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

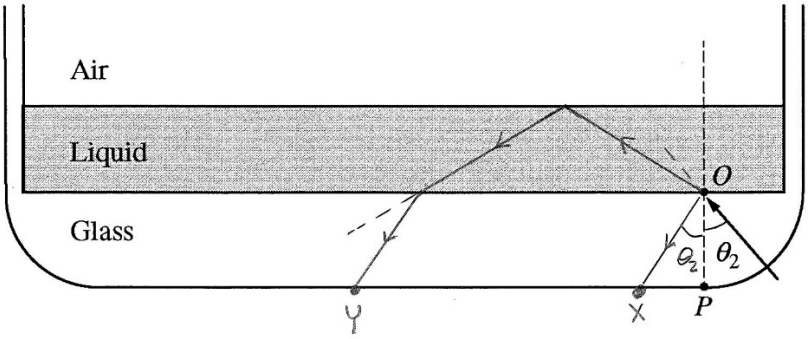
For explaining that Y is farther from P than X in terms of the geometry of the path — 1 point

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

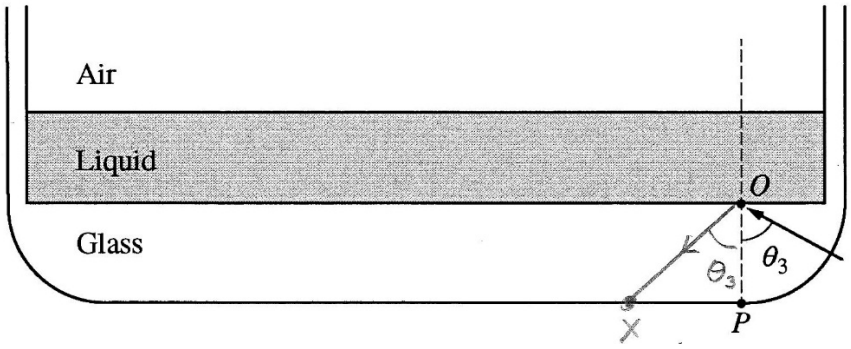
For indicating that Y becomes brighter in terms of the distribution of energy with and without total internal reflection — 1 point

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.

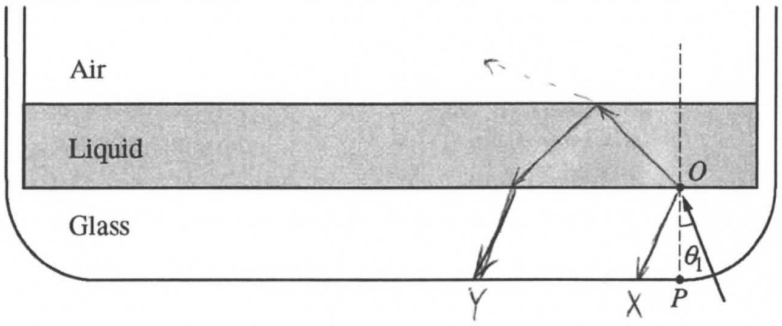
ii) 1 point

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

P2Q1 A1

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.

Spot X is formed by the light that bounces off of the liquid and directly onto the bottom of the glass. Spot Y is formed by the light that passes through the glass, into the liquid (refracted) then bounces off of the air-liquid boundary back into the liquid and is then refracted by the glass after passing through it making a spot on the bottom. The amounts of light that are a each stage reflected/refracted determines the spot brightness and the light that forms Y travels further horizontally as the liquid refracts and reflects it further than that of spot X.

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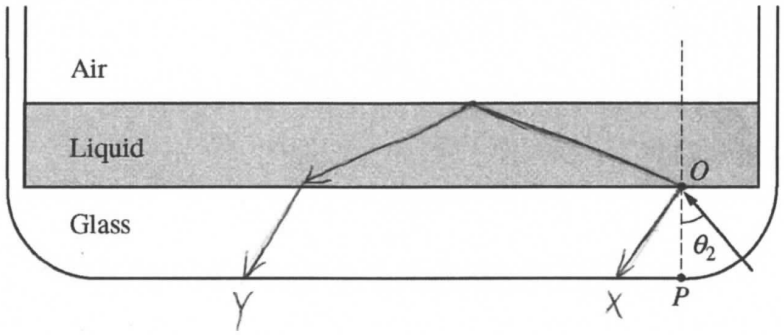
(b) When θ is increased to θ_2, one of the spots becomes brighter than it was before, due to total internal reflection.

