Course Updates

http://www.phys.hawaii.edu/~varner/PHYS272-Spr10/physics272.html

Reminders:

1) Assignment #13 → due today
2) Last meeting Wednesday ➔ Practice Final review
3) Will post final HWs, including online by end of week
4) Review quiz #6 (go through)
5) Practice Final posted

Final exam information:

1) 1 page of notes

2) 8 problems, 2 hours (~15 minutes/problem)

3) Roughly equal balance of material throughout the course

4) Don't miss/arrive late

5) Suggest writing key equation when starting each problem/problem sub-part

6) Units can be you best friend

1. **[50 points]** You are having trouble getting many bars on your cell phone. Your phone transmitter is limited to 1W and the minimum sensitivity of the receiver at your nearest service providers station is 1mV/m.

   (a) If your phone uses the upper end of the PHS band, using GSM technology, the frequency is in the range of 1930-1990 MHz. What range of wavelengths does this correspond to?

      i. 1.0-2.0 cm
      ii. 7.0-8.2 cm
      iii. 15.0-15.5 cm
      iv. 30 - 31 cm
      v. 97.1 - 97.3 cm

1. **[50 points]** You are having trouble getting many bars on your cell phone. Your phone transmitter is limited to 1W and the minimum sensitivity of the receiver at your nearest service providers station is 1mV/m.

   (a) If your phone uses the upper end of the PHS band, using GSM technology, the frequency is in the range of 1930-1990 MHz. What range of wavelengths does this correspond to?

      i. 1.0-2.0 cm
      ii. 7.0-8.2 cm
      iii. 15.0-15.5 cm
      iv. 30 - 31 cm
      v. 97.1 - 97.3 cm

$$\lambda = \frac{c}{f} = \frac{3\times10^{8}\, m/s}{1.930\times10^{9}\, s^{-1}} = 15.5\, cm$$

$$\lambda = \frac{c}{f} = \frac{3\times10^{8}\, m/s}{1.990\times10^{9}\, s^{-1}} = 15.0\, cm$$

1. **[50 points]** You are having trouble getting many bars on your cell phone. Your phone transmitter is limited to 1W and the minimum sensitivity of the receiver at your nearest service providers station is 1mV/m.

   (b) What is the minimum intensity that can be detected at the base station?

      i. 1.33 $\mathrm{nW/m^2}$
      ii. 1.33 nJ
      iii. 2.66 $\mathrm{nW/m^2}$
      iv. 2.66 nJ
      v. 3.14159 $\mathrm{T^2}$

1. **[50 points]** You are having trouble getting many bars on your cell phone. Your phone transmitter is limited to 1W and the minimum sensitivity of the receiver at your nearest service providers station is 1mV/m.

   (b) What is the minimum intensity that can be detected at the base station?

      i. 1.33 nW/m^2

      ii. ~~1.33 nJ~~

      iii. 2.66 nW/m^2

      iv. ~~2.66 nJ~~

      v. ~~3.14159 T^2~~

Units!!

1. **[50 points]** You are having trouble getting many bars on your cell phone. Your phone transmitter is limited to 1W and the minimum sensitivity of the receiver at your nearest service providers station is $\boxed{1\text{mV/m.}}$

(b) What is the minimum intensity that can be detected at the base station?

i. 1.33 nW/m^2

~~ii. 1.33 nJ~~

iii. 2.66 nW/m^2

~~iv. 2.66 nJ~~

~~v. 3.14159 T^2~~

$$I = \frac{1}{2}\varepsilon_0 c E_{\max}^2$$

$$\boxed{E_{\max} = 1\frac{mV}{m}}$$

$$I = (0.5)(8.85\times10^{-12}\, C/W^2 \bullet m)(3\times10^8\, m/s)(1mV/m)^2 = 1.33\times10^{-9}\, W/m^2$$

1. **[50 points]** You are having trouble getting many bars on your cell phone. Your phone transmitter is limited to 1W and the minimum sensitivity of the receiver at your nearest service providers station is 1mV/m.

(c) If you have no bars, at least how far away must the nearest base station be? (assume your cell phone transmitter broadcasts isotropically)

   i. about 250m
   ii. about 1.7 km
   iii. about 3.2 km
   iv. about 7.7 km
   v. about 14.9 km

Uniform over surface
Of a sphere:

$$4\pi r^2$$

1. **[50 points]** You are having trouble getting many bars on your cell phone. Your phone transmitter is limited to 1W and the minimum sensitivity of the receiver at your nearest service providers station is 1mV/m.

Uniform over surface
Of a sphere:

$$4\pi r^2$$

(c) If you have no bars, at least how far away must the nearest base station be? (assume your cell phone transmitter broadcasts isotropically)

i. about 250m

ii. about 1.7 km

iii. about 3.2 km

iv. about 7.7 km

v. about 14.9 km

$$I = P_{max} / A = 1W / 4\pi r^2 = 1.33 \times 10^{-9} W / m^2$$

$$r = \sqrt{\frac{1}{4\pi (1.33 \times 10^{-9} W / m^2)}}$$

r=7735m

1. **[50 points]** You are having trouble getting many bars on your cell phone. Your phone transmitter is limited to 1W and the minimum sensitivity of the receiver at your nearest service providers station is 1mV/m.

Recall difference between black and silver spaceships

(d) When your friend is standing next to you, a meter away, and you are broadcasting at full power, what is the radiation pressure you are subjecting them to? (assuming they are wearing "radio dark" clothes)

i. 2.65×10^{-10} Pa

ii. 8.31×10^{-10} Pa

iii. 8.31×10^{-10} V

iv. 8.31×10^{-10} T·m

v. 8.31×10^{-10} Wb

1. **[50 points]** You are having trouble getting many bars on your cell phone. Your phone transmitter is limited to 1W and the minimum sensitivity of the receiver at your nearest service providers station is 1mV/m.

Recall difference between black and silver spaceships

(d) When your friend is standing next to you, a meter away, and you are broadcasting at full power, what is the radiation pressure you are subjecting them to? (assuming they are wearing "radio dark" clothes)

Units!

i. 2.65×10^{-10} Pa

ii. 8.31×10^{-10} Pa

~~iii. 8.31×10^{-10} V~~

~~iv. 8.31×10^{-10} T·m~~

~~v. 8.31×10^{-10} Wb~~

1. **[50 points]** You are having trouble getting many bars on your cell phone. Your phone transmitter is limited to 1W and the minimum sensitivity of the receiver at your nearest service providers station is 1mV/m.

Recall difference between black and silver spaceships

(d) When your friend is standing next to you, a meter away, and you are broadcasting at full power, what is the radiation pressure you are subjecting them to? (assuming they are wearing "radio dark" clothes)

i. 2.65×10^{-10} Pa

ii. 8.31×10^{-10} Pa

~~iii. 8.31×10^{-10} V~~

~~iv. 8.31×10^{-10} T·m~~

~~v. 8.31×10^{-10} Wb~~

Units!

$$P_{av} = \frac{I}{c}$$

Average pressure (absorbing)

$$I = P_{\max} / A = 1W / 4\pi r^2$$

$\boxed{r=1m}$

$$I = 1W / 4\pi(1m)^2 = 79.6\,mW / m^2$$

$$P_{av} = \frac{79.6\,mW / m^2}{3\times10^8\,m / s}$$

1. **[50 points]** You are having trouble getting many bars on your cell phone. Your phone transmitter is limited to 1W and the minimum sensitivity of the receiver at your nearest service providers station is 1mV/m.

Recall difference between black and silver spaceships

(e) How much would this pressure change if they had shiny, reflective clothing on?

i. about Half

ii. same

iii. double

iv. quadruple

1. **[50 points]** You are having trouble getting many bars on your cell phone. Your phone transmitter is limited to 1W and the minimum sensitivity of the receiver at your nearest service providers station is 1mV/m.

Recall difference between black and silver spaceships

(e) How much would this pressure change if they had shiny, reflective clothing on?

   i. about Half

   ii. same

   iii. double

   iv. quadruple

$$P_{av} = \frac{I}{c}$$

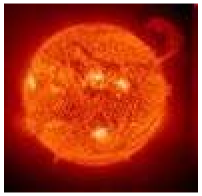
Average pressure (absorbing) "black"

$$P_{av} = \frac{2I}{c}$$

Average pressure (reflecting) "silver"

2. **[50 points]** You and your friend are scuba diving in open water and neither of you brought a watch. However you notice the sun now appears to be about 42° above the horizon and you write on your pad that it is time to go. Your friend disagrees and says that based on this sun angle, you should have about 3 hours left. You shake your head.

