.)

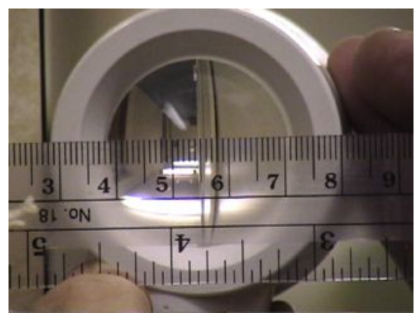
- Use the equation:
  - Exiting vergence (V) = entering vergence (U) + equivalent power of the lens (P_e)
    - Or $V = U + P_e$
    - Solve for U
      - We know V by taking the inverse of the image distance (v)
- Now that you know U and V
  - The ratio of U/V is the image enlargement
    - Or lateral magnification or enlargement ratio (ER)

Measuring equivalent power

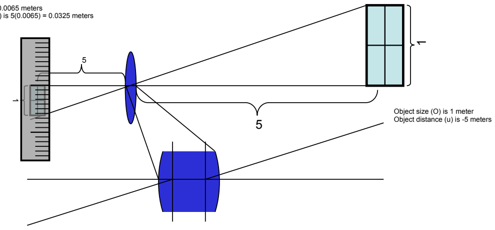


Use a light, window, doorway, something that is well lit. Measure how big the object is and measure a distance from the object that is a multiple of its size (makes the math more straight-forward). If the window is 3 feet across, measure 12, 15, 18, etc. feet from the window. This will give a ratio of 1 to 4, 5, 6 etc. Next find a clear ruler with metric markings. Place a bit of Scotch magic tape (not the clear stuff) onto the scale of the ruler. Holding the magnifier at the measured distance, move the ruler back and forth from the magnifier until the window (or whatever object you've chosen) makes a clear image on the tape/ruler. While the image is in focus, measure how big it is. Multiply this by the ratio (4, 5, 6, etc) to arrive at the equivalent power focal length. The inverse of this is the equivalent power.

Measuring equivalent power



Measuring equivalent power



In this example, the window measures 6.5 mm in height. Since the ratio of height to distance must be maintained on the image side of the lens, the focal length must be 5 x 6.5 mm = 32.5 mm (3.25 cm). The inverse of 3.25 cm is 30.77 diopters which is the equivalent power.

More accurate calculation

To be more precise we should take into account the fact that the object is not at optical infinity and, therefore, the image is not located exactly at the focal point of the lens. To do this we need to use some formulas. First, using the lateral magnification formula we can derive this relationship:

$$\frac{v}{u} = \frac{I}{O}$$
$$v = u\left(\frac{I}{O}\right)$$

Because P = V – U = 1/v – 1/u we can substitute and get:

$$P = \frac{1}{u\left(\frac{I}{O}\right)} - \frac{1}{u} = \left(\frac{1}{u}\right)\left(\frac{O}{I}\right) - \frac{1}{u}$$

Using that last formula for our example: the object size is 1 meter, the image size is -6.5 mm (because it's on the opposite side of the optic axis it's a minus size) and the object distance is -5 meters.
Therefore, P = (1/-5 m)(1 m/-0.0065 m) – (1/-5 m) = (-0.2 D)(-153.85) – (-0.2 D) = (30.77 D) – (-0.2 D) = 30.97 D

Bottom line, you end up adding back in the vergence (subtracting a minus vergence) of the object to correct for the fact that it's not at optical infinity. The longer the object distance the less you have to add back in. Clinically, adding back in 0.2 D (as in this example) is not going to make much difference.

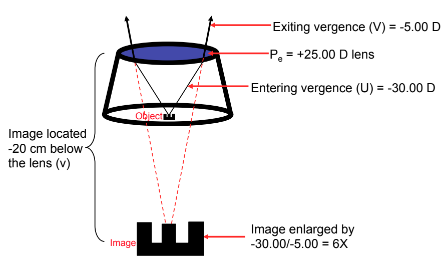
Back to calculating image enlargement

- Use the equations:
  - $V = U + P_e$
  - $V = 1/v$
    - v = image distance in meters
    - It's a negative distance so it's negative vergence
  - Since $V = U + P_e$ then $U = V - P_e$
  - And lastly, image enlargement = the ratio of incoming to outgoing vergence or U/V
    - Also known as lateral magnification or enlargement ratio (ER)

Example of calculating image enlargement

- Example
  - Image distance is 20 cm below the lens
    - Actually -20 cm below the lens
    - The exiting vergence V = 1/v = 1/-0.2 meters = -5.00 D
  - Our measurements find that the equivalent power of the lens is = +25.00 D
  - Entering vergence U = -5.00 D - 25.00 D = -30.00 D
  - Image size = -30.00/-5.00 = 6X
  - So the image of anything that the magnifier is placed on (text, skin, photographs, etc.) will be 6 times larger and located 20 cm below the lens

Graphical representation of image enlargement example



Now that you can measure the image location and figure out the image enlargement…

So what?!

