2024

AP® Physics 1: Algebra-Based

Sample Student Responses and Scoring Commentary

Inside:

Free-Response Question 4

- ☑ **Scoring Guidelines**
- ☑ **Student Samples**
- ☑ **Scoring Commentary**

Question 4: Paragraph — 7 points

(a) For indicating **one** of the following: **1 point**

- That the gravitational force would be smaller for a greater radius
- That the gravitational field strength would be smaller for a greater radius
- That the acceleration due to gravity would be smaller for a greater radius

For indicating **one** of the following: **1 point**

- The sphere travels the same vertical distance in both scenarios
- The amount of work done on the sphere is dependent on the magnitude of the gravitational force
- The change in gravitational potential energy is less on Planet X

Example Response

The mass is the same and the radius is larger, so the force of gravity is less. The work done depends on the force times distance. Because the distance is the same, the work is less.

Total for part (a) 2 points

(b) For relating a larger planetary mass to a **one** of the following: **1 point**

- A larger weight of the sphere
- A larger acceleration due to gravity g
- A larger gravitational field strength

For indicating that the period is inversely related to **one** of the following: **1 point**

- The acceleration due to gravity g
- The gravitational field strength

For indicating that the amount of stretch is dependent on **one** of the following: **1 point**

- The weight of the sphere
- The acceleration due to gravity g
- The gravitational field strength

For relating the length of the string to the period of the pendulum **1 point**

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

Example Response

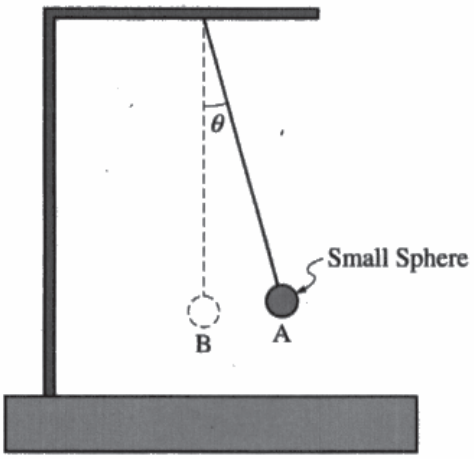
$T = 2\pi\sqrt{\frac{\ell}{g}}$. *On Planet* Y *the gravitational force on the sphere is larger than when on Earth. Therefore, the sphere will experience a larger acceleration due to gravity on Planet* Y*. Because "g" is in the denominator of the equation, a larger acceleration due to gravity leads to a potentially smaller period. However, the increased gravitational force exerted on the sphere by Planet* Y *could result in the string stretching. This could result in the length of the pendulum increasing. Because* T *increases with the length of the pendulum, a longer string could potentially lead to a larger period.*

Total for part (b) 5 points

Total for question 4 7 points

Question 4

Begin your response to **QUESTION 4** on this page.



4. (7 points, suggested time 13 minutes)

A simple pendulum consists of a small sphere that hangs from a string with negligible mass. The top end of the string is fixed. The sphere is pulled to Point A so that the string makes a small angle θ with the vertical, as shown. The sphere is then released from rest and swings through its lowest point at Point B. The work done on the sphere by Earth between points A and B is W_E. $W = Fd = \Delta E = Fd\cos\theta$

The pendulum is then taken to Planet X. The mass of Planet X is the same as the mass of Earth, but the radius of Planet X is greater than the radius of Earth. The sphere is again brought to Point A (displaced θ from the vertical), released from rest, and swings through its lowest point at Point B. The work done on the sphere by Planet X between points A and B is W_X.

(a) **Justify** why W_X is less than W_E.

$W = Fd\cos\theta$

Force here is due to gravity. $F_g = \frac{Gm_1m_2}{r^2}$, on planet X the radius from center to the pendulum is greater. If r is greater, than according to this F_g would be less. If the F_g is less on planet X than on earth than the work will also be less because $W = Fd\cos\theta$.

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Question 4

Continue your response to **QUESTION 4** on this page.

