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Chapter 13

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Chapter 13

Due: 11:59pm on Tuesday, April 16, 2019

To understand how points are awarded, read the Grading Policy for this assignment.

± Gravitational Force of Three Identical Masses

Description: ± Includes Math Remediation. Calculate the net gravitational force on a mass at the origin exerted by two other identical masses, one on the positive x axis and one on the negative x axis.

Three identical very dense masses of 3400 kg each are placed on the *x* axis. One mass is at x_1 = -110 cm , one is at the origin, and one is at x_2 = 390 cm .

Part A

What is the magnitude of the net gravitational force $F_{\rm grav}$ on the mass at the origin due to the other two masses?

Take the gravitational constant to be G = 6.67×10^{-11} $\mathrm{N \cdot m^2/kg^2}$.

Express your answer in newtons to three significant figures.

Hint 1. How to approach the problem

Calculate the force on the mass at the origin, including magnitude and direction, exerted by each of the other masses, then use vector addition to find the total force on it.

Hint 2. Calculate the gravitational force from the first mass

Calculate the gravitational force F_1 exerted on the mass at the origin by the mass at x_1 = -110 cm .

Express your answer in newtons to three significant figures.

Hint 1. Law of gravitation

Recall that Newton's law of gravitation states that the force exerted on a mass m_1 by a second mass m_2 is

$$F = G\,\frac{m_1 m_2}{r^2},$$

where r is the distance between the two masses and 6.67×10^{-11} $\mathrm{N \cdot m^2/kg^2}$ is the gravitational constant.

ANSWER:

F_1 = $\frac{Gm^2}{(x_1)^2}$ = 6.37×10^{-4} N

Hint 3. Determine the direction of the gravitational force from the first mass

What is the direction of the gravitational force due to the mass at x_1 = -110 cm ?

ANSWER:

- ○ +*x* direction
- ● -*x* direction

Since the gravitational force is attractive, the mass at x_1 = -110 cm will pull the mass at the origin in the -*x* direction. An equal but opposite force will also be exerted by the mass at the origin on the mass at x_1 = -110 cm .

Hint 4. Calculate the gravitational force from the second mass

Calculate the gravitational force F_2 exerted on the mass at the origin by the mass at x_2 = 390 cm .

Express your answer in newtons to three significant figures.

Hint 1. Law of gravitation

Recall that Newton's law of gravitation states that the force exerted on a mass m_1 by a second mass m_2 is

$$F = G\frac{m_1 m_2}{r^2},$$

where r is the distance between the two masses and 6.67×10^{-11} $\mathrm{N \cdot m^2/kg^2}$ is the gravitational constant.

ANSWER:

F_2 = $\frac{Gm^2}{(x_2)^2}$ = 5.07×10^{-5} N

Hint 5. Determine the direction of the gravitational force from the second mass

What is the direction of the gravitational force due to the mass at x_2 = 390 cm ?

ANSWER:

- ● +*x* direction
- ○ -*x* direction

Since the gravitational force is attractive, the mass at x_2 = 390 cm will pull the mass at the origin in the +*x* direction. An equal but opposite force will also be exerted by the mass at the origin on the mass at x_2 = 390 cm .

ANSWER:

F_{grav} = $G\left(m^2\right)\left({x_1}^{-2} - {x_2}^{-2}\right)$ = 5.87×10^{-4} N

Part B

What is the direction of the net gravitational force on the mass at the origin due to the other two masses?

ANSWER:

- +*x* direction
- -*x* direction (selected)

The closer together two masses are, the stronger is the gravitational attraction between them. Thus, the mass at the origin is more strongly attracted to the mass at x_1 = -110 cm than it is to the mass at x_2 = 390 cm . Thus, the net force on the mass at the origin is in the -*x* direction.

Exercise 13.4

Description: Two uniform spheres, each with mass M and radius R, touch one another. (a) What is the magnitude of their gravitational force of attraction?

Two uniform spheres, each with mass M and radius R, touch one another.

Part A

What is the magnitude of their gravitational force of attraction?

Express your answer in terms of the variables M, R, and appropriate constants.

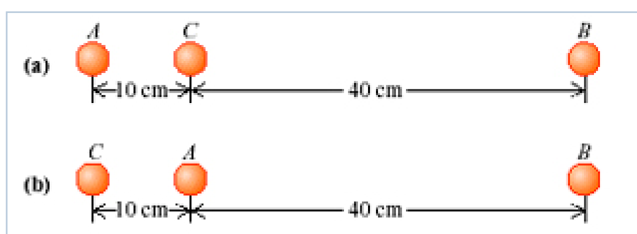
ANSWER:

$$\frac{GM^2}{4R^2}$$

Exercise 13.6

Description: Each mass is ## kg. (a) Find the magnitude of the net gravitational force on mass A due to masses B and C in the figure (a). (b) Find the direction of the net gravitational force on mass A due to masses B and C in the figure (a). (c) Find the...