Prescribing stand magnifiers

- Knowing image location and enlargement helps you accurately and confidently prescribe stand magnifiers
- Here's how…

Table of stand magnifiers

Magnifier	Rated mag	P_e	v (cm)	ER
COIL 6329	14.7X	51.7	15.3	8.9
COIL 6319	12X	39.5	25.9	11.2
COIL 6309	10.1X	35.4	30.4	11.8
COIL 5210	10X	30.7	25.0	8.7
COIL 6299	12X	30.2	29.4	9.9
COIL 5228	8X	23.7	67.5	17.0
COIL 5226	6X	23.7	41.5	10.8

Prescribing a stand magnifier

Mag	v (cm)	ER
COIL 6329	15.3	8.9
COIL 6319	25.9	11.2
COIL 6309	30.4	11.8
COIL 5210	25.0	8.7
COIL 6299	29.4	9.9
COIL 5228	67.5	17.0
COIL 5226	41.5	10.8

Example: Your patient is able to read 4 M print with good efficiency at 20 cm with a +5.00 add. At what distance (assuming good focus) would the patient be able to read our goal of 1 M print?

5 cm, because 0.2/4 M = 0.05/1 M.

So the patient has revealed that the angle made by 4 M print at 20 cm (which is the same as the angle made by 1 M print at 5 cm) is the smallest angle that still allows he/she to read efficiently. We just need to choose a stand mag that creates that same angle when 1 M print is under it.

Prescribing a stand magnifier; distance from mag to patient

Mag	v (cm)	ER
COIL 6329	15.3	8.9
COIL 6319	25.9	11.2
COIL 6309	30.4	11.8
COIL 5210	25.0	8.7
COIL 6299	29.4	9.9
COIL 5228	67.5	17.0
COIL 5226	41.5	10.8

Example continued: Remember that the angle created by print will depend on how far away the print is. In the case of a stand magnifier, you need to know where the image is (we now know how to measure that) but you also need to know the distance from the patient to the magnifier. For this I recommend that you use your clinical wisdom and make a guess. Most patients will place themselves about 10 cm above the magnifier. Some will get closer, others will be much farther away. Let's assume our example patient is 10 cm above the magnifier. Knowing that, which magnifier on the left will do the job?

Prescribing a stand magnifier; choosing a magnifier

Mag	v (cm)	ER
COIL 6329	15	9
COIL 6319	26	11
COIL 6309	30	12
COIL 5210	25	9
COIL 6299	30	10
COIL 5228	68	17
COIL 5226	42	11

Example continued: For ease of math (if you want to estimate mentally), I've taken the liberty of rounding all the values for the magnifiers.

Let's work through a couple of magnifiers to see what it will do given that the patient is 10 cm above the magnifier.

COIL 6329: the image is 15 cm below the lens, the patient is 10 cm above the lens so the patient is 25 cm away from the image. The image has been enlarged by 9 times. So, the patient is staring at 9 M print (1 M print enlarged by a factor of 9) that is 25 cm away. Does this create a suitable angle? Well, 0.25/9 M = 0.027/1 M. It's a huge angle, probably overkill. It's an angle equivalent to when 1 M print is 2.7 cm away. We'd like the magnifier to produce an angle that is similar to when 1 M print is 5 cm away (also known as the EVD).

