HW #2: Kinematics in two dimensions

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HW #2: Kinematics in two dimensions

Due: 11:59pm on Wednesday, September 18, 2024

You will receive no credit for items you complete after the assignment is due. Grading Policy

Problem 3.34

Description: You are fixing the roof of your house when a hammer breaks loose and slides down. The roof makes an angle of theta with the horizontal, and the hammer is moving at v when it reaches the edge. Assume that the hammer is moving from the top...

You are fixing the roof of your house when a hammer breaks loose and slides down. The roof makes an angle of 45° with the horizontal, and the hammer is moving at 9.5 $\mathrm{m/s}$ when it reaches the edge. Assume that the hammer is moving from the top of the roof to its right edge.

Part A

What is the horizontal component of the hammer's velocity just as it leaves the roof?

Express your answer with the appropriate units. Enter positive value if the x-component of the velocity is to the right and negative value if the x-component of the velocity is to the left.

ANSWER:

v_x = $v\cos(\theta)$ = 6.7 $\frac{\mathrm{m}}{\mathrm{s}}$

Also accepted: $v\cos(\theta)$ = 6.72 $\frac{\mathrm{m}}{\mathrm{s}}$, $v\cos(\theta)$ = 6.7 $\frac{\mathrm{m}}{\mathrm{s}}$

Part B

What is the vertical component of the hammer's velocity just as it leaves the roof?

Express your answer with the appropriate units. Enter positive value if the direction of the y-component of the velocity is upward and negative value if the y-component of the velocity is downward.

ANSWER:

v_y = $-v\sin(\theta)$ = -6.7 $\frac{\mathrm{m}}{\mathrm{s}}$

Also accepted: $-v\sin(\theta)$ = -6.72 $\frac{\mathrm{m}}{\mathrm{s}}$, $-v\sin(\theta)$ = -6.7 $\frac{\mathrm{m}}{\mathrm{s}}$

Problem 3.31 - Enhanced - with Video Tutor Solution

Description: Ruth sets out to visit her friend Ward, who lives ## mi north and 100 mi east of her. She starts by driving east, but after ## mi she comes to a detour that takes her 15 mi south before going east again. She then drives east for 8 mi and runs out of...

Ruth sets out to visit her friend Ward, who lives 60 mi north and 100 mi east of her. She starts by driving east, but after 60 mi she comes to a detour that takes her 15 mi south before going east again. She then drives east for 8 mi and runs out of gas, so Ward flies there in his small plane to get her.

Part A

What is Ward's displacement vector? Give your answer in component form, using a coordinate system in which the y-axis points north.

Express your answers in miles and separated by a comma.

Hint 1. How to approach the problem

Use the point where Ruth starts her travel as the origin. Find vectors whose components are easy to determine and whose sum or difference equals the displacement vector. Use them to find the components of the displacement vector.

ANSWER:

r_x, r_y = $l_x + 8 - 100,\ -15 - l_y$ = -32, -75 mi

Also accepted: $l_x + 8 - 100,\ -15 - l_y$ = -32.0, -75.0, $l_x + 8 - 100,\ -15 - l_y$ = -32, -75

Part B

What is the magnitude of Ward's displacement vector?

Express your answer in miles.

Hint 1. How to approach the problem

Recall how to find the magnitude of a vector if you know its x- and y-components. Notice how this rule differs from determining a vector from its component vectors.

ANSWER:

r = $\sqrt{(l_x+8-100)^2+(15+l_y)^2}$ = 82 mi

Also accepted: $\sqrt{(l_x+8-100)^2+(15+l_y)^2}$ = 81.5, $\sqrt{(l_x+8-100)^2+(15+l_y)^2}$ = 82

Part C

What is the direction of Ward's displacement vector?

Express your answer in degrees measured clockwise from the negative y-axis.

Hint 1. How to approach the problem

Mark the angle in the xy-plane and choose the appropriate expression to find it using the x- and y-components of the vector.

ANSWER:

θ = $\mathrm{atan}\left(\frac{100-l_x-8}{15+l_y}\right)$ = 23 $\circ$

Also accepted: $\mathrm{atan}\left(\frac{100-l_x-8}{15+l_y}\right)-360$ = -337, $\mathrm{atan}\left(\frac{100-l_x-8}{15+l_y}\right)$ = 23.1, $\mathrm{atan}\left(\frac{100-l_x-8}{15+l_y}\right)$ = 23

Problem 4.12 - Enhanced - with Video Solution

Description: [[Video Tutor Solution]] A supply plane needs to drop a package of food to scientists working on a glacier in Greenland. The plane flies ## m above the glacier at a speed of ## m/s.For help with math skills, you may want to review: Mathematical...

A supply plane needs to drop a package of food to scientists working on a glacier in Greenland. The plane flies 200 m above the glacier at a speed of 200 $\mathrm{m/s}$.

For help with math skills, you may want to review: Mathematical Expressions Involving Squares

For general problem-solving tips and strategies for this topic, you may want to view a Video Tutor Solution of Dock jumping.