A new pendulum is made by hanging the same small sphere from a different string with negligible mass. The new string is slightly elastic, and the length of the string may increase or decrease depending on the tension applied to the string. On Earth, when the sphere is again displaced θ from the vertical and released from rest, the new pendulum oscillates with period T_E.

The new pendulum is then taken to a different planet, Planet Y. The radius of Planet Y is the same as the radius of Earth, but the mass of Planet Y is larger than the mass of Earth. On Planet Y, when the sphere is again displaced from the vertical and released from rest, the new pendulum oscillates with period T_Y.

(b) In a clear, coherent paragraph-length response that may also contain drawings, **explain** how T_Y could be larger than T_E but also could be smaller than T_E.

If planet Y has a greater mass but same radius, than F_g would increase according to $F_g = \frac{Gmm}{r^2}$. If the force is greater on planet y the string will stretch more and cause l to increase. According to $T = 2\pi\sqrt{\frac{l}{g}}$ if l increases so will T.

$T = 2\pi\sqrt{\frac{m}{k}}$ $T = 2\pi\sqrt{\frac{l}{g}}$

$\frac{m}{k} = \frac{l}{g}$

However, if F_g increases, then g also increases according to $g = \frac{F_g}{m}$. and if g increases then according to $T = 2\pi\sqrt{\frac{l}{g}}$ the period T would decrease.

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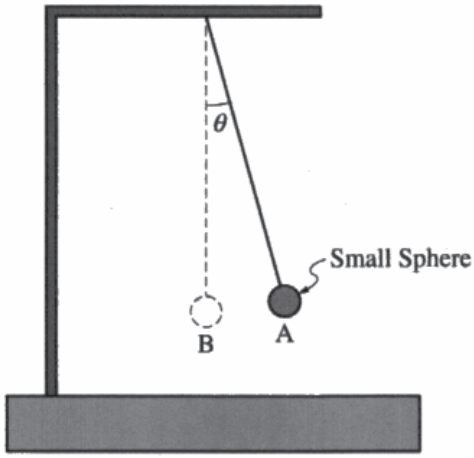

4. (7 points, suggested time 13 minutes)

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The pendulum is then taken to Planet X. The mass of Planet X is the same as the mass of Earth, but the radius of Planet X is greater than the radius of Earth. The sphere is again brought to Point A (displaced θ from the vertical), released from rest, and swings through its lowest point at Point B. The work done on the sphere by Planet X between points A and B is W_X.

(a) **Justify** why W_X is less than W_E.

According to the equation $g = \frac{Gm}{r^2}$ where g is the gravitational field strength a planet with a bigger radius compared to that of another would have a lower field strength and therefore less acceleration due to gravity

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The new pendulum is then taken to a different planet, Planet Y. The radius of Planet Y is the same as the radius of Earth, but the mass of Planet Y is larger than the mass of Earth. On Planet Y, when the sphere is again displaced from the vertical and released from rest, the new pendulum oscillates with period T_Y.

(b) In a clear, coherent paragraph-length response that may also contain drawings, **explain** how T_Y could be larger than T_E but also could be smaller than T_E.

T_Y could be larger than T_E because it is not explicitly stated if the displacement of the pendulum on Planet Y is equal to that on Earth. T_Y could very well be smaller than T_E aswell. This is due to the fact that according to $g = \frac{Gm}{r^2}$ where g is the gravitational field strength of a given planet and given that the mass of Planet y is larger than that of earth, the field strength and acceleration due to gravity will be greater on Planet Y than on earth resulting in what might very well be a shorter period, making $T_Y < T_E$

Question 4

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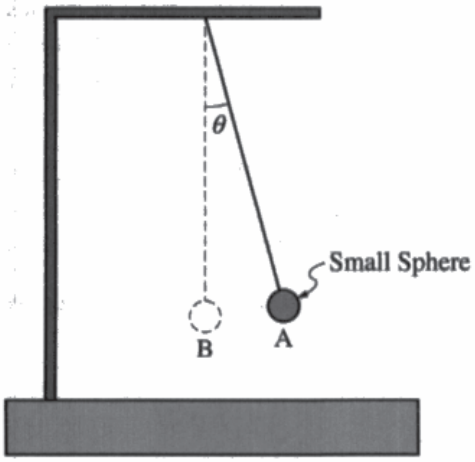

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(a) **Justify** why W_X is less than W_E.