Prescribing a stand magnifier; choosing another magnifier

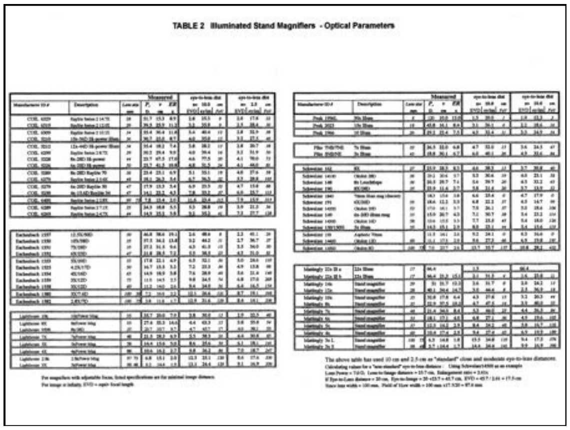
Mag	v (cm)	ER
COIL 6329	15	9
COIL 6319	26	11
COIL 6309	30	12
COIL 5210	25	9
COIL 6299	30	10
COIL 5228	68	17
COIL 5226	42	11

Example continued: So what about the COIL 6299: the image is 30 cm below the lens, the patient is 10 cm above the lens so the patient is 40 cm away from the image. The image has been enlarged by 10 times. So, the patient is staring at 10 M print (1 M print enlarged by a factor of 10) that is 40 cm away. Does this create a suitable angle? Well, 0.4/10 M = 0.04/1 M. It's a angle slightly larger than our desired angle, which is probably okay. It's an angle equivalent to when 1 M print is 4 cm away. We'd like the magnifier to produce an angle that is similar to when 1 M print is 5 cm away.

Now that we think the angle is relatively good, the next question is: Is the image in reasonable focus for the patient? This patient came in with a +5.00 add. In our scenario above, that would be much too strong of an add. A more appropriate add would be a +2.50.

Let your fingers do the walking: the yellow pages

- The "yellow" pages contain information on many, but not all, stand magnifiers
  - Equivalent power
  - Image distance
  - Image enlargement
  - EVD calculations

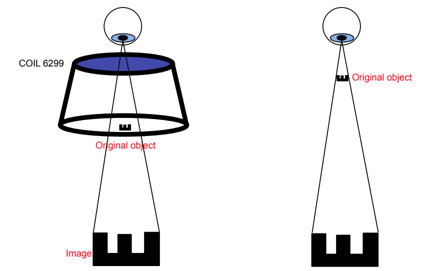


Manufacturer ID #	Description	Lens size mm		Measured P_e D.	Measured v cm	Measured ER x	eye-to-lens dist z= 10.0 cm EVD	ey/im	FoV	eye-to-lens dist z= 2.5 cm EVD	ey/im	FoV
COIL 6329	Raylite Series 2 14.7X	28		51.7	15.3	8.9	2.8	25.3	8	2.0	17.8	22
COIL 6319	Raylite Series 2 12.0X	29		39.5	25.9	11.2	3.2	35.9	9	2.5	28.4	30
COIL 6309	Raylite Series 2 10.1X	34		35.4	30.4	11.8	3.4	40.4	12	2.8	32.9	38
COIL 5210	10x-36D Hi-power illum	36		30.7	25.0	8.7	4.0	35.0	15	3.2	27.5	46
COIL 5212	12x-44D Hi-power Illum	34		35.4	18.2	7.4	3.8	28.2	13	2.8	20.7	38
COIL 6299	Raylite Series 2 8.7X	39		30.2	29.4	9.9	4.0	39.4	16	3.2	31.9	50
COIL 5228	8x-28D Hi-power	44		23.7	67.5	17.0	4.6	77.5	20	4.1	70.0	73
COIL 5226	6x-20D Hi-power	50		23.7	41.5	10.8	4.8	51.5	24	4.1	44.0	81
COIL 5289	8x-28D Raylite 70	36		23.4	25.1	6.9	5.1	35.1	18	4.0	27.6	58
COIL 6279	Raylite Series 2 5.4X	48		18.1	26.3	5.4	6.7	36.3	32	5.3	28.8	103
COIL 5279	6x-20D Raylite 50	47		17.9	13.3	3.4	6.9	23.3	32	4.7	15.8	88
COIL 5259	4x-15.6D Raylite 34	47		14.1	23.2	4.3	7.8	33.2	37	6.0	25.7	113
COIL 6400	Raylite Series 2 2.8X	99	73	7.8	13.4	2.0	11.6	23.4	115	7.9	15.9	313
COIL 6289	Raylite Series 2 7.1X	35		24.3	18.8	5.5	5.3	28.8	19	3.9	21.3	56
COIL 6269	Raylite Series 2 4.7X	44		14.9	25.2	3.8	9.2	35.2	41	7.3	27.7	128

Patient can efficiently read 3.2 M print at 12.5 cm with a +8.00 D add. Our goal is to have the patient read 1 M print with the same efficiency. 0.125/3.2 M = 0.04/1 M. So, when 1 M print is 4 cm away it makes the same angle as 3.2 M print when it's 12.5 cm away. We want the stand magnifier to produce an angle that is the same or larger than the angle produced by 1 M print when it is 4 cm away. In other words, the stand magnifier should have an Equivalent Viewing Distance (EVD) of 4 cm (or smaller). EVD is the distance the original object would need to be to produce the same angle as the device.

