AP® PHYSICS 1
2016 SCORING GUIDELINES

Question 5

7 points total **Distribution of points**

(a) 2 points

For indicating that there is more rope or weight below one point than the other — 1 point

For indicating (explicitly or implicitly) that the tension at any point counteracts or supports the weight below that point — 1 point

Examples:

The rope at *P* supports more weight than the rope at *Q* so the tension must be higher at *P*.

The section of rope below *P* has an upward force from the rope above it and a downward gravitational force. The same goes for *Q*. Because the gravitational force is greater on the longer section (the section below *P*), the upward force — the tension — must be greater at *P*.

(b) 5 points

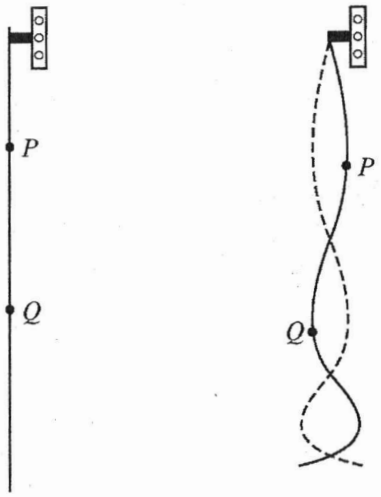
For indicating that the wavelength is longer near the top of the rope (or shorter near the bottom) — 1 point

For indicating (explicitly or implicitly) that the frequency is the same throughout the rope — 1 point

For using $v = \lambda f$ to conclude that wave speed is greater near the top of the rope (or less near the bottom), based on the difference in wavelength — 1 point

For indicating (explicitly or implicitly) that, as stated in part (a), tension is greater near the top of the rope (or less near the bottom) — 1 point

For a response that has sufficient paragraph structure, as described in the published requirements for the paragraph-length response — 1 point



5. (7 points, suggested time 13 minutes)

The figure above on the left shows a uniformly thick rope hanging vertically from an oscillator that is turned off. When the oscillator is on and set at a certain frequency, the rope forms the standing wave shown above on the right. P and Q are two points on the rope.

(a) The tension at point P is greater than the tension at point Q. Briefly explain why.

Point P is closer to the oscillator and therefore has a greater mass hanging below it. The force of tension is equal and opposite to the force of gravity, so since $F_g = mg$ and the mass is greater at point P than point Q, the F_T is greater at point P than point Q.

$F_T = -F_g$

(b) A student hypothesizes that increasing the tension in a rope increases the speed at which waves travel along the rope. In a clear, coherent paragraph-length response that may also contain figures and/or equations, explain why the standing wave shown above supports the student's hypothesis.

The wavelength (λ) at point P is greater than that at point Q. Since $v \propto \lambda$ as shown by $v = \lambda f$, the velocity at point P must also be greater than point Q. Since point P and point Q are on the same string and only their tensions differ, the greater tension at point P correlates with the greater wavelength and therefore speed.

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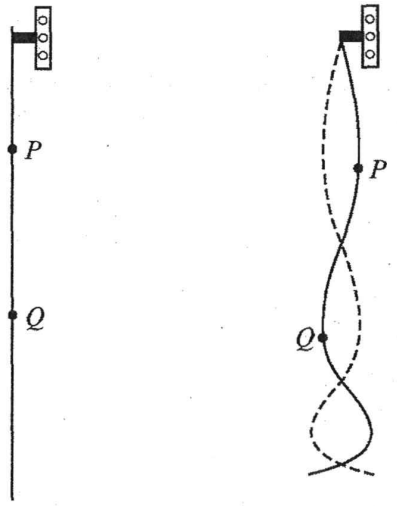
P1 Q5 B1



5. (7 points, suggested time 13 minutes)

The figure above on the left shows a uniformly thick rope hanging vertically from an oscillator that is turned off. When the oscillator is on and set at a certain frequency, the rope forms the standing wave shown above on the right. P and Q are two points on the rope.

(a) The tension at point P is greater than the tension at point Q. Briefly explain why.