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

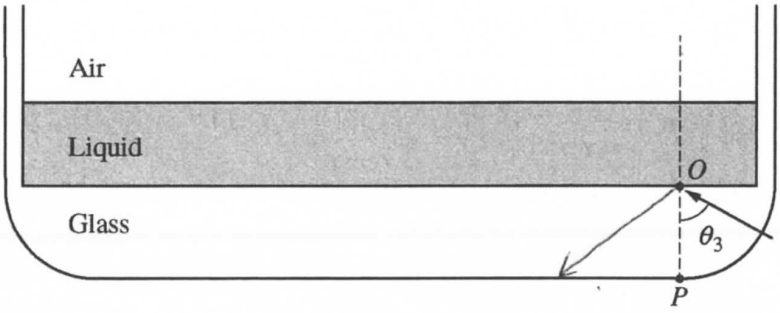


ii. Which spot, X or Y, becomes brighter than it was before due to total internal reflection? Explain your reasoning.

At some angle θ_2 that angle within the ~~critical~~ liquid passes the critical angle after which there is total internal reflection off of the air so more light gets reflected, making Y brighter

(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.

At θ_3 the critical angle for the glass-liquid boundary is surpassed and the light is totally internally reflected so none of it can create Y, so it dissappears.

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P2Q1 B1

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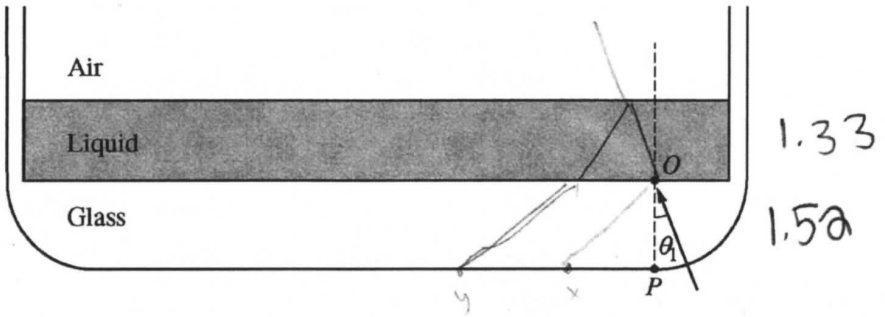

1. (10 points - suggested time 20 minutes)

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.

The formation of spots X and Y occure when a beam of light from the left of pont P shines through the glass and into the liquid. when the beam travels from the glass to the liquid some light is reflected back into the glass creating bright spot X. Some of the light, however, goes through the liquid and is reflected back when the light hits the phase change from liquid to air. This light then reflects back down into the liquid and glass creating bright spot Y. Y is farther because the light is reflected at a farthur point than X is.

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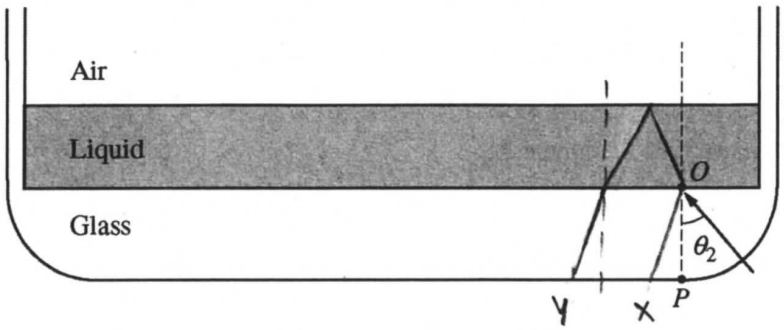
(b) When θ is increased to θ_2, one of the spots becomes brighter than it was before, due to total internal reflection.

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

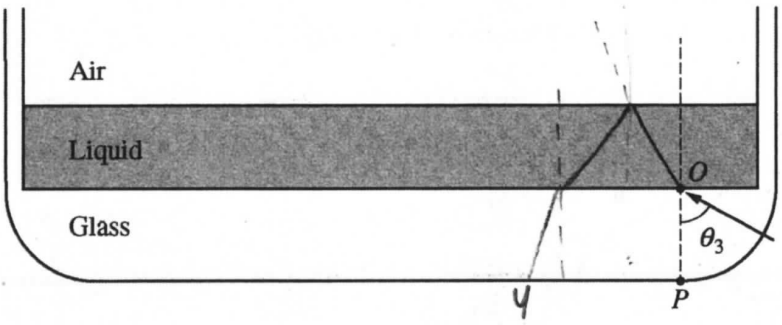


ii. Which spot, X or Y, becomes brighter than it was before due to total internal reflection? Explain your reasoning.

Y becomes brighter because some of the light does not escape into the air but ratter is internally reflected so that no light escapes making it brighter.

(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.

X disappears because at θ_3 all light is able to pass through the liquid and not be reflected back into the glass. Total internal reflection only occurs at certain angles and at θ_3 it is too great of an angle to be reflected back to form spot X.

