Begin your response to **QUESTION 1** on this page.

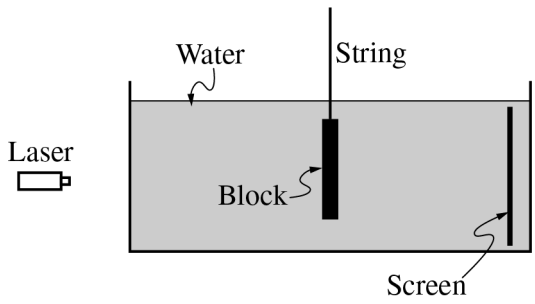
PHYSICS 2

SECTION II

Time—1 hour and 30 minutes

4 Questions

Directions: Questions 1 and 4 are short free-response questions that require about 20 minutes each to answer and are worth 10 points each. Questions 2 and 3 are long free-response questions that require about 25 minutes each to answer and are worth 12 points each. Show your work for each part in the space provided after that part.



1. (10 points, suggested time 20 minutes)

Students are investigating electromagnetic wave phenomena in transparent media. They use a string to support a stationary thin, rectangular block of mass m_b, volume V_b, and density ρ_b. The block has two narrow slits in its center and is submerged in a glass tank containing water with density ρ_w, as shown above.

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Continue your response to **QUESTION 1** on this page.

(a)

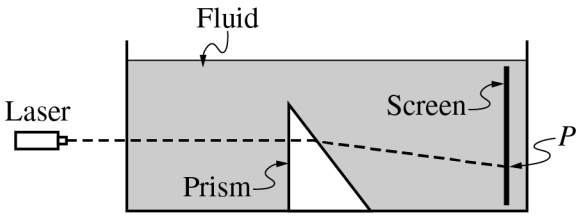
i. On the dot below, which represents the block, draw and label the forces that are exerted on the block. Each force must be represented by a distinct arrow starting on, and pointing away from, the dot.

ii. Derive an expression for the force exerted on the block by the string in terms of the given quantities and physical constants, as appropriate.

GO ON TO THE NEXT PAGE.

Continue your response to **QUESTION 1** on this page.

(b) A monochromatic laser beam is incident perpendicular to the wall of the tank. The beam passes through the slits in the block. An interference pattern is formed on the screen inside the tank. The water is then replaced with a clear fluid with a greater index of refraction than that of water. In a coherent, paragraph-length response, describe how the greater index of refraction of the new fluid affects the interference pattern. Explain your reasoning in terms of speed, frequency, and wavelength of the light.



(c) The block is replaced by a triangular prism, as shown above. The path of the beam is indicated by the dotted line, and the beam reaches the screen at point P. The fluid is then removed from the tank, and the prism is surrounded by air. Predict whether the beam will reach the side of the tank above point P, at point P, or below point P when the prism is surrounded by air. Support your answer using physics principles.

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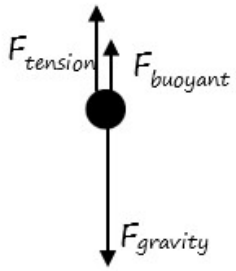
Question 1: Short Answer Paragraph Argument — 10 points

(a)(i) For correctly drawing and labeling the gravitational, buoyant, and tension forces with no extraneous forces — **1 point**

Example Response



(a)(ii) For an application of Newton's laws that is correct or consistent with the diagram in part (a)(i) and indicates zero net force — **1 point**

For a correct substitution of the buoyant force into a solution that is consistent with the previous equation — **1 point**

Scoring Note: A correct answer with no supporting work earns this point.

Example Response

$\Sigma \vec{F} = m\vec{a}$

$F_T + F_B - F_g = 0$

$F_T + F_B = F_g$

$F_T = F_g - F_B$

$F_T = m_b g - \rho_w V_b g$

Total for part (a) 3 points

(b) For correctly relating the speed of the light in the new medium to the index of refraction — **1 point**

For indicating that the frequency does not change — **1 point**

For a correct relationship between speed and wavelength — **1 point**

For a correct relationship between wavelength and fringe separation — **1 point**

For a logical, relevant, and internally consistent argument that addresses the question asked and follows the guidelines described in the published requirements for the paragraph-length response — **1 point**

Example Response

The speed of light in the new fluid is less than the speed of light in water because the fluid has a greater index of refraction. This means that the wavelength of the light in the beam will be smaller because the frequency does not change. Since the wavelength is smaller, the angular separation of the bright fringes will decrease, as described by the equation $m\lambda = d\sin\theta$.

Total for part (b) 5 points

(c) For explicitly indicating that the amount of refraction at the fluid-prism interface depends on the ratio of the indices of refraction of the materials **1 point**

Scoring Note: Basing the explanation on the difference in refractive indices is acceptable.

For correctly relating a larger angle of refraction to the beam hitting the screen below point *P* **1 point**

Example Response

The beam refracts more when the air is present because the difference between the indices of refraction between the prism and the surrounding medium is greater. So, the beam hits the screen below point P.

Total for part (c) 2 points

Total for question 1 10 points