Each mass is 1.00 kg .



Part A

Find the magnitude of the net gravitational force on mass A due to masses B and C in the figure (a).

ANSWER:

$F = m^2 \cdot 6.67 \cdot 10^{-11} \left(\frac{1}{0.01} + \frac{1}{0.25}\right)$ = 6.94×10^−9 N

Part B

Find the direction of the net gravitational force on mass A due to masses B and C in the figure (a).

ANSWER:

- ○ To the left
- ◉ To the right

Part C

Find the magnitude of the net gravitational force on mass A due to masses B and C in the figure (b).

ANSWER:

$F = m^2 \cdot 6.67 \cdot 10^{-11} \left(\frac{1}{0.01} - \frac{1}{0.16}\right)$ = 6.25×10^−9 N

Part D

Find the direction of the net gravitational force on mass A due to masses B and C in the figure (b).

ANSWER:

- ◉ To the left
- ○ To the right

Exercise 13.18

Description: Ten days after it was launched toward Mars in December 1998, the Mars Climate Orbiter spacecraft (mass 629 kg) was 2.87 * 10^6 (km) from the earth and traveling at 1.20 * 10^4 (km)/h relative to the earth. (a) At this time, what was the...

Ten days after it was launched toward Mars in December 1998, the *Mars Climate Orbiter* spacecraft (mass 629 kg) was $2.87 \times 10^6 \mathrm{~km}$ from the earth and traveling at $1.20 \times 10^4 \mathrm{~km/h}$ relative to the earth.

Part A

At this time, what was the spacecraft's kinetic energy relative to the earth?

ANSWER:

K = 3.49×10^{9} J

Part B

What was the potential energy of the earth-spacecraft system?

ANSWER:

U = -8.73×10^{7} J

Exercise 13.21

Description: (a) For a satellite to be in a circular orbit h above the surface of the earth, what orbital speed must it be given? (b) What is the period of the orbit (in hours)?

Part A

For a satellite to be in a circular orbit 710 km above the surface of the earth, what orbital speed must it be given?

Express your answer with the appropriate units.

ANSWER:

$$v_{\mathrm{orbital}} = \sqrt{\frac{6.67\cdot10^{-11}\cdot5.97\cdot10^{24}}{6.37\cdot10^{6}+h}} = 7500\,\frac{\mathrm{m}}{\mathrm{s}}$$

Part B

What is the period of the orbit (in hours)?

ANSWER:

$$T = \frac{2\pi\left(6.37\cdot10^{6}+h\right)}{\sqrt{\frac{6.67\cdot10^{-11}\cdot5.97\cdot10^{24}}{6.37\cdot10^{6}+h}}}\frac{1}{3600} = 1.65 \quad \mathrm{h}$$

Exercise 13.24

Description: The International Space Station makes 15.65 revolutions per day in its orbit around the earth. (a) Assuming a circular orbit, how high is this satellite above the surface of the earth?

The International Space Station makes 15.65 revolutions per day in its orbit around the earth.

Part A

Assuming a circular orbit, how high is this satellite above the surface of the earth?

ANSWER:

h = 380 km

Exercise 13.29

Description: The dwarf planet Pluto has an elliptical orbit with a semi-major axis of 5.91*10^12 m and eccentricity 0.249. (a) Calculate Pluto's orbital period. Express your answer in seconds. (b) Calculate Pluto's orbital period. Express your answer in...

The dwarf planet Pluto has an elliptical orbit with a semi-major axis of 5.91×10^{12} m and eccentricity 0.249.

Part A

Calculate Pluto's orbital period. Express your answer in seconds.

ANSWER:

T = 7.84×10^{9} s

Part B

Calculate Pluto's orbital period. Express your answer in earth years.

ANSWER:

T = 248 yr

Part C

During Pluto's orbit around the sun, what is its closest distance from the sun?

Express your answer with the appropriate units.

ANSWER:

d_{min} = 4.44×10^{12} m

Part D

During Pluto's orbit around the sun, what is its farthest distance from the sun?

Express your answer with the appropriate units.

ANSWER:

d_{max} = 7.38×10^{12} m

Problem 13.55

Description: An astronaut, whose mission is to go where no one has gone before, lands on a spherical planet in a distant galaxy. As she stands on the surface of the planet, she releases a small rock from rest and finds that it takes the rock t to fall 1.90 m. (a) ...

An astronaut, whose mission is to go where no one has gone before, lands on a spherical planet in a distant galaxy. As she stands on the surface of the planet, she releases a small rock from rest and finds that it takes the rock 0.410 s to fall 1.90 m.

Part A

If the radius of the planet is $8.60 \times 10^{7}\ \mathrm{m}$, what is the mass of the planet?

Express your answer to three significant figures and include the appropriate units.

