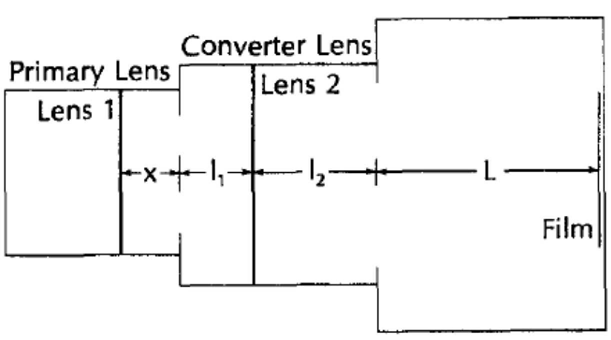
Modern Optics, Prof. Ruiz, UNCA **doctorphys.com**
Chapter H Solutions. Camera Lenses

HW H1. Close-Up Photography.

	
Courtesy Andrew Magill via Flickr and Wikipedia	Courtesy Wikipedia: Fg2

You have there close-up lens attachments $+1D$, $+2D$**, and** $+4D$ along with three extension tubes of lengths 12 mm, 20 mm, and 36 mm. You have an SLR camera with its standard 50 mm focal length lens. The most you can turn the focusing mechanism to focus close up gets you a maximum lens-to-film distance of $s_i = 60\text{ mm}$, which allows you to bring a subject as close as $s_o = 300\text{ mm}$ for a magnification of $M = -\frac{s_i}{s_o} = -\frac{60}{300} = -\frac{1}{5} = -0.2$. Even though you know that the optical quality due to aberrations will not be ideal, you thread on all three close-up attachments to the front of your 50 mm lens and use all three extension tubes between the lens and the camera body. Calculate the closest you can bring an object now for photographing and determine the magnification for your image on the photo. While the lens projects an inverted and left-right flipped image, you simply turn the photo around and all looks good. Report your answers to two significant figures. Comment on your magnification comparing it to life size.

HW H2. The Teleconverter I: Formula for Diverging Insert.



A primary camera lens with focal length $f_{\text{camera}} = f_1$ can be converted into a telephoto lens by inserting a diverging lens, the converter secondary lens with focal length f_2, between the primary lens and camera body. Start with the back focal length formula

$$f_b = \frac{f_2(f_1 - d)}{f_1 + f_2 - d}$$ and derive the following formula

for the focal length of the diverging lens:

$$f_2 = -\frac{(L+l_2)(L-l_1)}{(l_1+l_2)}.$$

Hints: For telephoto lens analysis all subject distances are very far away. In your analysis you should justify why $x + L = f_1$.

HW H3. The Teleconverter II: Multiplication Factor. The figure of HW H2 applies here. The multiplication factor α is defined as the ratio of the effective focal length for the system compared to f_{camera}. As an example, if with your inserted teleconverter your new focal length for the lens system is now $f = 2f_{\text{camera}}$, then you have $\alpha = 2$ we say you have a 2x converter.

Find the simplest form for the multiplication factor α in terms of the following parameters in the schematic: l_1, l_2, and L. The function $\alpha = \alpha(l_1, l_2, L)$ will not be a function of x.

HW H4. Depth of Field. In the previous chapter we found that the depth of field can be approximated as $DoF = \frac{2s_o^2 c}{fd}$. Explain in words why each parameter affects the DoF the way it does. **Here is a sample answer if the question had been for the fundamental frequency on a string:** $f = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$, where T is the string tension, L the string length, and μ the string density (mass per unit string length).

1) Length L. Formula says increase L => decrease f. If the string is longer, the wavelength will be longer. Longer wavelengths mean lower pitches. Compare the long strings of the contrabass with its corresponding low pitches to the shorter strings of a violin which plays higher notes.

2) Tension T. Formula says increase T => increase f. If you increase the tension of a string, the tighter string will vibrate faster as the waves travel back and forth on the string more quickly. If you turn the tuning peg for a guitar string to tighten it, the pitch will raise.

3) Density μ. Formula says increase μ => decrease f. If you increase the density for a given string length you increase the mass, which makes the vibrations more sluggish due to the increased inertia, i.e., lower pitch. On a piano the thicker more massive strings are in the bass region. The high-pitch strings are thin, i.e., less density μ.

The above three laws are Mersenne's Laws (1637).
A Mersenne Prime: $M_n = 2^n - 1$ is prime where n is a positive integer.
Solutions for the first four Mersenne Primes: n = 2, 3, 5, 7 (known in antiquity)
n=13 (5^{th} discovered in 1456), n=17 (6^{th},1588), n=19 (7^{th},1588), n=31 (8^{th},1772)
n=61 (9^{th},1883), n=89 (10^{th},1911), n=107 (11^{th},1914), n=127 (12^{th},1876), n=521 (13^{th},1952)
The 51^{st} Mersenne Prime (latest) n=82,589,933 discovered in 2018
The 51^{st} Mersenne Prime has 24,862,048 digits. Primes are relevant in encryption.