   (a) Sketch a diagram indicating the relevant positions and angles (assume $n_{\text{water}} \approx 1.33$).

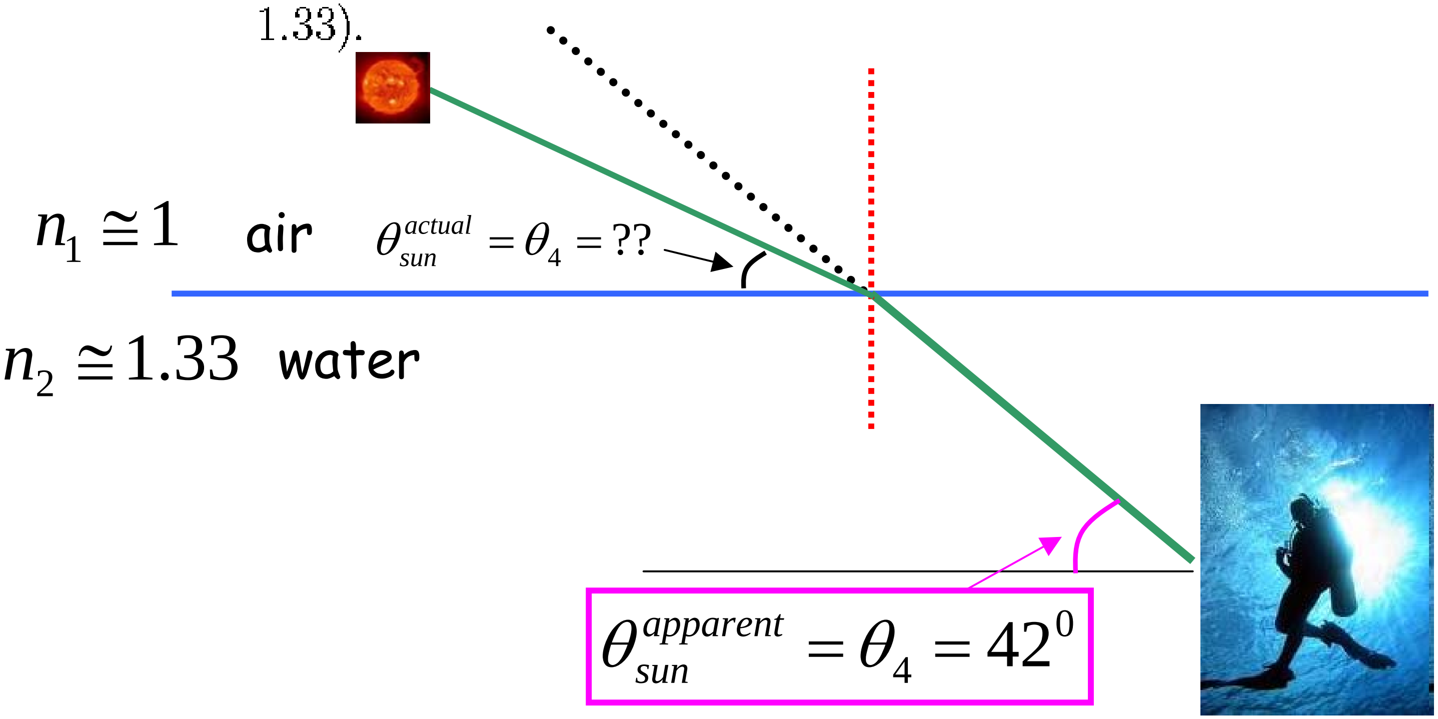


General strategy: indices of refraction given → think Snell's Law

2. **[50 points]** You and your friend are scuba diving in open water and neither of you brought a watch. However you notice the sun now appears to be about 42° above the horizon and you write on your pad that it is time to go. Your friend disagrees and says that based on this sun angle, you should have about 3 hours left. You shake your head.

    (a) Sketch a diagram indicating the relevant positions and angles (assume $n_{\text{water}} \approx 1.33$).

1) Sketch knowns/ unknowns



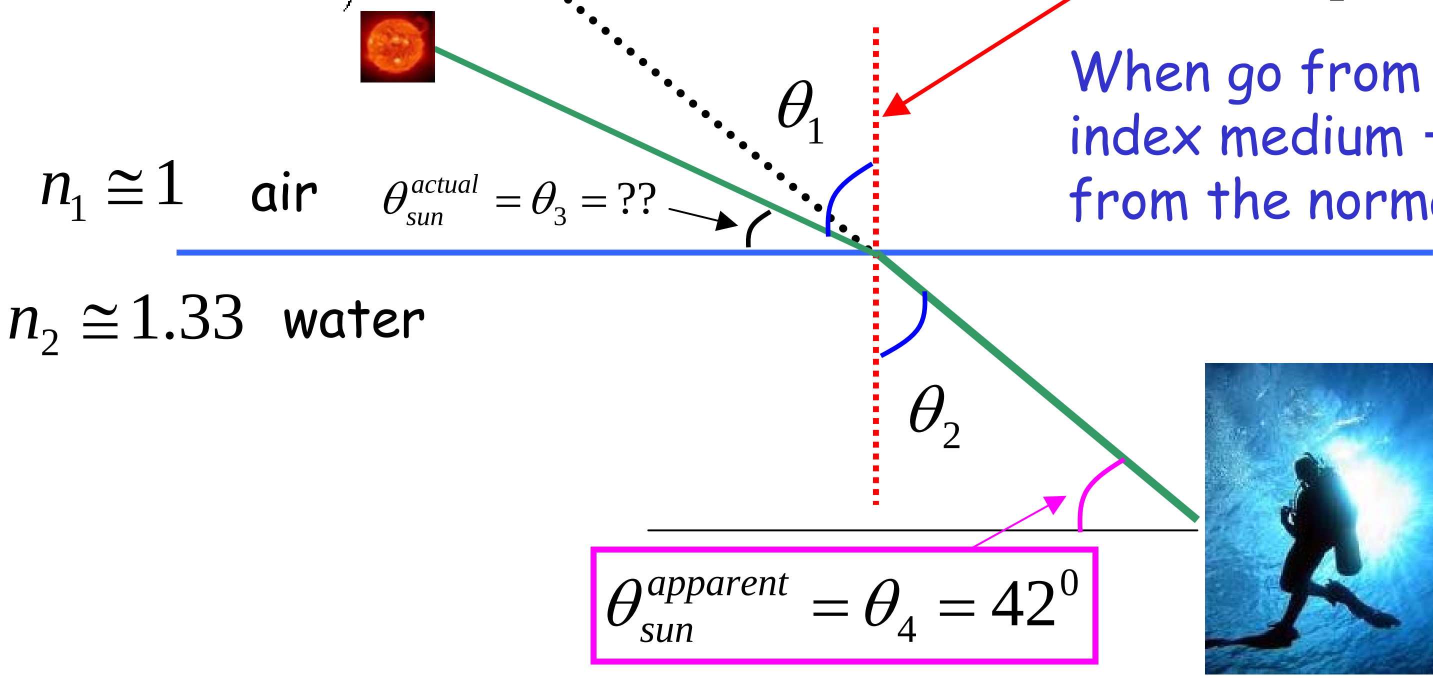
2. **[50 points]** You and your friend are scuba diving in open water and neither of you brought a watch. However you notice the sun now appears to be about 42° above the horizon and you write on your pad that it is time to go. Your friend disagrees and says that based on this sun angle, you should have about 3 hours left. You shake your head.

(a) Sketch a diagram indicating the relevant positions and angles (assume $n_{water} \approx 1.33$).

1) Sketch knowns/ unknowns
2) Normal to surface defines Snell's Law angles

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

When go from higher to lower index medium → refract away from the normal



2. **[50 points]** You and your friend are scuba diving in open water and neither of you brought a watch. However you notice the sun now appears to be about 42° above the horizon and you write on your pad that it is time to go. Your friend disagrees and says that based on this sun angle, you should have about 3 hours left. You shake your head.

