Student Name: _____
OPTI 201R
Homework 4--Grading Sheet _____ **TOTAL POINTS** (out of 100 points)

4.2 What are the glass numbers for:
a. N-BK7
b. N-SF11
c. N-LASF9

Use the Schott glass data sheet. (Round up the n_d values to the 3rd decimal place; round up the $V_d^{\#}$ values to the first decimal place):

(a) N-BK7:	$n_d = 1.51680$	$V_d^{\#} = 64.17$	Glass number = 517642
(b) N-SF11	$n_d = 1.78472$	$V_d^{\#} = 25.68$	Glass number = 785257
(c) N-LASF9	$n_d = 1.85025$	$V_d^{\#} = 32.17$	Glass number = 850322

_____ (3) Correct answer for N-BK7
_____ (3) Correct answer for N-SF11
_____ (3) Correct answer for N-LASF9

4.7 Calculate the angle of deviation for *F, d* and *C* light for a prism made of SF4 (755276) glass with a 22° apex angle and 30° angle of incidence.

SF4 is listed on page 89 in the Schott data sheets. From that data sheet:
$n_F = 1.77468$ $n_d = 1.75520$ $n_C = 1.74730$
$A = +22°$ $I_1 = +30°$

We are <u>not</u> assuming this is a thin prism, so use the exact solution from equation (4.13):

$$\delta_p(\lambda) = A - I_1 + \sin^{-1}\left[\sin I_1 \cos A - (\sin A)\left[n(\lambda)^2 - \sin^2 I_1\right]^{1/2}\right]$$

$$\delta_{p,F}(\lambda) = 22° - 30° + \sin^{-1}\left[\sin(30°)\cos(22°) - \sin(22°)\left[(1.77468)^2 - \sin^2(30°)\right]^{1/2}\right] = -18.04°$$

$$\delta_{p,d}(\lambda) = 22° - 30° + \sin^{-1}\left[\sin(30°)\cos(22°) - \sin(22°)\left[(1.75520)^2 - \sin^2(30°)\right]^{1/2}\right] = -17.59°$$

$$\delta_{p,C}(\lambda) = 22° - 30° + \sin^{-1}\left[\sin(30°)\cos(22°) - \sin(22°)\left[(1.74730)^2 - \sin^2(30°)\right]^{1/2}\right] = -17.42°$$

_____ (5) Correct approach using equation (4.13).
_____ (3) Correct answer for F-light: $\delta_{p,F} = -18.04°$
_____ (3) Correct answer for d-light.: $\delta_{p,d} = -17.59°$
_____ (3) Correct answer for C-light: $\delta_{p,C} = -17.42°$

4.11 A student has two glass rods. Rod *A* is # 300800 glass and rod *B* is # 900400 glass.

a. What is the ratio of velocities of light in glass (*A*) to glass (*B*)?
b. In which rod is the velocity of light slower, (*A*) or (*B*)?
c. Which is the crown glass?

(a) From the glass numbers: n_d(Rod A) = 1.300, $V^{\#}$ = 80.0 ; n_d(Rod B) = 1.900, $V^{\#}$ = 40.0

$$v_{(Rod\ A)} = \frac{c}{n_{d,(Rod\ A)}} \quad ; \quad v_{(Rod\ B)} = \frac{c}{n_{d,(Rod\ B)}}$$

$$so \quad \frac{v_{(Rod\ A)}}{v_{(Rod\ B)}} = \frac{n_{d,(Rod\ B)}}{n_{d,(Rod\ A)}} = \frac{1.900}{1.300} = 1.462$$

(b) The light will travel slowest in the material having the highest refractive index. Light will travel slowest in ***Rod B***.

(c) Crown glasses have Abbe numbers > 55 (high Abbe-number, low dispersion compared to Flint glasses). ***Rod A*** is the crown glass-type.