Since the radius is greater than Earth's the work done will be less because $F_g = G\frac{m_E m_X}{R_X^2}$ since R is larger and all other numbers are the same, Fg on Planet X will be smaller. Which will consequently influence work since $W = Fd$ and gravity and tension are the forces responsible for pendulum function.

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(b) In a clear, coherent paragraph-length response that may also contain drawings, **explain** how T_Y could be larger than T_E but also could be smaller than T_E.

Ty could be larger due to Planet Y's greater mass, but as a result of the strings oscilations the spring's constant (k) must be considered producing uncertainty. Thus, the period T_y could be smaller with a large enough spring constant.

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Question 4

Note: Student samples are quoted verbatim and may contain spelling and grammatical errors.

Overview

The responses were expected to demonstrate the ability to:

- Explain how changing characteristics of a planet affect the gravitational force or acceleration near the planet's surface.
- Justify how work done by gravity will change if only the force of gravity changes in a scenario using the equation for work or the work-energy principle.
- Predict the effect of changing gravitational acceleration and pendulum length on the period of a pendulum.
- Predict the effect of changing force on the length of an elastic string.
- Construct a justification for why changing the gravitational force applied to an elastic pendulum could lead to an increase or a decrease in the period of the pendulum.

Sample: 4A
Score: 7

Part (a) earned 2 points. The first point was earned for correctly indicating the gravitational force would be smaller for a greater radius. The second point was earned for correctly indicating the amount of work done on the sphere is dependent on the magnitude of the gravitational force. Part (b) earned 5 points. The first point was earned for indicating the larger planetary mass leads to a larger gravitational force. This is equivalent to relating the planetary mass to a larger weight of the sphere. The second point was earned for correctly indicating the period is inversely related to the acceleration due to gravity g. The third point was earned for indicating the amount of stretch of the string is dependent on the weight of the sphere. The fourth point was earned for relating the length of the string to the period of the pendulum. The fifth point was earned for connecting several physics concepts in a logical, relevant, and internally consistent argument that addresses the required arguments.

Sample: 4B
Score: 4

Part (a) earned 1 point for correctly indicating the acceleration due to gravity would be smaller for a greater radius. The response would have also earned the point for indicating the gravitational field strength would be smaller due to a greater radius. The second point was not earned because the response does not indicate the sphere travels the same vertical distance in both scenarios, or that the amount of work done on the sphere is dependent on the magnitude of the gravitational force, or that the change in gravitational potential energy is less on Planet X. Part (b) earned 3 points. The first point was earned for correctly indicating the larger planetary mass leads to a larger gravitational field strength. The second point was earned for indicating T_{Y} will be smaller than T_{E} due to a larger gravitational field strength on Planet Y. The third point was not earned because the response does not indicate any cause for the amount of stretch of the string. The fourth point was not earned because the response does not relate the length of the string to the period of the pendulum. The fifth point was earned for connecting several physics concepts in a logical, relevant, and internally consistent argument that addresses the required argument.

Question 4 (continued)

Sample: 4C
Score: 2

Part (a) earned 2 points. The first point was earned for correctly indicating the gravitational force would be smaller for a greater radius. The second point was earned for indicating the amount of work done on the sphere is dependent on the magnitude of the gravitational force. Part (b) did not earn any points. The first point was not earned because the response does not relate the larger planetary mass to a larger weight or acceleration of the sphere or larger gravitational field. The second point was not earned because the response does not indicate the period is inversely related to the acceleration due to gravity g. The third point was not earned because the response does not relate the amount of stretch of the string to any of the possible options. The fourth point was not earned because the response does not relate the length of the string to the period of the pendulum. The fifth point was not earned because the response introduces only one physics idea and not given in the prompt so there are no multiple physics ideas combined in a logical, relevant, and internally consistent argument.