   (a) Sketch a diagram indicating the relevant positions and angles (assume $n_{\text{water}} \approx 1.33$).

1) Sketch knowns/ unknowns
2) Normal to surface defines Snell's Law angles
3) Relate angles

θ_1

$n_1 \cong 1$ air $\theta_{sun}^{actual} = \theta_3 = ??$

$n_2 \cong 1.33$ water

θ_2

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

$$\downarrow$$

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

$$\boxed{\theta_{sun}^{apparent} = \theta_4 = 42^0}$$

$$\theta_1 + \theta_3 = 90^0 \rightarrow \theta_3 = 90^0 - \theta_1$$

$$\theta_2 + \theta_4 = 90^0 \rightarrow \theta_2 = 90^0 - \theta_4$$

$$\downarrow$$

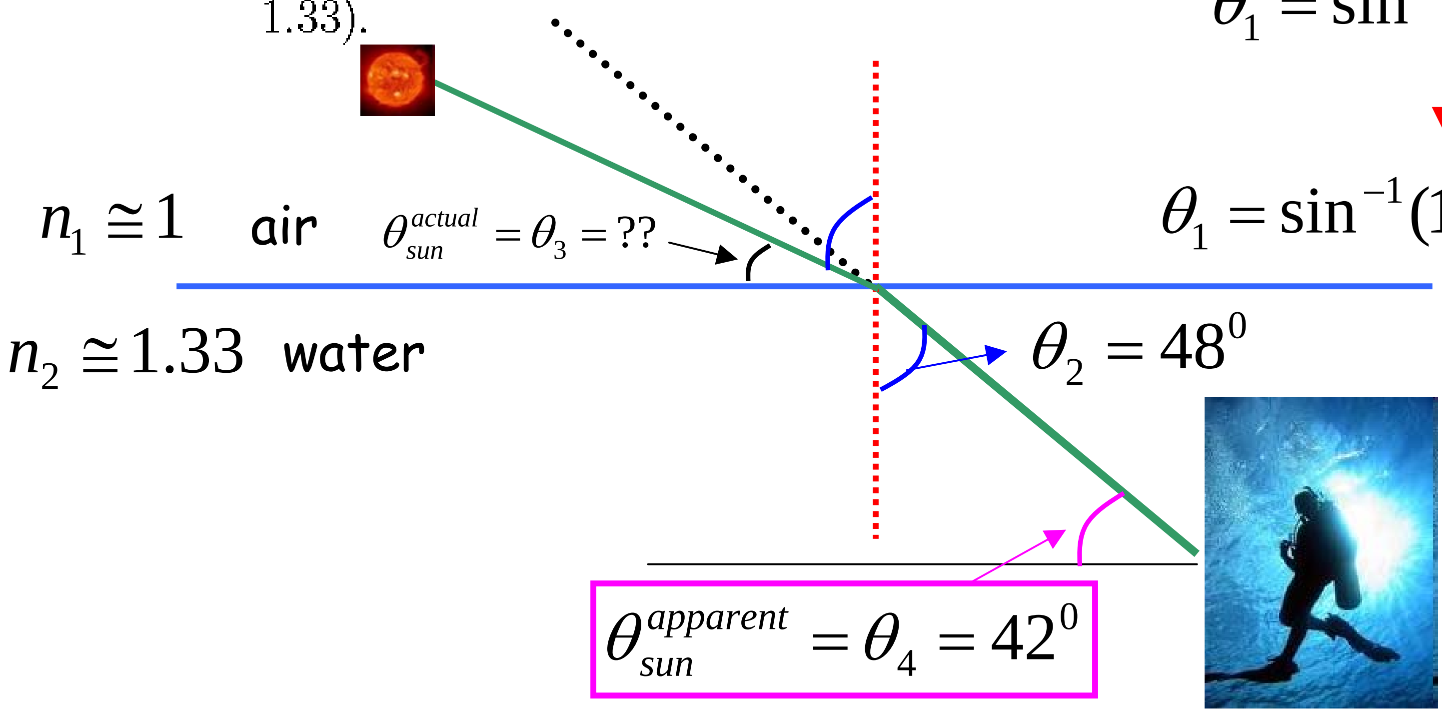
$$\theta_2 = 90^0 - 42^0$$

$$\downarrow$$

$$\boxed{\theta_2 = 48^0}$$

2. **[50 points]** You and your friend are scuba diving in open water and neither of you brought a watch. However you notice the sun now appears to be about 42° above the horizon and you write on your pad that it is time to go. Your friend disagrees and says that based on this sun angle, you should have about 3 hours left. You shake your head.

   (a) Sketch a diagram indicating the relevant positions and angles (assume $n_{\text{water}} \approx 1.33$).



1) Sketch knowns/ unknowns
2) Normal to surface defines Snell's Law angles
3) Relate angles
4) Solve for θ_1

$$\theta_1 = \sin^{-1}(n_2 \sin\theta_2)$$

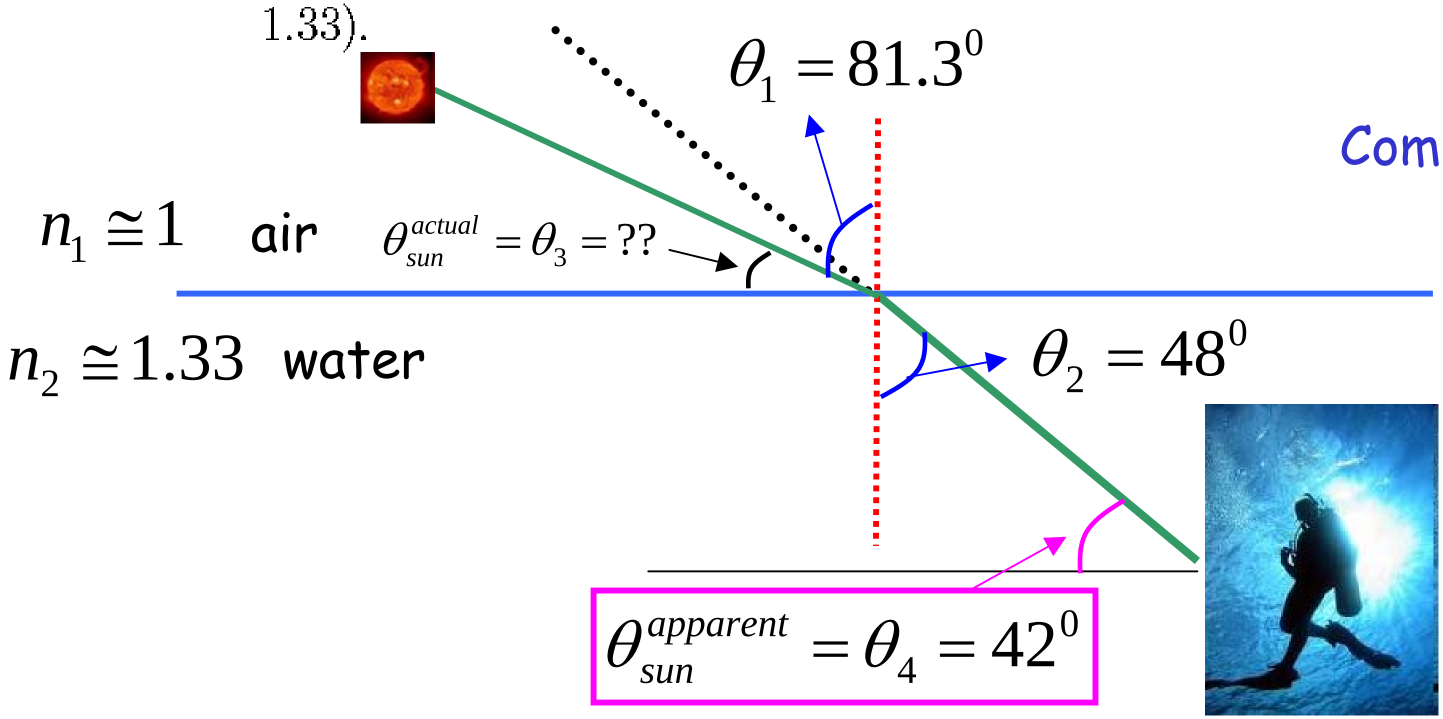
$$\theta_1 = \sin^{-1}(1.33 \sin 48^0)$$

$$\boxed{\theta_1 = 81.26^0}$$

2. **[50 points]** You and your friend are scuba diving in open water and neither of you brought a watch. However you notice the sun now appears to be about 42° above the horizon and you write on your pad that it is time to go. Your friend disagrees and says that based on this sun angle, you should have about 3 hours left. You shake your head.