_____ (5) Correct answer for part (a): 1.462
_____ (5) Correct answer for part (b): Rod B
_____ (5) Correct answer for part (c): Rod A

4.16 What is the minimum refractive index that a right-angle prism must have to reflect light by 90° with TIR?

As shown in the figure, the angle of incidence at the front face of the prism is 90°. Therefore, the angle of incidence at the hypotenuse is 45°. For the prism to reflect light at this surface by TIR, set the angle of refraction = 90° and solve for the refractive index of the prism:

$$n_g \sin(I_{critical}) = n_g \sin 45° = (1)\sin 90° \quad ; \quad n_g = \left(\frac{1}{\sin 45°}\right) = 1.414$$

$$n_g \geq \frac{1}{\sin(I_{critical})} \geq 1.414 \quad so \quad \frac{1}{1.414} \geq \sin(I_{critical})$$

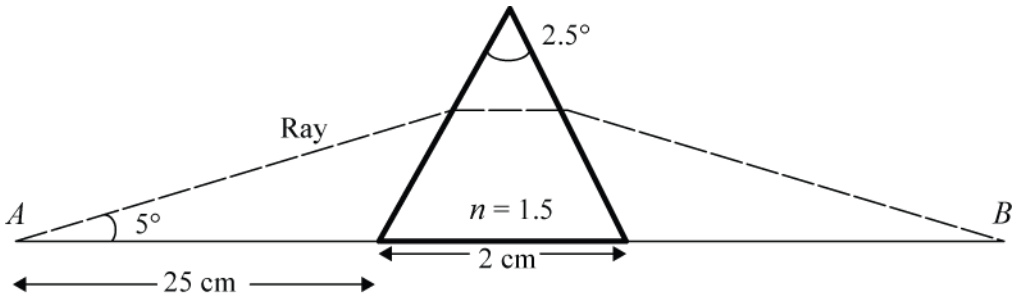
$$\therefore \sin(I_{critical}) \leq \frac{1}{1.414} \quad ; \quad \sin(I_{critical}) \leq .7072 \quad ; \quad \therefore I_{critical} \leq \sin^{-1}(.7072) = 45°$$

$$so\ I_{critical} \leq 45°\ as\ long\ as\ n_g \geq 1.414$$

In other words, as long as $n_g \geq 1.414$, the hypotenuse will support TIR. So this value for n_g does indeed represent a minimum value for the index.

_____ (5) Correct answer for the index: $n_g \geq 1.414$

4.17 For the drawing below using an isosceles glass prism (n = 1.5), the apex angle (2.5°) is such that the ray is parallel to the axis inside the prism. What is the optical path length for the ray? What is it along the axis?



OPL is defined as $\sum$(refractive index) x (physical path length) $= \sum_{i=1}^{m} n \cdot L$

$OPL_{Ray} = a + b + (1.5)c + |d + e = 2a + 2b + (1.5)c$ *due to symmetry*

$\cos 5° = \frac{a}{25cm}$; $a = 24.904cm$; $\sin 5° = \frac{s}{25cm}$; $s = 2.1788cm$

$\tan 6.25° = \frac{b}{s}$; $b = .2386cm$; $h = \sqrt{s^2 + b^2} = \sqrt{2.1788^2 + .2386^2} = 2.1918cm$

$\cos 88.75° = \frac{x}{h} = \frac{x}{2.1918cm}$; $x = .0478144cm$

$c = 2cm - 2x = 2cm - 2(.0478144cm)$; $c = 1.904371cm$

so finally : $OPL_{Ray} = 2a + 2b + (1.5)c = 2(24.904cm) + 2(.2386cm) + 1.5(1.904371cm)$

$OPL_{Ray} = 53.14cm$

$OPL_{Axis} = 25cm + (1.5)2cm + 25cm = 53cm$ (*traveling in the prism*)

$OPL_{Axis} = 25cm + (1)2cm + 25cm = 52cm$ (*traveling along the axis in air*)

_____ (5) Correct answer for OPL along the Ray path: OPL_{Ray} = 53.14cm

_____ (5) Correct answer for OPL along the Axis: OPL_{Axis} = 53cm or 52cm
(I'll accept either answer…..problem wasn't clearly stated).

