1. A telescope with a 4-m diameter \( f/3 \) primary mirror is used in the standard Cassegrain configuration to produce an \( f/8 \) focal plane located 1.5-m behind the vertex of the primary. (The vertex of the primary is the middle of the “dish”, on the front reflecting surface.)

a) Measured along the telescope axis from the primary vertex, where is the secondary located?  
b) What is the focal length of the secondary?  
c) Measured from the primary vertex, where is the exit pupil formed by the secondary?  
d) What is the diameter of the exit pupil?  
e) If a Cassegrain infrared instrument uses a field lens located 0.5-m behind the telescope focal plane, what focal length must the field lens have to reimage the exit pupil exactly onto a 1-cm diameter cold stop in the dewar?

Be very careful with the signs (±) of distances and focal lengths!

2. What is the kTC noise for a detector/amplifier combination operated at 100K, with a net capacitance of 1 pF? Suppose the resistance of this combination is \( 10^{14} \) ohms. What is the RC time constant? Suppose the signal from the detector is read out holding the detector impedance fixed (no resetting) and for an integration time of 10 seconds, then what is the amplitude of the kTC noise that appears on the signal?

3. (XC for 418) Consider the signal to noise achievable through two means of multiple sampling on the output of an integrating amplifier. In the first place, assume that 8 samples are taken at the beginning and eight at the end of the integrating ramp, each set is averaged, and the slope of the ramp is computed from the difference of these averages divided by the time interval between them. Compute the signal to noise that would be achieved assuming that each readout of the amplifier has an rms uncertainty of \( \sigma \). A second approach is to take the 16 samples distributed uniformly over the integration ramp and to determine the slope by a least squares fit to them. Either by analysis or just plain logic, do you believe this second approach will yield larger, smaller, or the same uncertainties in the slope compared with the first one? Can you think of any other reasons besides signal to noise to prefer one readout scheme over the other?