   (a) Sketch a diagram indicating the relevant positions and angles (assume $n_{\text{water}} \approx 1.33$).

1) Sketch knowns/ unknowns
2) Normal to surface defines Snell's Law angles
3) Relate angles
4) Solve for θ_1

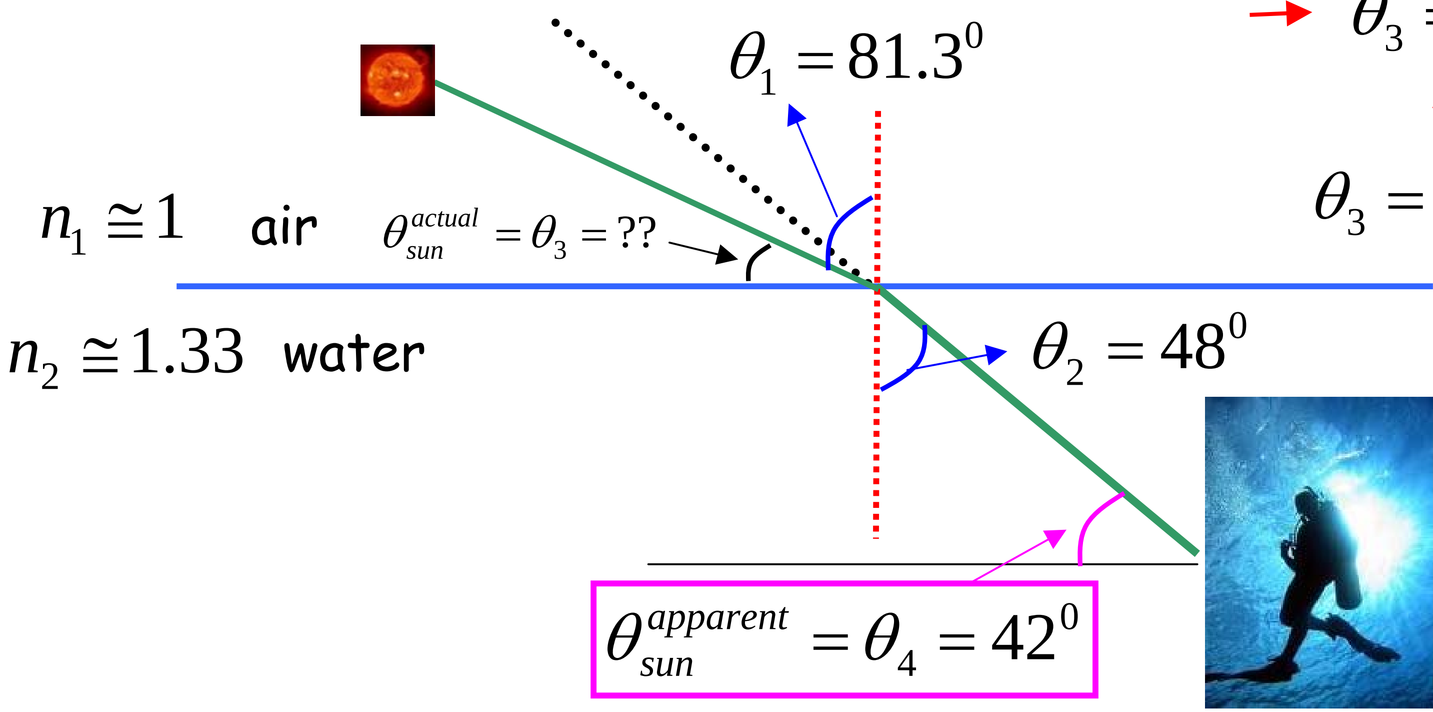


Completed sketch

2. **[50 points]** You and your friend are scuba diving in open water and neither of you brought a watch. However you notice the sun now appears to be about 42° above the horizon and you write on your pad that it is time to go. Your friend disagrees and says that based on this sun angle, you should have about 3 hours left. You shake your head.

   (b) What is the actual angle of the sun *above the horizon?*

1) Sketch knowns/ unknowns
2) Normal to surface defines Snell's Law angles
3) Relate angles
4) Solve for θ_1



$$\theta_3 = 90^0 - \theta_1$$

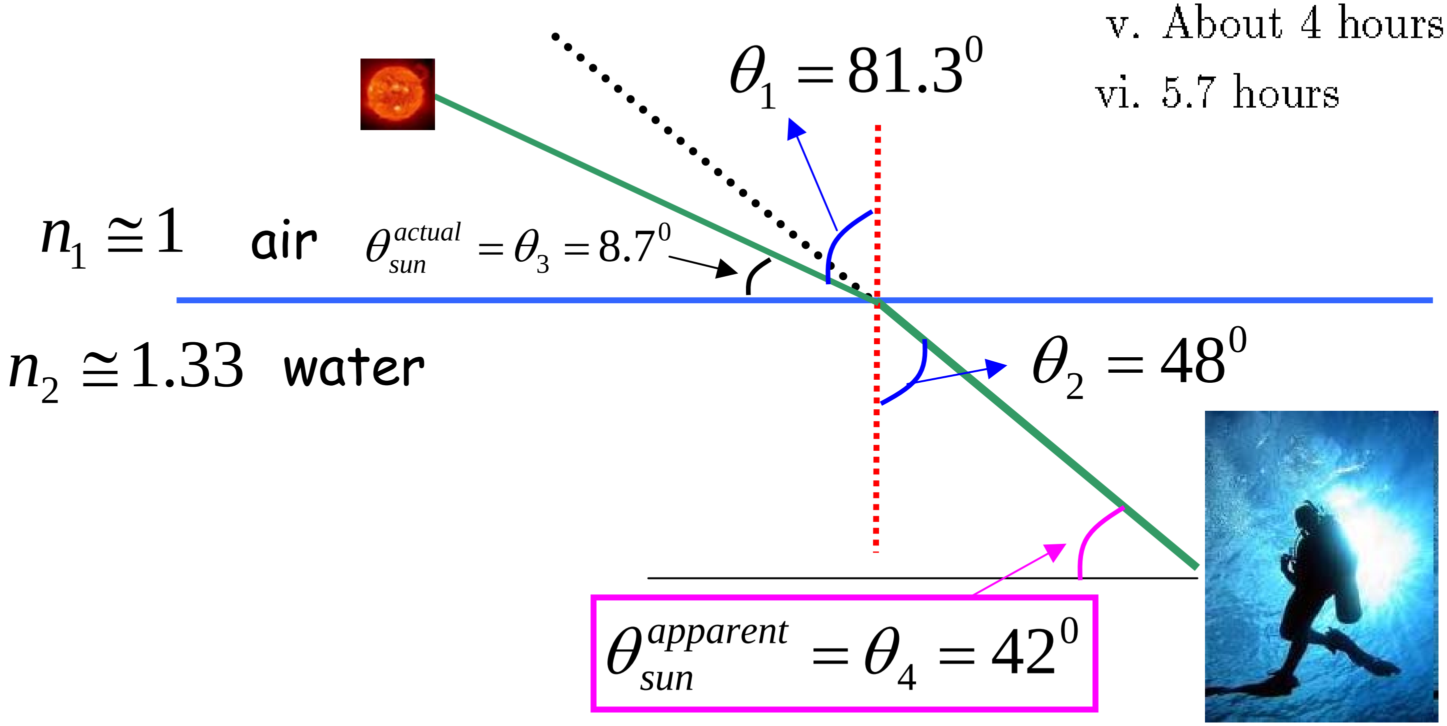
$$\theta_3 = 90^0 - 81.3^0$$

$$\boxed{\theta_1 = 8.7^0}$$

2. **[50 points]** You and your friend are scuba diving in open water and neither of you brought a watch. However you notice the sun now appears to be about 42° above the horizon and you write on your pad that it is time to go. Your friend disagrees and says that based on this sun angle, you should have about 3 hours left. You shake your head.

