```
atmref3
alpha =
         0.349065850398866
alpha_r =
         0.349063980913968
displ_0 =
          181985.117133101
displ_atm_mod =
          181984.058561991
dalpha_r =
      1.8694848983869e-006
effect_m =
          1.05857110992656
term2 =
     2.46734626918163e-032
K =
                  4.67e-006
dalpha_s =
     1.69974099402316e-006
effect_s_m =
         0.962455927481642
diary off
```

radians, from refraction comp. & NASA model

displacement, meters, from above model

radians

radians, from saastamoinen

displacement meters, from saastamoinen

```
% atmref3.m  13-feb-11
% model atmospheric refraction with layered atmosphere
% and NASA Glenn equations that convert altitude to pressure
% then use simon newcomb's formula to convert pressure
% to refractive index n^2 = 1 + 2*C*rho
% rho = pressure kg/m^3
% C = 0.00022667, constant from schut, PERS v. 35, 1969, p. 81
% do again nadir aligned vertically per sketch
% this one hardwired for H=500 km and 20 degree off-nadir view

C=0.00022667;
degrad=180/pi;
alpha=20/degrad;
x=0;
y=6871;
R=y;
B=-pi/2 - alpha;
H=500;
for i=1:5000
  %i
  v=[cos(B);sin(B)];
  m=v(2)/v(1);
  b=y - m*x;
  % intersect next layer
  R=R-0.1;
  H=H-0.1;
  AA=1+m^2;
  BB=2*m*b;
  CC=b^2 - R^2;
  x=(-BB + sqrt(BB^2 - 4*AA*CC))/(2*AA);
  y=m*x + b;
  % unit normal vector (pointing down)
  n=[-x;-y];
  n=n/norm(n);
  costh1=dot(n,v);
  th1=acos(costh1);
  rho1=atmdens(H*1000 + 50);
  rho2=atmdens(H*1000 - 50);
  n1=sqrt(1+2*C*rho1);
  n2=sqrt(1+2*C*rho2);
  th2=asin((n1/n2)*sin(th1));
  Bnorm=atan2(n(2),n(1));
  Bnew=Bnorm - th2;
  B=Bnew;
  end

alpha
alpha_r=atan(abs(x)/(6871-y))
% effect in meters on the ground
displ_0=500000*tan(alpha)
displ_atm_mod=500000*tan(alpha_r)
```

```
dalpha_r=alpha - alpha_r
effect_m=displ_0 - displ_atm_mod

% compare with saastamoinen
K=saasta1(500,0)
dalpha_s=K*tan(alpha)
alpha_s=alpha-dalpha_s;
displ_sas=500000*tan(alpha_s);
effect_s_m=displ_0 - displ_sas
```

$\alpha = 20^\circ$
$\alpha_r = 19.999893$
$d\alpha = \alpha - \alpha_r = 0.000107^\circ$

Saastamoinen: $d\alpha = 0.000097^\circ$ differ by ~10%

$B = -110^\circ = -1.919862\ldots$ Rad

$\hat{v} = \begin{bmatrix} -.34202 \\ -.93969 \end{bmatrix}$

$m = v_y / v_x = 2.74747\ldots$

$b = 6871$

$y = mx + b$

intersect with

$x^2 + y^2 = (6870.9)^2$

$x^2 + m^2x^2 + b^2 + 2mbx - 6870.9^2 = 0$

$A = 1 + m^2$

$B = 2mb$ different B than bearing!

$C = b^2 - 6870.9^2$

$x = \dfrac{-B + \sqrt{B^2 - 4AC}}{2A}$

$x = -0.036397\ldots$
$y = 6870.8999\ldots$
} intersection with circle

$\hat{n} = [+.036397, -6870.8999]$ / length

$\hat{n} = \begin{bmatrix} .0000052\ldots \\ -.9999999\ldots \end{bmatrix}$

$\cos\theta_1 = \hat{n} \cdot \hat{v}$

$\theta_1 = .34907\ldots$ Rad

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

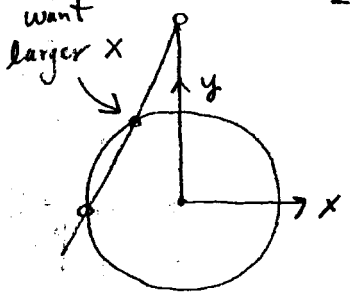
$\sin\theta_2 = \frac{n_1}{n_2} \sin\theta_1$