The tension is greater at point P than the tension at Point Q because the segment of the wave that point P is on has a longer wavelength so it has a more Tension

(b) A student hypothesizes that increasing the tension in a rope increases the speed at which waves travel along the rope. In a clear, coherent paragraph-length response that may also contain figures and/or equations, explain why the standing wave shown above supports the student's hypothesis.

Increasing the tension in a rope increases the speed at which waves travel along a rope. This is illustrated in the diagram above since point P has more tension than point Q, and clearly has a longer wavelength, there is an increase in speed. This is proven by the equation $V = f\lambda$. Since velocity and wavelength have a direct relationship, and wavelength and tension have a direct relationship, if one goes up, they all must go up.

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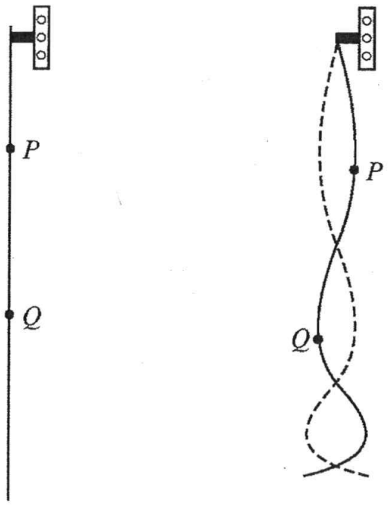

5. (7 points, suggested time 13 minutes)

The figure above on the left shows a uniformly thick rope hanging vertically from an oscillator that is turned off. When the oscillator is on and set at a certain frequency, the rope forms the standing wave shown above on the right. P and Q are two points on the rope.

(a) The tension at point P is greater than the tension at point Q. Briefly explain why.

The tensions at points P and Q have something to do with mass. Since the length of the rope below the point P is longer than the rope below Q, there is a stronger gravitational force at point P.

(b) A student hypothesizes that increasing the tension in a rope increases the speed at which waves travel along the rope. In a clear, coherent paragraph-length response that may also contain figures and/or equations, explain why the standing wave shown above supports the student's hypothesis.

Increasing the tension can mean increasing the length of the rope b/c the longer a rope is, the heavier it is. And the longer a rope is, the longer the period is, according to the equation, $T_p = 2\pi\sqrt{\frac{L}{g}}$. Since $T > \frac{1}{f}$ and speed is inversly proportional to f ($\lambda = \frac{v}{f}$), the increase in the period results in the increase in the speed of the wave.

AP® PHYSICS 1
2016 SCORING COMMENTARY

Question 5

Overview

This question assessed learning objectives 3.A.3.1, 3.B.1.1, 3.B.2.1, 6.A.1.2, 6.D.3.2, and 6.D.3.4. The question assessed the understanding of how tension is created by a hanging weight, balancing forces, and the relationship between the basic characteristics of a wave. The student had to create a scientific explanation in a coherent paragraph from a described observation and image.

Sample: P1 Q5 A
Score: 7

In part (a) both points were earned for indicating that there is more rope weight supported at point *P* and relating this to the rope tension. In part (b) 5 points were earned. Four points were earned for correctly indicating the longer wavelength at point *P*, the implication of equal frequencies throughout the rope, relating the longer wavelength to a greater wave speed, and relating these to the greater tension at point *P*. A fifth point was earned in part (b) for a response with sufficient paragraph structure.

Sample: P1 Q5 B
Score: 5

In part (a) no points were earned because there is no mention of the greater rope length or weight below point *P*, and no relation of the tension to the supported weight. In part (b) all 5 points were earned. That the frequency is the same throughout the rope is implied in this particular usage of the relation between wave speed, wavelength, and frequency.

Sample: P1 Q5 C
Score: 2

In part (a) both points were earned for indicating that there is more rope below point *P* and relating this to a stronger gravitational force and, by implication, rope tension. In part (b) no points were earned. The extraneous information relating the length and period of a pendulum means that the published requirements for the paragraph-length response are not met.