(c) How much time is left until sunset? (assume Hawaii latitude and approximately the Summer Equinox [sun roughly goes directly overhead at noon]).

i. Less than 5 minutes
ii. Less than an hour
iii. About 2 hours
iv. About 3 hours (you owe your friend a beer)
v. About 4 hours
vi. 5.7 hours



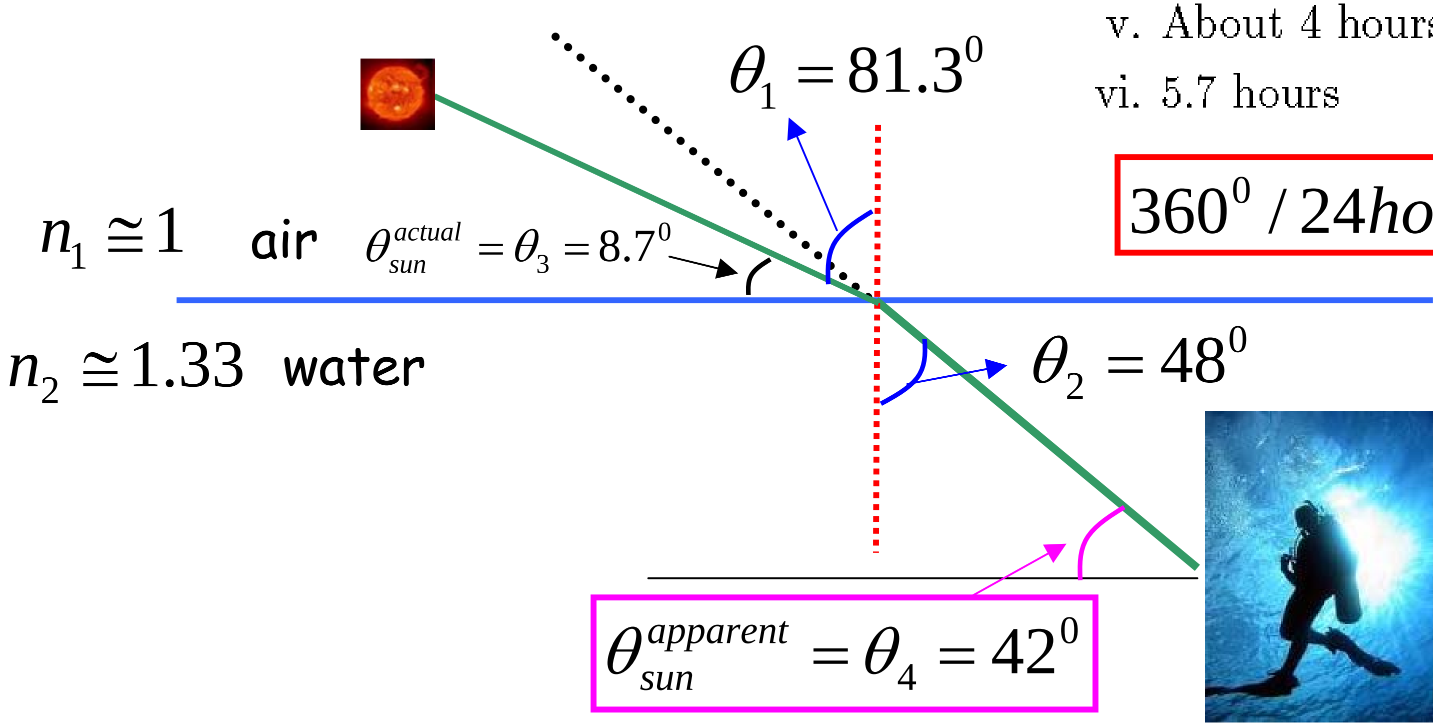
2. **[50 points]** You and your friend are scuba diving in open water and neither of you brought a watch. However you notice the sun now appears to be about 42° above the horizon and you write on your pad that it is time to go. Your friend disagrees and says that based on this sun angle, you should have about 3 hours left. You shake your head.

(c) How much time is left until sunset? (assume Hawaii latitude and approximately the Summer Equinox [sun roughly goes directly overhead at noon]).

   i. Less than 5 minutes
   ii. Less than an hour
   iii. About 2 hours
   iv. About 3 hours (you owe your friend a beer)
   v. About 4 hours
   vi. 5.7 hours

→Sun directly overhead: 360^0 in 24 hours

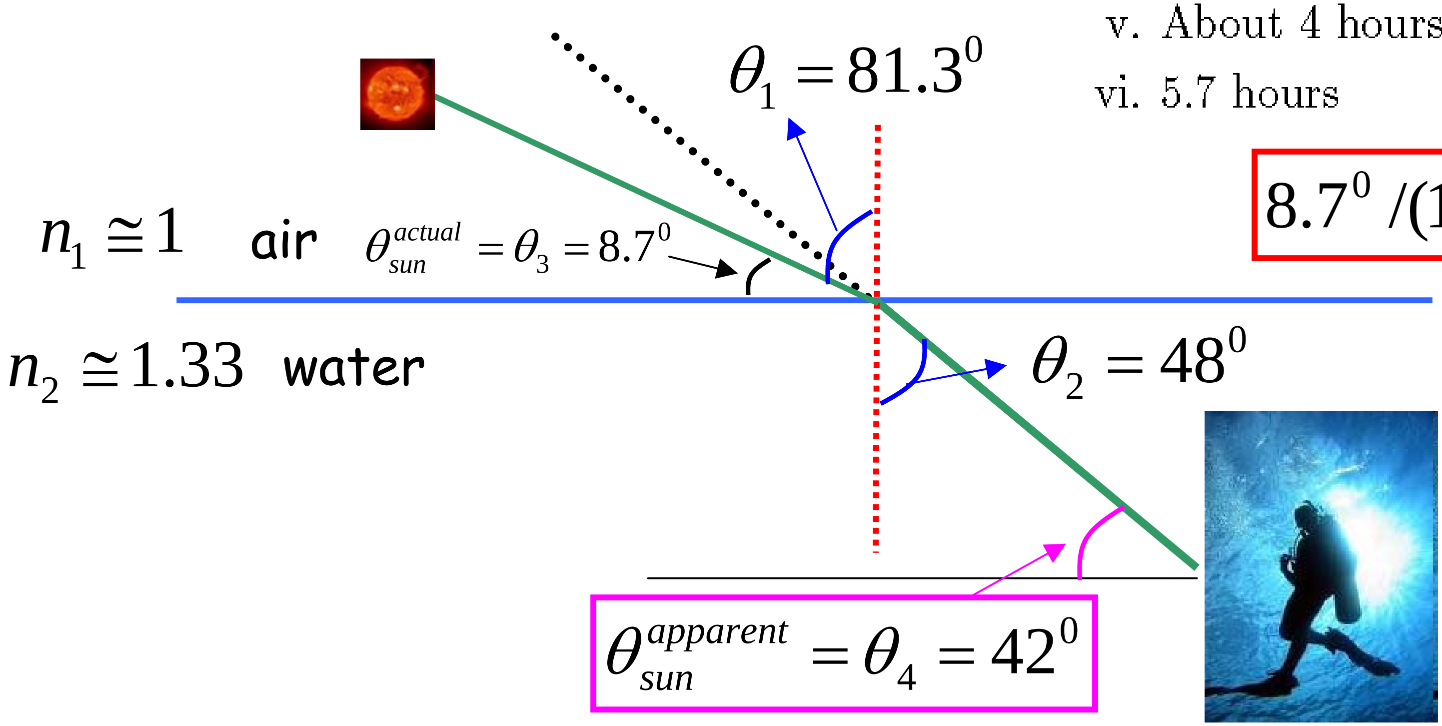
$$\boxed{360^0 / 24 hours = 15^0 / hour}$$



2. **[50 points]** You and your friend are scuba diving in open water and neither of you brought a watch. However you notice the sun now appears to be about 42° above the horizon and you write on your pad that it is time to go. Your friend disagrees and says that based on this sun angle, you should have about 3 hours left. You shake your head.