4.18 What are the Abbe numbers and glass numbers for the following materials used in eyeglass lenses (problem modified from the one in the book):

(a)	Polycarbonate	n_d=1.586	$V_d^{\#}$=30	Glass Number = 586300
(b)	CR-39	n_d=1.498	$V_d^{\#}$=59.3	Glass Number = 498593
(c)	Trivex	n_d=1.532	$V_d^{\#}$=43-45	Glass Number = 532430 - 532450

_____ (2) Correct answer for (a)
_____ (2) Correct answer for (b)
_____ (2) Correct answer for (c)

4.19 A crown (BaK4) thin prism with an apex angle of 15° is to be combined with a flint prism (SF12) so as to produce no net deviation for *d* light.

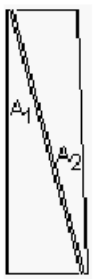
a. Find the apex angle for the contact flint prism.
b. Find the angular deviation for *C* light for this prism combination.

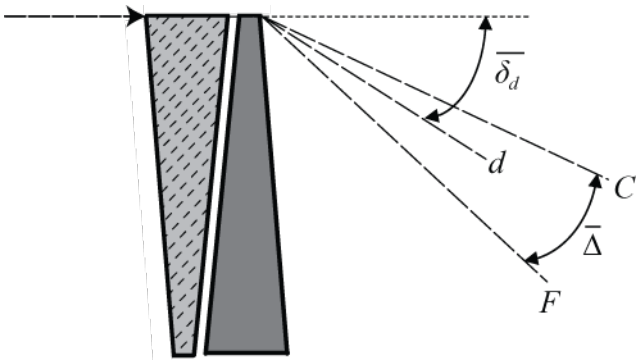
The problem states that this is a "thin" prism, so just use equation (4.28):
$\delta_{\min} = -A(n-1)$ *n is the index of the prism*
Also, as equation (A.3) states and as we learned in class, the total deviation for 2 thin prisms is simply the sum of the individual deviation angles:
$\delta_{d,TOTAL} = \delta_{1,d} + \delta_{2,d} = -A_1(n_{1,d}-1) - A_2(n_{2,d}-1) = 0$

(a) This problem is to find the apex angle A_2 for the second (flint) prism, with the condition that the combination of these 2 prisms produces no net deviation for d light. (The only issue with this problem is that BaK4 and SF12 are no longer in the Schott catalog. Ok, so, do what an engineer working in the real-world has to do—find another, reasonable solution. BaK4 has been replaced with N-BAK4, so use that value instead. For SF12, either go find n_d for SF12 (not too difficult using a web search) OR pick another type of flint glass.) Looking at the Schott catalog, I find values for N-SF10 and N-SF11:

n_d (N-BAK4) = 1.56883 ; n_d (SF12) = 1.64831 ; n_d (N-SF10) = 1.72828 ; n_d (N-SF11) = 1.78472
n_C (N-BAK4) = 1.56575 ; n_C (N-SF10) = 1.72091 ; n_C (N-SF11) = 1.77596

*****Note that, according to our sign conventions, A_1 is a positive angle, but A_2 is a negative angle.





► Using SF12:

$$\delta_{d,TOTAL} = \delta_{1,d} + \delta_{2,d} = -A_1(n_{1,d} - 1) - A_2(n_{2,d} - 1) = 0$$
$$= -15°(1.56883 - 1) - A_2(1.64831 - 1) = 0$$
$$so\ A_2 = \frac{-15°(1.56883 - 1)}{(1.64831 - 1)} = -13.16°$$

► Using N-SF10:

$$\delta_{d,TOTAL} = \delta_{1,d} + \delta_{2,d} = -A_1(n_{1,d} - 1) - A_2(n_{2,d} - 1) = 0$$
$$= -15°(1.56883 - 1) - A_2(1.72828 - 1) = 0$$
$$so\ A_2 = \frac{-15°(1.56883 - 1)}{(1.72828 - 1)} = -11.72°$$

► Using N-SF11:

$$\delta_{d,TOTAL} = \delta_{1,d} + \delta_{2,d} = -A_1(n_{1,d} - 1) - A_2(n_{2,d} - 1) = 0$$
$$= -15°(1.56883 - 1) - A_2(1.64831 - 1) = 0$$
$$so\ A_2 = \frac{-15°(1.56883 - 1)}{(1.64831 - 1)} = -10.87°$$

(b) To find the total angular deviation for C light for these prism combinations, use the values of refractive index for C light and solve for the total angular deviation (don't first set it =0!!):
(I was not able to find the value of nC for SF12, so I'll solve using either N-SF10 or N-SF11).

