This print-out should have 11 questions. Multiple-choice questions may continue on the next column or page – find all choices before answering.

**Helium Neon Laser 02**

001 (part 1 of 3) 10.0 points
The wavelength of red light in air is 992 nm. What is its frequency? The speed of light in air is $2.99792 \times 10^8$ m/s.

Correct answer: $3.0221 \times 10^{14}$ Hz.

002 (part 2 of 3) 10.0 points
What is its wavelength in glass that has an index of refraction of 1.11?

Correct answer: 893.694 nm.

003 (part 3 of 3) 10.0 points
What is its speed in the glass?

Correct answer: $2.70083 \times 10^8$ m/s.

**Refraction in Silica 02**

004 10.0 points
A ray of light in air is incident on a planar surface of silica. The refracted ray makes an angle of $34.4^\circ$ with the normal. Refraction index for silica is 1.49. Calculate the angle of incidence.

Correct answer: $57.3308^\circ$.

**Flashlight Under Water**

005 (part 1 of 2) 10.0 points
The index of refraction of a transparent liquid (similar to water but with a different index of refraction) is 1.36. A flashlight held under the transparent liquid shines out of the transparent liquid in a swimming pool. This beam of light exiting the surface of the transparent liquid makes an angle of $\theta_a = 25^\circ$ with respect to the vertical.

At what angle (with respect to the vertical) is the flashlight being held under transparent liquid?

Correct answer: $18.1044^\circ$.

006 (part 2 of 2) 10.0 points
The flashlight is slowly turned away from the vertical direction. At what angle will the beam no longer be visible above the surface of the pool?

Correct answer: $47.3321^\circ$.

**Serway CP 22 22**

007 10.0 points
A submarine is 309 m horizontally out from the shore and 110 m beneath the surface of the water. A laser beam is sent from the submarine so that it strikes the surface of the water at a point 220 m from the shore.

If the beam just strikes the top of a building standing directly at the water’s edge, find the height of the building. The index of refraction of the water is 1.333.

Correct answer: 142.996 m.

**Glass Bottom Boat**

008 10.0 points
A diver shines a light up to the surface of a flat glass-bottomed boat at an angle of $20^\circ$ relative to the normal. If the indices of refraction of air, water, and glass are 1.0, 1.33, and 1.5 respectively, at what angle does the light leave the glass
(relative to its normal)?

Correct answer: $27.0577^\circ$.

Determine the maximum angle $\theta$ for which the light rays incident on the end of the light pipe shown in the figure above are subject to total internal reflection along the walls of the pipe. The pipe of diameter $3.13 \, \mu m$ has an index of refraction of 1.25 and the outside medium is air.

Correct answer: $48.5904^\circ$.

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As shown in the figure, a light ray is incident normally on one face of a $21^\circ$–$69^\circ$–$90^\circ$ block of dense flint glass (a prism) that immersed in water.

Find the exit angle $\theta_4$ of the light ray. (Assume the index of grass is 1.77, and that of water is 1.333.)

Correct answer: $80.6702^\circ$.

A substance is dissolved in the water to increase the index of refraction.

At what value of $n_2$ does total internal reflection cease at point $P$?

Correct answer: 1.65244.