(c) How much time is left until sunset? (assume Hawaii latitude and approximately the Summer Equinox [sun roughly goes directly overhead at noon]).

i. Less than 5 minutes
ii. Less than an hour
iii. About 2 hours
iv. About 3 hours (you owe your friend a beer)
v. About 4 hours
vi. 5.7 hours



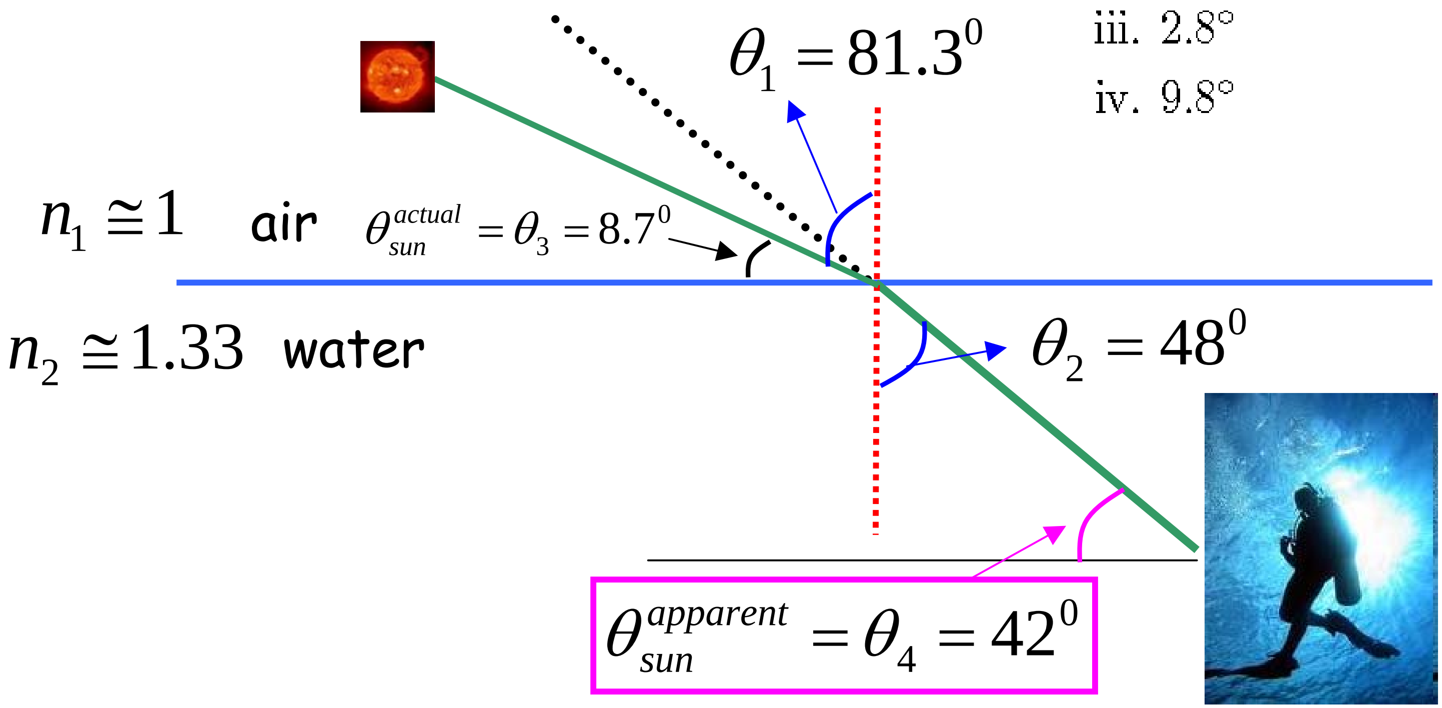
$$\boxed{8.7^0/(15^0/hour)}$$

$$\boxed{0.58\ hours}$$

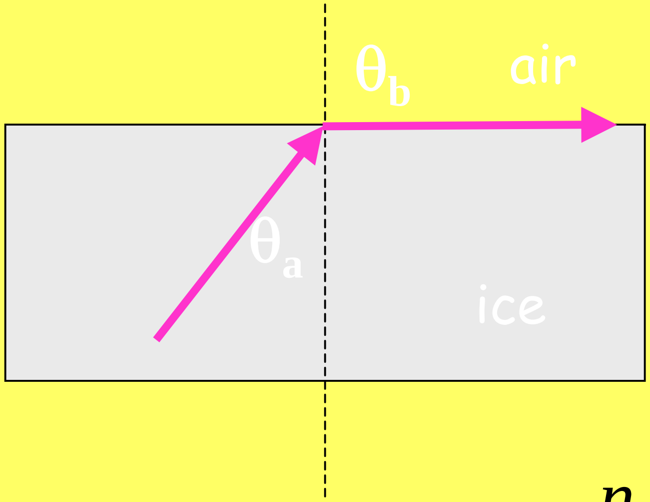
2. **[50 points]** You and your friend are scuba diving in open water and neither of you brought a watch. However you notice the sun now appears to be about 42° above the horizon and you write on your pad that it is time to go. Your friend disagrees and says that based on this sun angle, you should have about 3 hours left. You shake your head.

(d) Since your friend drove, you give in and decide to stay and stop paying attention to the time. At some point you notice the light fading and look up to see the sun setting. By how much has the sun appeared to move on the sky from under the water? **HINT: for partial credit, at least try the calculation.**

   i. Less than a degree
   ii. 2.1°
   iii. 2.8°
   iv. 9.8°



. inverse Problem



$$n_{ice} \sin \theta_a = n_{air} \sin \theta_b$$

$$(1.8) \sin(34°) = (1) \sin \theta_b$$

$$\sin \theta_b = (1.8) \sin(34°) = 1.0$$

$$\theta_b = 90°$$

. Sunset when θ_b=90^0

2. **[50 points]** You and your friend are scuba diving in open water and neither of you brought a watch. However you notice the sun now appears to be about 42° above the horizon and you write on your pad that it is time to go. Your friend disagrees and says that based on this sun angle, you should have about 3 hours left. You shake your head.

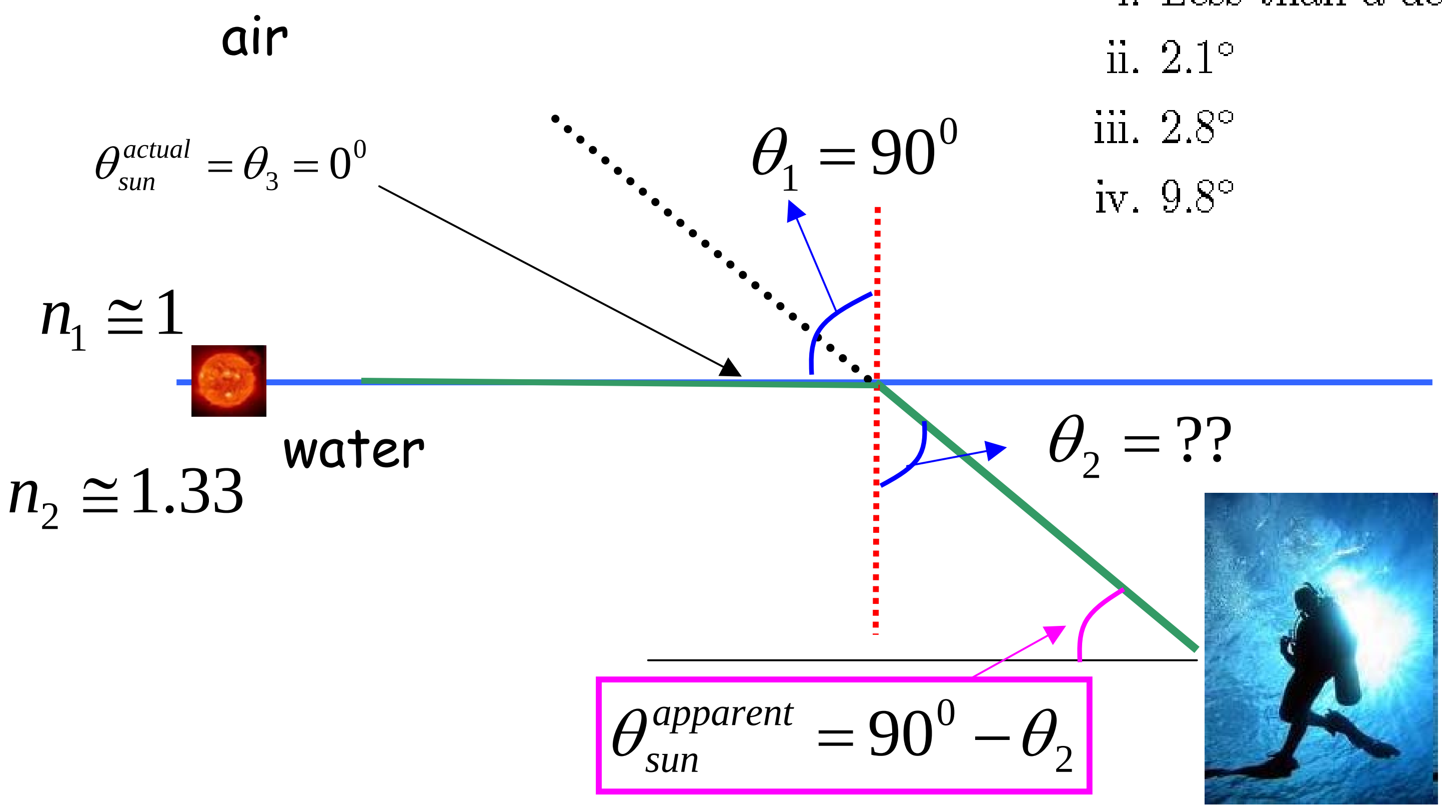
(d) Since your friend drove, you give in and decide to stay and stop paying attention to the time. At some point you notice the light fading and look up to see the sun setting. By how much has the sun appeared to move on the sky from under the water? **HINT: for partial credit, at least try the calculation.**