► Using N-SF10:

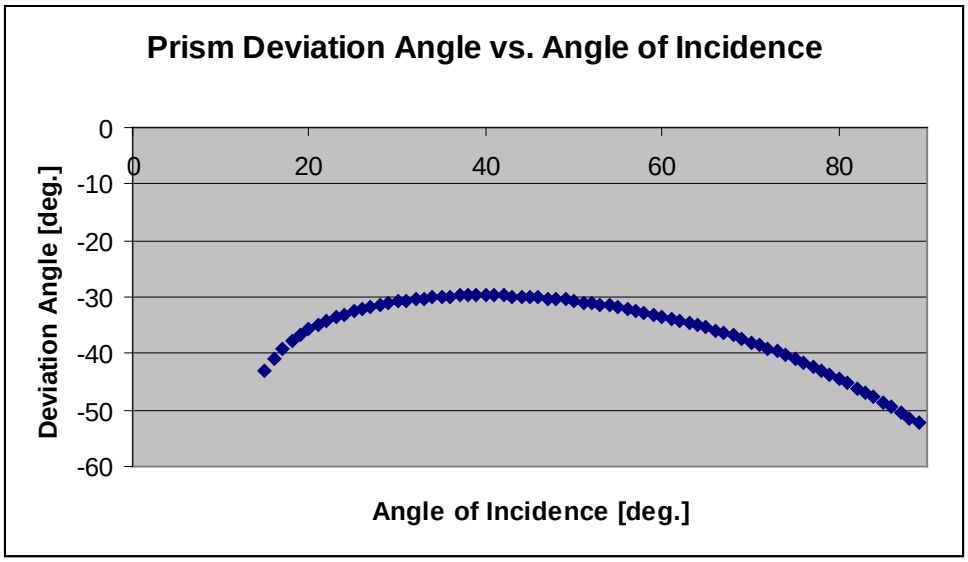
$$\delta_{C,TOTAL} = \delta_{1,C} + \delta_{2,C} = -A_1(n_{1,C} - 1) - A_2(n_{2,C} - 1)$$
$$= -15°(1.56575 - 1) - (-11.72°)(1.72091 - 1)$$
$$\delta_{C,TOTAL} = -.0372°$$

► Using N-SF11:

$$\delta_{C,TOTAL} = \delta_{1,C} + \delta_{2,C} = -A_1(n_{1,C} - 1) - A_2(n_{2,C} - 1)$$
$$= -15°(1.56575 - 1) - (-10.87)(1.77596 - 1)$$
$$\delta_{C,TOTAL} = -.0516°$$

_____	(5)	Correct approach for (a)	(setting the total angle of deviation for d-light =0)
_____	(3)	Correct answer for (a)	(based on using some type of <u>flint</u> glass).
_____	(5)	Correct approach for (b)	(using values for n_C and finding $\delta_{C,TOTAL}$)
_____	(3)	Correct answer for (b)	(based on using the same flint glass).

4.24 Plot the deviation angle (δ) versus incident angle (I_1) for a prism with an apex angle of 50°, made of N-BK7 glass, using *d* light. At what angle does the minimum deviation occur?



Minimum deviation occurs at an angle of incidence of about 20 degrees.

_____ (10) Correct plot.
_____ (5) Correct answer of ≈ 29°.

4.32 The index of refraction for a glass at three different wavelengths is shown is below:

λ (nm)	*n*
486.1	1.525
587.6	1.517
656.3	1.514

a. What is the Abbe number?

The Abbe number ($V^{\#}$) is: $V^{\#} = \dfrac{n_d - 1}{n_F - n_C} = \dfrac{1.517 - 1}{1.525 - 1.514} = 47.0$

b. What is the glass number?

The glass number is given by the first 3 digits of the value of n_d, followed by the first 3 digits of the Abbe #: 517470

_____ (5) Correct value for the Abbe number. (47.0)
_____ (5) Correct answer for the glass number. (517470)