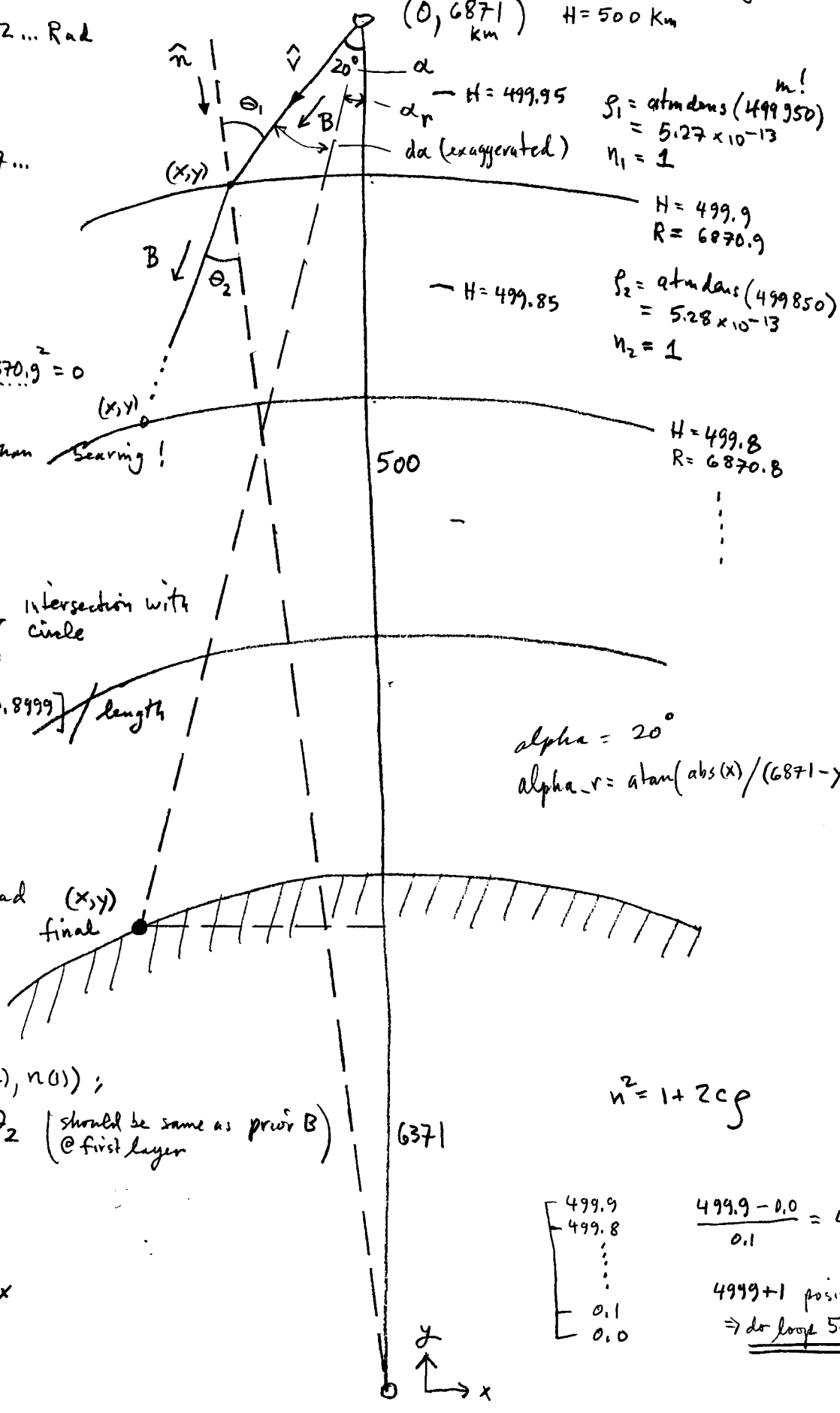
$\theta_2 = \theta_1$!

Bnorm = atan2(n(2), n(1));

Bnew = Bnorm − θ_2 (should be same as prior B @ first layer)

want larger X





ρ_1 = atmdens(499950) m!
$= 5.27 \times 10^{-13}$
$n_1 = 1$

ρ_2 = atmdens(499850)
$= 5.28 \times 10^{-13}$
$n_2 = 1$

alpha = 20°
alpha_r = atan(abs(x)/(6871 − y))

$n^2 = 1 + 2c\rho$

499.9
499.8
⋮
0.1
0.0

$\frac{499.9 - 0.0}{0.1} = 4999$ intervals

4999 + 1 positions
⇒ do loop 5000 times