i. Less than a degree

ii. 2.1°

iii. 2.8°

iv. 9.8°



2. [**50 points**] You and your friend are scuba diving in open water and neither of you brought a watch. However you notice the sun now appears to be about 42° above the horizon and you write on your pad that it is time to go. Your friend disagrees and says that based on this sun angle, you should have about 3 hours left. You shake your head.

(d) Since your friend drove, you give in and decide to stay and stop paying attention to the time. At some point you notice the light fading and look up to see the sun setting. By how much has the sun appeared to move on the sky from under the water? **HINT: for partial credit, at least try the calculation.**

i. Less than a degree

ii. 2.1°

iii. 2.8°

iv. 9.8°

$$\sin 90^0 = 1$$

air

$$\theta_{sun}^{actual} = \theta_3 = 0^0$$

$$\theta_1 = 90^0$$

$$\theta_2 = \sin^{-1}(1.33^{-1}) = 48.75^0$$

$$n_1 \cong 1$$

water

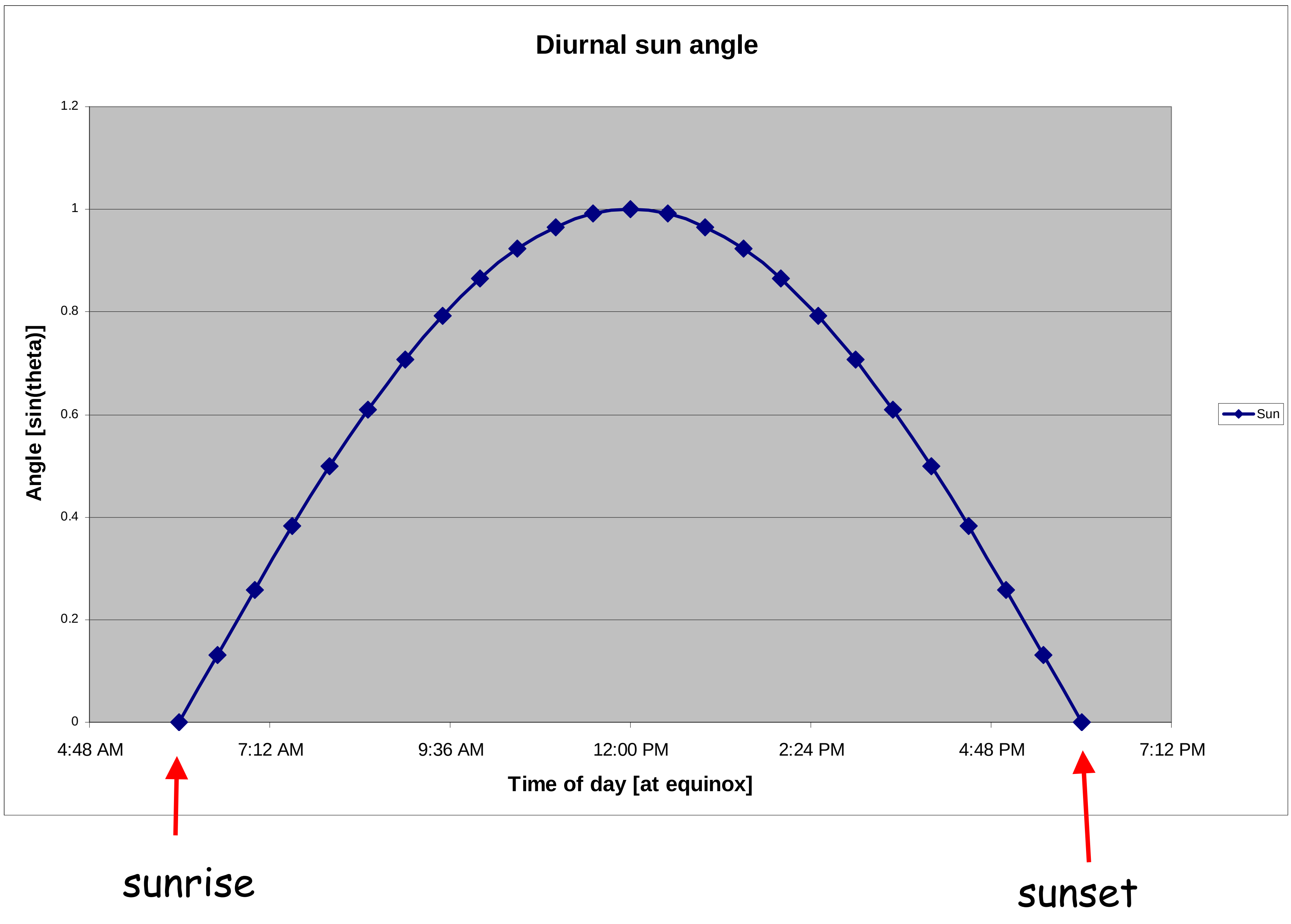
$$n_2 \cong 1.33$$

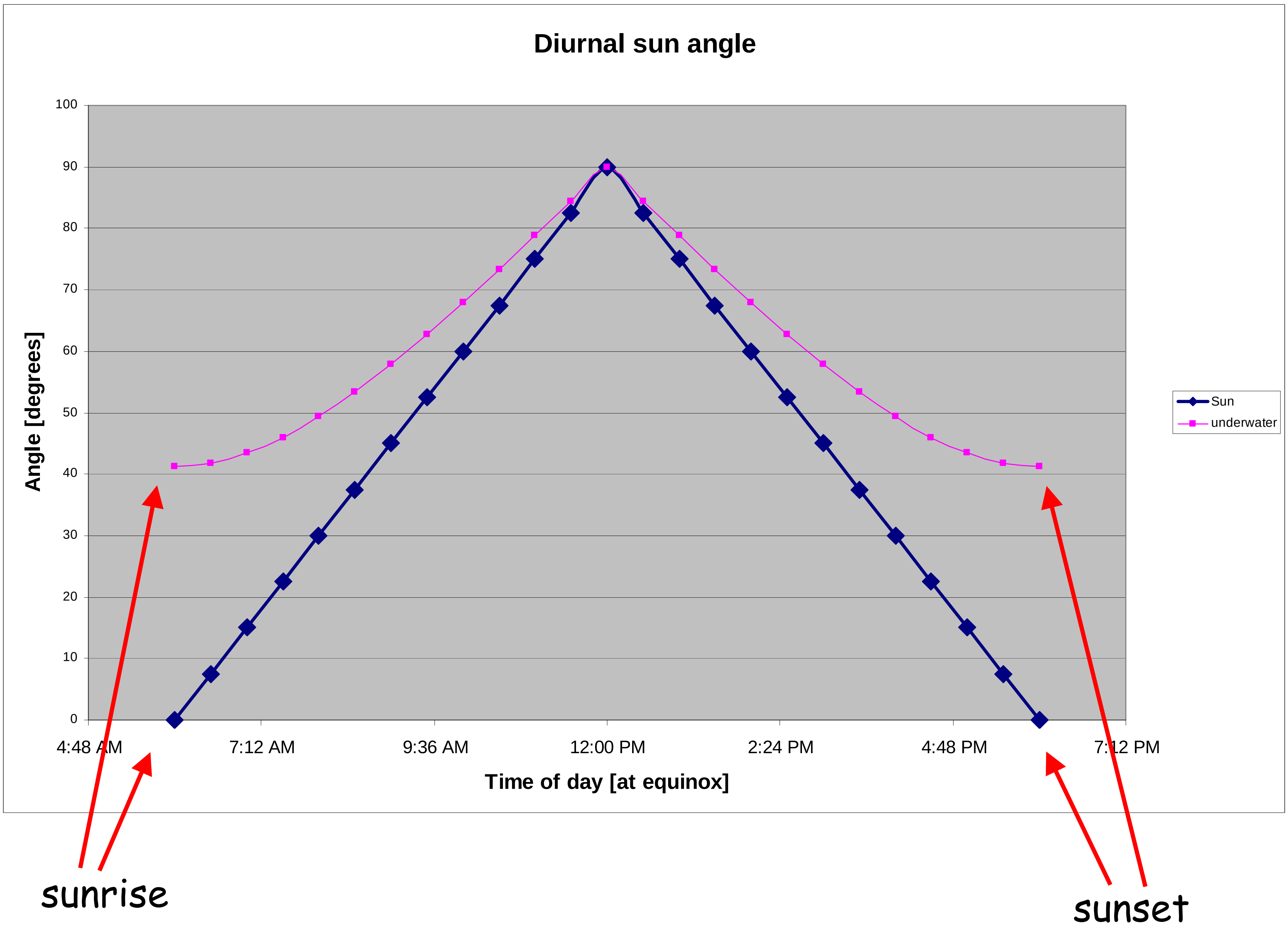
$$\theta_2 = 48^0 --> 48.8^0$$

$$\boxed{\theta_{sun}^{apparent} = 90^0 - \theta_2}$$

$$\boxed{41.2^0}$$

Was 42^0


Diurnal sun angle
1.2
1
0.8
0.6
0.4
0.2
0
Angle [sin(theta)]
4:48 AM
7:12 AM
9:36 AM
12:00 PM
2:24 PM
4:48 PM
7:12 PM
Time of day [at equinox]
Sun
sunrise
sunset


Diurnal sun angle
Angle [degrees]
100
90
80
70
60
50
40
30
20
10
0
4:48 AM
7:12 AM
9:36 AM
12:00 PM
2:24 PM
4:48 PM
7:12 PM
Time of day [at equinox]
Sun
underwater
sunrise
sunset

Final exam information:

1) 1 page of notes

2) 8 problems, 2 hours (~15 minutes/problem)

3) Roughly equal balance of material throughout the course

4) Don't miss/arrive late

5) Suggest writing key equation when starting each problem/problem sub-part

6) Units can be you best friend

Problem 1: 25 points

A very long conducting tube (hollow cylinder) has inner radius a and outer radius b. It carries charge per unit length $+\alpha$, where α is a positive constant with units of C/m. A line of charge lies along the axis of the tube. The line of charge has charge per unit length $+\alpha$.

(a) Calculate the electric field in terms of α and distance r from the axis of the tube for

1. $r < a$
2. $a < r < b$
3. $r > b$

(b) Show your results in graph of E as a function of r, making sure to indicate the relevant radii.

(b) What is the charge per unit length on

1. the inner surface of the tube
2. the outer surface of the tube

Problem 2: 25 points

An electron (charge -e = 1.6×10^{-19}C) moves in a straight line from point a to point b inside an old Cathode Ray Tube television set, a total distance of $d = 0.5$m. The electric field is uniform along this line with magnitude $E = 1.7 \times 10^4$N/C in the direction from a to b. Determine

(a) the force on the electron?

(b) the work done on it by the field ?

(c) the potential difference $V_a - V_b$?

Problem 3: 25 points

A single charged particle of charge q is moving in the x direction at time $t = 0$ with instantaneous velocity $\vec{v} = v\hat{\imath}$ in the presence of a magnetic field $\vec{B} = B\hat{\jmath}$.

(a) Sketch the motion of the charged particle.

(b) If the magnetic field strength is increased, what will happen to the motion of the charged particle?

(c) Will the charged particle speed up or slow down?

(d) When the magnetic field is stable, how much work is being done on the charged particle?