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P2Q1 C1

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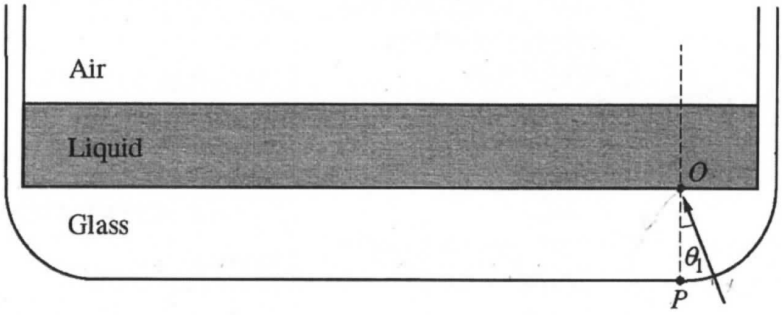

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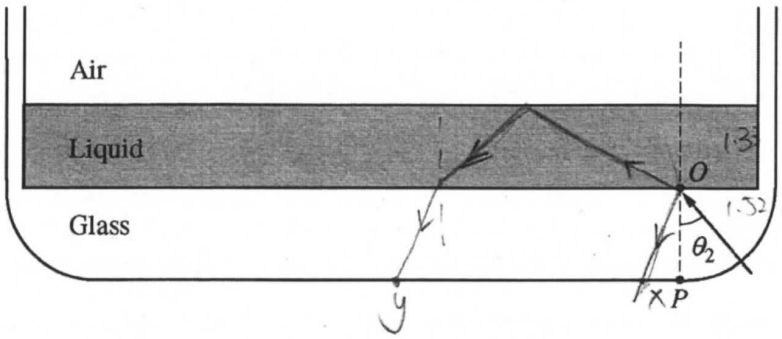
(a) In a coherent paragraph-length answer, describe the processes involved in the formation of spots X and Y when $\theta = \theta_1$. Include an explanation of why spot Y is located farther from point P than spot X is and what factors affect the brightness of the spots.

X point is formed by reflection
Y point is formed by refraction
Because the difference in the index of refraction and the different reflection caused by different surface, point Y locates farther from point P.
The angle of θ will affect the brightness of the spots.
Since the wave length will change in different material
Also $E = \frac{hc}{\lambda}$ → so the energy will be affected by wavelength. The energy is propation to the brightness of the light. So the wavelength will affect the brightness

GO ON TO THE NEXT PAGE.

(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 $\theta = \theta_2$.

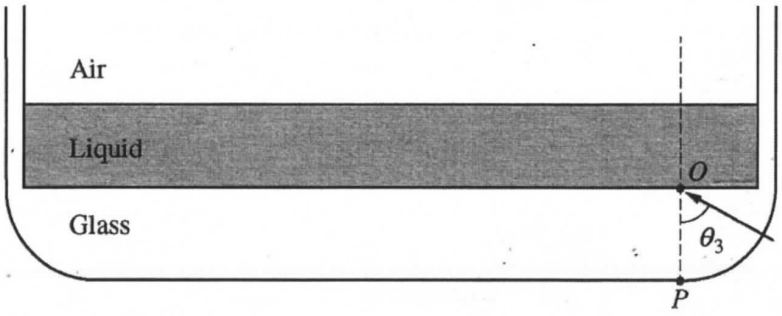


ii. Which spot, X or Y, becomes brighter than it was before due to total internal reflection? Explain your reasoning.

Y point will be brighter Since the beam is total reflected so the total energy will transfer to the point which was formed by refraction.

(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.

Point X will disappear. Because the $\theta_3 > \theta_2$ and θ_2 is already an angle that beam becomes total reflected. So there is no energy remains for reflect. The entire energy convey to form point Y.

AP® PHYSICS 2
2015 SCORING COMMENTARY

Question 1

Overview

The intent of this question was to assess student knowledge of ray optics including reflection, refraction, Snell's law, and total internal reflection. Understanding was to be conveyed in a written form using a combination of words, diagrams, and mathematics.

Sample: P2Q1 A
Score: 10

This response is clearly written and well-organized and earned full credit.

Sample: P2Q1 B
Score: 5

Part (a) earned 3 points for explaining that the light that results in spot *X* reflects at the glass-liquid interface, for explaining that the light that results in spot *Y* is reflected at the liquid-air interface, and for explaining that *Y* is farther from *P* than *X* in terms of the geometry of the path. Part (b) earned 2 points for drawing a reasonably accurate path for the rays that form spot *X* and for indicating that *Y* becomes brighter in terms of the distribution of energy with and without total internal reflection. It is not clear that any refraction is intended at the glass-liquid interface. Part (c) earned no credit.

Sample: P2Q1 C
Score: 3

Part (a) has descriptions that are not detailed enough and information that is not correct and earned no credit. Part (b) has a correct drawing and an acceptable explanation and earned 3 points for full credit. Part (c) earned no credit.