Assume the patient will be 10 cm above the magnifier (z = 10 cm) and look down the EVD column for an EVD of 4 cm. The COIL 5210, 5212 and 6299 all fit the bill. Look at the next column to the right to see how far the image is from the patient. It's 35 cm, 28.2 cm and 39.4 cm. The patient has a +2.50 add so the 6299 would be in the best focus.

Equivalent viewing distance EVD



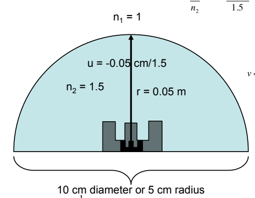
Dome and ruler magnifiers - the other stand mag

- Dome (aka; hemisphere magnifier) and ruler magnifiers behave quite differently

Dome and ruler magnifiers - the other stand mag

$$P = \frac{n_2 - n_1}{r} = \frac{1.5 - 1}{0.05} = \frac{0.5}{0.05} = +10.00D$$

$$V = U + P = \frac{1}{\frac{r}{n_2}} + P = \frac{1}{\frac{-0.05}{1.5}} + 10 = \frac{1.5}{-0.05} + 10 = -30 + 10 = -20.00D$$



$$v = \frac{1}{-20} = -0.05m$$

$$ER = \frac{U}{V} = \frac{-30}{-20} = 1.5$$

$$ER = \frac{U}{V} = \frac{\frac{1}{\frac{-r}{n_2}}}{\frac{1}{\frac{-r}{n_2}} + \frac{n_2 - n_1}{r}} = \frac{-\frac{n_2}{r}}{\frac{n_2 - n_1}{r} - \frac{n_2}{r}} = \frac{-\frac{n_2}{r}}{\frac{n_2 - n_1 - n_2}{r}} = \frac{-n_2}{-n_1} = \frac{n_2}{n_1}$$

Dome and ruler magnifiers - the other stand mag

- From the previous slide the following may not have been obvious:
  - The image of a dome or ruler magnifier is in the same location as the object
  - The image is larger than the object by the index of refraction of the material
    - All dome magnifiers (hemispheres) magnify by the index of refraction of their material
      - The curvature has no bearing on the magnification

Dome and ruler magnifiers - the other stand mag

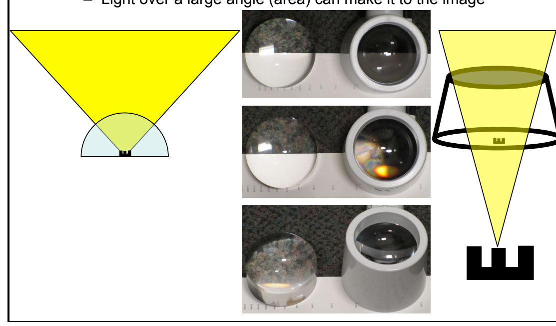
- Since dome and ruler magnifiers are nearly always made of plastic (n = 1.49) or glass (n = 1.523) the magnification is about 1.5 times for all dome magnifiers
  - Exception
    - If the dome magnifier is not a true hemisphere
      - Lens is held off the page or has a concave surface
      - The image will be a bit further away than the object and will be a bit larger than the index of refraction

Prescribing dome & ruler magnifiers

- Remember that the patient will only see an image that is 1.5 times larger
  - On a reading chart this will only allow the patient to read about 2 lines smaller
- Focus with a dome or ruler magnifier is the same with or without the magnifier
  - Young patients can accommodate the same amount and presbyopes can continue to use the same add

Dome & ruler magnifiers

- Good for gathering available light
  - Light over a large angle (area) can make it to the image



Summary

- Stand magnifiers are one of the most technically challenging magnifiers to prescribe well
  - Understanding the optics allows for improved prescribing and better troubleshooting
- If optics are not your thing, then consider portable CCTV's or magnifying apps such as VisionAssist or EyeSight
  - These are the "stand magnifiers" of today