Problem 4: 25 points

A conducting bar with mass m and length L slides over horizontal rails that are connected to a voltage source. The voltage source maintains a constant current I in the rails and bar, and a constant, uniform vertical magnetic field $\vec{B}$ fills the region between the rails.

(a) Find the magnitude and direction of the net force on the conducting bar. (ignore friction, air resistance, and electrical resistance)

(b) If the bar has mass m, find the distance that the bar must move to attain speed v

(c) It has been suggested that rail guns based on this principle could be used to accelerate payloads into earth orbit or beyond. Find the distance the bar must travel along the rails if it is to reach the escape speed for earth (11.2 km/s). Let $B = 0.5$ T, $I = 2.0 \times 10^3$A, m=25 kg, and $L = 50$ cm.

Problem 5: 25 points

You are using a *loop antenna* with area 0.1 m^2 to detect EM waves for which $B_{rms} = 10^{-9}$ T.

(a) If the wave frequency is 1 MHz, what is the *maximum* value of the emf induced in the antenna ?

(b) What is the *rms* E field of these waves ?

(c) What is the velocity of these EM waves ?

(d) What is the intensity of these EM waves ?

Problem 6: 25 points

Evil Mr. Laserhands has tracked him down and found Mister Bond hiding in an aquarium filled with water (n=1.33). The window glass (n=1.5) is 3 cm thick and our secret agent is 5m below and 10m away from the window.

(a) Sketch the scene. Our villian uses a laser in the place of his right hand to finish off his victims. At what angle should he fire to hit 007 ?

(b) How does this differ from the direction Mr. Bond appears to be ?

(c) How deep would our hero have to dive (staying same distance from window), to avoid getting blasted ?

Problem 7: 25 points

(a) Copper sphere A has radius 5 cm, while copper sphere B has a radius of 10 cm. The two spheres are connected by a conducting wire. Is the magnitude of the electric potential of sphere A (*larger than, smaller than, or the same as*) that of sphere B ? (explain).

(b) Consider a series R-L-C ($R = 1\ \Omega$, $L = 1$ mH, and $C = 1$ pF) circuit with an ac generator that runs at 10 kHz. Which is larger, the *resistance*, *capacitive reactance*, *inductive reactance* (pick one) ?

(c) Far away from a dipole, electric field falls of like $1/r^2$, $1/r$, $1/r^3$ *(pick one)*

(d) According to Ampere's Law, the magnetic field of a long straight current-carrying wire falls off like $1/r^2$, $1/r$, $1/r^3$ *(pick one)* and is in the **radial, azimuthal or along the wire (pick one)** direction.

Problem 8: 25 points

(a) Will total internal reflection occur for light going from air towards water ? How about from water towards air ? Explain.

(b) Why is the sky red/orange at sunset ? (give a short explanation).

(c) Given supplies/equipment you can find at a hardware store, explain how you might make a magnet to generate a 1 T magnetic field.

(d) Arrange the following types of electromagnetic radiation in order of *increasing energy*: infrared light, ultraviolet light, microwaves, x-rays, FM radio.

(e) Explain how a mass spectrometer is used to separate isotopes of different materials.

For next time

- Homework #13 (last!) → due <u>now</u>

- Make sure to try all Practice Final problems prior to class Wednesday

- Bring your clickers on Wednesday