A. 1. Angle between sources barely resolved through a circular opening:

\[ \theta = \tan^{-1} \left( \frac{\lambda}{2s} \right) = 1.22\times10^{-5} \text{rad} \]

Now from \( \theta \), find \( s \). Technically this is an isosceles triangle. However, because it is so long and thin, you can take a shortcut. The base angles are very close to 90°, so it makes only a very small error if you treat it like a right triangle.

\[ \tan \theta = \frac{\text{opp}}{\text{adj}} = \frac{s}{29000 \text{ m}} \]

\[ s = 29000 \tan(1.769 \times 10^{-5} \text{rad}) = 0.513 \text{ m} \]

(Be sure calculator is in radian mode.)

2. With \( n \) higher on one side of the film and lower on the other, there is destructive interference when

\[ 2nt = (m + \frac{1}{2})\lambda \]

For the minimum thickness, \( m = 0 \).

\[ 2 \times (1.30) t = \frac{1}{2} (500 \text{ nm}) \]

\[ t = \frac{500}{2(1.3)} = 96.2 \text{ nm} \]

B. (a) Grating equation: \( m \lambda = d \sin \theta \)

(3) \( (5.00 \times 10^{-7} \text{ m}) = d \sin 32^\circ \)

\[ d = \frac{1.5 \times 10^{-6}}{\sin 32^\circ} = 2.83 \times 10^{-6} \text{ m} = 2.83 \times 10^{-4} \text{ cm} \]

Slits per cm = \( 1 / (\text{cm per slit}) = 1 / (2.83 \times 10^{-4}) = 3.53 \times 10^3 \) ans.

(b) From the grating equation: \( \sin \theta = m \lambda / d \)

Try larger and larger values of \( m \) until \( \sin \theta \) passes 1. The sine function can't ever be more than 1, so that shows you the largest possible \( m \).
\[
\sin \theta = \frac{(5)(5.00 \times 10^{-7} \text{ m})}{(2.83 \times 10^{-6} \text{ m})} = 0.883 \quad \text{ok}
\]
\[
\sin \theta = \frac{(6)(5.00 \times 10^{-7} \text{ m})}{(2.83 \times 10^{-6} \text{ m})} = 1.06 \quad \text{nope.}
\]

ans: 5th order

C. 1. Oil’s n must be less than water’s. (and more than air’s.) If both rays reflect off a higher n, both undergo the same 180° phase shift. That way, interference is constructive when the thickness is nearly zero.

2.

\[
\tan \theta = \frac{A}{1.2 \text{ m}}
\]

Bright fringes are at \(d \sin \theta = m \lambda\), so \(\sin \theta = \frac{m \lambda}{d}\)

Because \(\theta\) is small, \(\tan \theta\) approximately equals \(\sin \theta\).

\[
\frac{A}{1.2 \text{ m}} = \frac{m \lambda}{d}
\]

\[m = 1 \text{ because first order}\]

\[A = (1.2 \text{ m}) = \frac{(1)(5.461 \times 10^{-7} \text{ m})}{0.0025 \text{ m}} = 0.00262 \text{ m}\]

D. 1. Destructive. The reason for coating a lens is to make it nonreflective. That is accomplished by having the two reflected rays destroy each other.

2. One ray reflects off a higher n (the soap film), the other off a lower n (the air under the film). This gives one ray a 180° phase shift and the other ray none. So, with a path difference of about zero, they are 180° out of phase.
3. Single slit maxima are where
   \[ a \sin \theta = (m + \frac{1}{2}) \lambda \]
   \( a = \text{slit width} = .8 \text{ mm} \)
   \( m = 2 \) because second order

   Because \( \theta \) is very small, \( \sin \theta \approx \tan \theta = \frac{1}{4} \frac{mm}{800 \text{ mm}} = .00175 \)
   
   So, \( (.0008 \text{ m})(.00175) = (2 + \frac{1}{2}) \lambda \)

   \[ \lambda = \frac{(0.0008)(0.00175)}{2.5} = 5.60 \times 10^{-7} \text{ m} = 560 \text{ nm} \]

E. 1. i. \( a \) is the width of the slit.
   ii. \( d \) is its reciprocal. (cm per line = 1 / lines per cm.)

2. Destructively. The path difference of \( 2\lambda \) would normally give constructive interference, but ray A has a 180\(^\circ\) phase shift when it is reflected, while B does not. Therefore, the waves are out of phase and cancel.

3. Constructive interference if path difference = \( m\lambda \).
   First order means \( m = 1 \).
   
   \[ (1)\lambda = 16.12 - 14 = 2.12 \text{ cm} \]
\[ F_A = 2 F_B \quad \text{Each } F \text{ is given by } k \frac{q_1 q_2}{r^2} \]

\[
\frac{k q_1 q_2}{r_A^2} = 2 \left[ k \frac{q_1 q_2}{(3.3 \times 10^{-9} m)^2} \right]
\]

\[
\frac{2}{r_A^2} = \frac{(2)(3)}{(3.3 \times 10^{-9})^2}
\]

\[
(3.3 \times 10^{-9})^2 = r_A^2
\]

\[
\frac{3.3 \times 10^{-9}}{\sqrt{3}} = r_A
\]

\[
1.91 \times 10^{-9} m \quad \text{ANS}
\]