ANSWER:

$$m_{\mathrm{p}} = \frac{3.8r^2}{t^2 \cdot 6.674 \cdot 10^{-11}} = 2.51 \times 10^{27}\ \mathrm{kg}$$

Problem 13.56

Description: Your starship, the Aimless Wanderer, lands on the mysterious planet Mongo. As chief scientist-engineer, you make the following measurements: a 2.50-kg stone thrown upward from the ground at v returns to the ground in t; the circumference...

Your starship, the *Aimless Wanderer,* lands on the mysterious planet Mongo. As chief scientist-engineer, you make the following measurements: a 2.50-kg stone thrown upward from the ground at 13.0 $\mathrm{m/s}$ returns to the ground in 4.50 s ; the circumference of Mongo at the equator is $3.00 \times 10^{5}\ \mathrm{km}$; and there is no appreciable atmosphere on Mongo.

Part A

The starship commander, Captain Confusion, asks for the following information: what is the mass of Mongo?

Express your answer with the appropriate units.

ANSWER:

$$m = \frac{\frac{\frac{\frac{vL^2}{2}}{\pi^2}}{6.673 \cdot 10^{-11}}}{t} = 1.97 \times 10^{26}\ \mathrm{kg}$$

Part B

If the *Aimless Wanderer* goes into a circular orbit 30,000 km above the surface of Mongo, how many hours will it take the ship to complete one orbit?

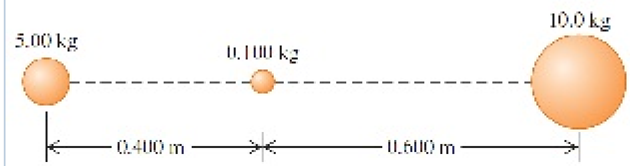
ANSWER:

$$t = \frac{\frac{4\pi^2}{L}\sqrt{\frac{t\left(\frac{L}{2\pi}+s\right)^3}{\frac{v}{2}}}}{3600} = 10.4\ \mathrm{h}$$

Problem 13.58

Description: The 0.100-kg sphere is released from rest at the position shown in the sketch, with its center 0.400 m from the center of the 5.00-kg mass. Assume that the only forces on the 0.100-kg sphere are the gravitational forces exerted by the other two...

The 0.100-kg sphere is released from rest at the position shown in the sketch, with its center 0.400 m from the center of the 5.00-kg mass. Assume that the only forces on the 0.100-kg sphere are the gravitational forces exerted by the other two spheres and that the 5.00-kg and 10.0-kg spheres are held in place at their initial positions.



Part A

What is the speed of the 0.100-kg sphere when it has moved 0.200 m to the left from its initial position?

Express your answer to three significant figures and include the appropriate units.

ANSWER:

v = $3.33\times10^{-5}\ \frac{\mathrm{m}}{\mathrm{s}}$

Problem 13.68

Description: A rocket with mass m is in a circular orbit of radius r_i around the earth. The rocket's engines fire for a period of time to increase that radius to r_f, with the orbit again circular. (a) What is the change in the rocket's kinetic...

A rocket with mass $4.00\times10^{3}\ \mathrm{kg}$ is in a circular orbit of radius $7.10\times10^{6}\ \mathrm{m}$ around the earth. The rocket's engines fire for a period of time to increase that radius to $8.60\times10^{6}\ \mathrm{m}$, with the orbit again circular.

Part A

What is the change in the rocket's kinetic energy? Does the kinetic energy increase or decrease?

Express your answer with the appropriate units. Enter positive value if the kinetic energy increases and negative value if the kinetic energy decreases.

ANSWER:

ΔK = $\frac{1}{2}m\cdot5.97\cdot10^{24}\left(6.67\cdot10^{-11}\right)\left(\frac{1}{r_f}-\frac{1}{r_i}\right)$ = $-1.96\times10^{10}\,\mathrm{J}$

Part B

What is the change in the rocket's gravitational potential energy? Does the potential energy increase or decrease?

Express your answer with the appropriate units. Enter positive value if the gravitational potential energy increases and negative value if the gravitational potential energy decreases.

ANSWER:

ΔU = $m \cdot 5.97 \cdot 10^{24}\left(6.67 \cdot 10^{-11}\right)\left(\frac{-1}{r_f}+\frac{1}{r_i}\right)$ = $3.91 \times 10^{10}\,\mathrm{J}$

Part C

How much work is done by the rocket engines in changing the orbital radius?

Express your answer with the appropriate units.

ANSWER:

W = $\frac{1}{2} m \cdot 5.97 \cdot 10^{24}\left(6.67 \cdot 10^{-11}\right)\left(\frac{-1}{r_f}+\frac{1}{r_i}\right)$ = $1.96 \times 10^{10}\,\mathrm{J}$

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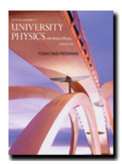

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