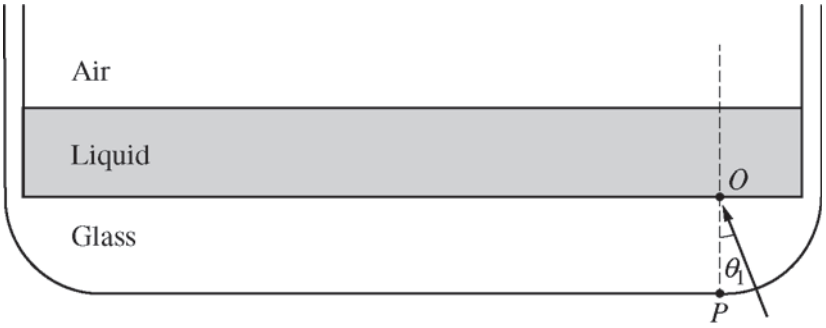
PHYSICS 2
Section II
4 Questions
Time—90 minutes

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.



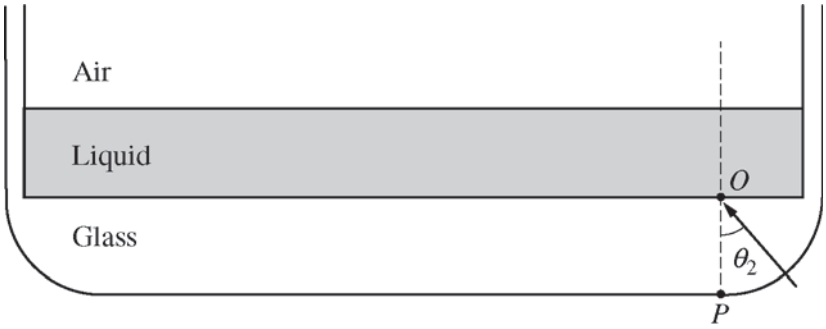
1. (10 points - suggested time 20 minutes)

   The figure above shows a cross section of a drinking glass (index of refraction 1.52) filled with a thin layer of liquid (index of refraction 1.33). The bottom corners of the glass are circular arcs, with the bottom right arc centered at point O. A monochromatic light source placed to the right of point P shines a beam aimed at point O at an angle of incidence θ. The flat bottom surface of the glass containing point P is frosted so that bright spots appear where light from the beam strikes the bottom surface and does not reflect. When $\theta = \theta_1$, two bright spots appear on the bottom surface of the glass. The spot closer to point P will be referred to as X; the spot farther from P will be referred to as Y. The location of spot X and that of spot Y both change as θ is increased.

   (a) In a coherent paragraph-length answer, describe the processes involved in the formation of spots X and Y when $\theta = \theta_1$. Include an explanation of why spot Y is located farther from point P than spot X is and what factors affect the brightness of the spots.

(b) When θ is increased to θ_2, one of the spots becomes brighter than it was before, due to total internal reflection.

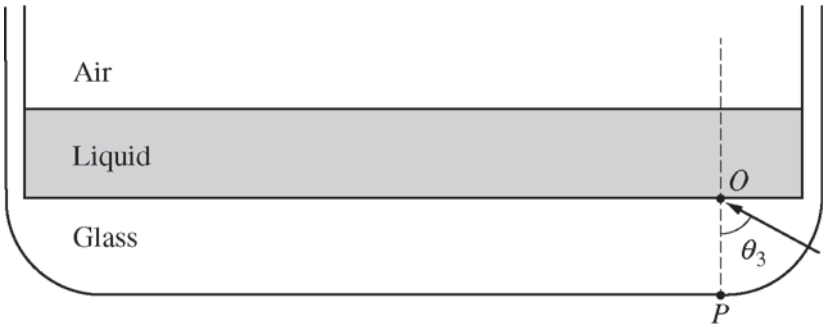
i. On the figure below, draw a ray diagram that clearly and accurately shows the formation of spots X and Y when $\theta = \theta_2$.



ii. Which spot, X or Y, becomes brighter than it was before due to total internal reflection? Explain your reasoning.

(c) When θ is further increased to θ_3, one of the spots disappears entirely.

i. On the figure below, draw a ray diagram that clearly and accurately shows the formation of the remaining spot, X or Y, when $\theta = \theta_3$.



ii. Indicate which spot, X or Y, disappears. Explain your reasoning in terms of total internal reflection.

AP® PHYSICS 2
2015 SCORING GUIDELINES

Question 1

10 points total | **Distribution of points**

(a) 5 points

For explaining that the light that results in spot X reflects at the glass-liquid interface — 1 point

For explaining that the light that results in spot Y is refracted both as it leaves the glass and reenters the glass (direction of refraction need not be correct) — 1 point

For explaining that the light that results in spot Y is reflected at the liquid-air interface — 1 point

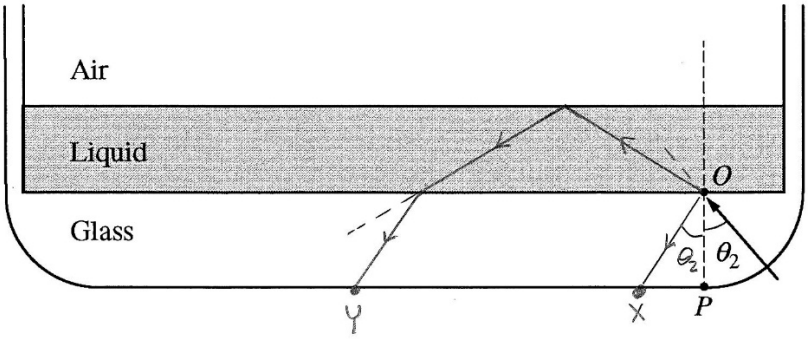
For explaining that Y is farther from P than X in terms of the geometry of the path — 1 point

For explaining that at each interface the brightness is affected by reflection, and by transmission and/or refraction as appropriate — 1 point

Students may reference a diagram to support the reasoning, but it cannot supplant the written reasoning.

(b)

i) 2 points



For drawing a reasonably accurate path for the rays that form spot X — 1 point

For drawing a reasonably accurate path for the rays that form spot Y, including correct directions of refraction, with no rays in the air — 1 point

ii) 1 point

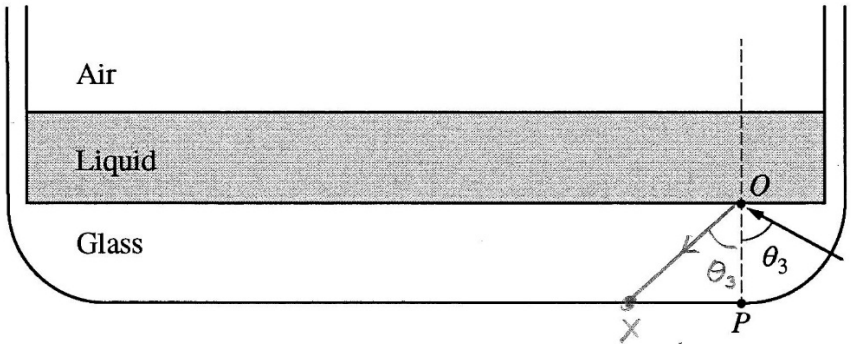
For indicating that Y becomes brighter in terms of the distribution of energy with and without total internal reflection — 1 point

Question 1 (continued)

Distribution of points

(c)

i) 1 point



For drawing rays to show reflection at the glass-liquid interface — 1 point
One point will be deducted for drawing any rays above the glass-liquid interface.

ii) 1 point

For indicating that Y disappears and indicating that total internal reflection takes place at the glass-liquid interface — 1 point