Part A

How far short of the target should it drop the package?

Express your answer with the appropriate units.

ANSWER:

$v\sqrt{\frac{2h}{9.81}}$ = 1300m

Also accepted: $v\sqrt{\frac{2h}{9.81}}$ = 1280m, $v\sqrt{\frac{2h}{9.8}}$ = 1300m

Problem 4.17 - Enhanced - with Expanded Hints

Description: [[Enhanced item has hints walking students through the problem-solving steps. All parts and hints contain wrong answer feedback, with a worked solution available upon completing the part.]] On the Apollo 14 mission to the moon, astronaut Alan Shepard...

On the Apollo 14 mission to the moon, astronaut Alan Shepard hit a golf ball with a 6 iron. The acceleration due to gravity on the moon is 1/6 of its value on earth. Suppose he hits the ball with a speed of 10 $\mathrm{m/s}$ at an angle 50 $^\circ$ above the horizontal.

For help with math skills, you may want to review: Quadratic Equations

Part A

How much farther did the ball travel on the moon than it would have done on earth?

Express your answer with the appropriate units.

Hint 1. How to approach the problem

Start by drawing a picture of the golf ball's path, showing its starting and ending points. Choose a coordinate system, and label the origin (it is conventional to let *x* be the horizontal direction and *y* the vertical direction). Some information you should note are the x and y components of the initial velocity as well as the acceleration. Next, apply the equations for x and y as a function of time, $x\left(t\right)$ and $y\left(t\right)$. Given the final position of the ball upon hitting the ground, you should be able to combine these two equations to solve for the total distance traveled in each case.

Hint 2. Simplify: distance equation

Using the kinematic equation for the vertical position of the ball, you can find the expression for its flight time and then insert it into the equation for the ball's horizontal position.

Derive the expression for the horizontal distance traveled in terms of the ball's initial velocity v_0, the launch angle θ, and the free-fall acceleration g.

Express your answer in terms of v_0, θ, and g.

ANSWER:

$$\Delta x = \frac{2{v_0}^2 \sin(\theta)\cos(\theta)}{g}$$

Also accepted: $\frac{{v_0}^2 \sin(2\theta)}{g}$, $\frac{2{v_0}^2 \sin(\theta)\cos(\theta)}{g}$

Hint 3. Simplify: distance traveled on the moon

Calculate the horizontal distance traveled by the ball on the moon.

Express your answer with the appropriate units.

ANSWER:

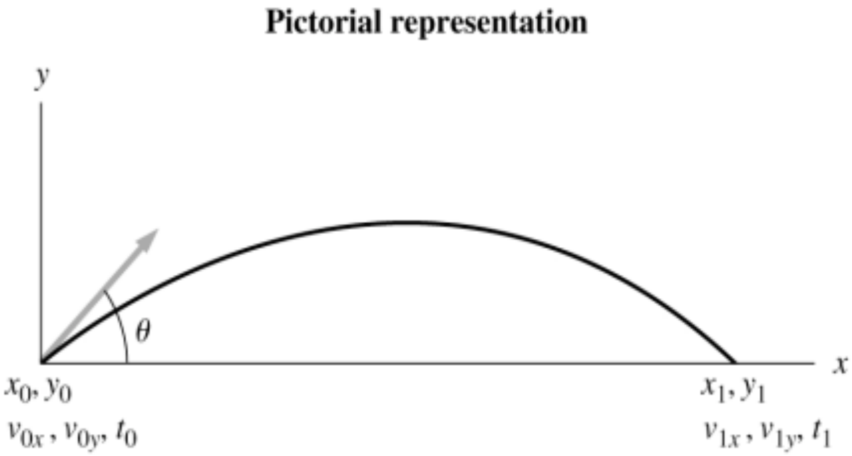
$$(\Delta x)_{\mathrm{moon}} = \frac{6 \cdot 2v^2 \sin(\theta)\cos(\theta)}{9.8} = 60.3\,\mathrm{m}$$

ANSWER:

$$L = \frac{5\left(v^2\right)\sin(2\theta)}{9.8} = 50\,\mathrm{m}$$

MODEL: The golf ball is a particle following projectile motion.

VISUALIZE:



Known

$x_0 = y_0 = t_0 = 0$
$v_0 = 10 \text{ m/s}$
$\theta = 50^\circ$
$a_x = 0$
$a_y = -g$
$g_{\text{earth}} = 9.8 \text{ m/s}^2$
$g_{\text{moon}} = g_{\text{earth}}/6$

Find

x_1, t_1

SOLVE: The distance traveled is $x_1 = v_{0x}t_1 = v_0 \cos\theta\, t_1$. The flight time is found from the y-equation, using the fact that the ball starts and ends at $y = 0$:

$$y_1 - y_0 = 0 = v_0 \sin\theta\, t_1 - \frac{1}{2}gt_1^2 = (v_0 \sin\theta - \frac{1}{2}gt_1)t_1 \Rightarrow t_1 = \frac{2v_0 \sin\theta}{g}$$

Thus the distance traveled is

$$x_1 = v_0 \cos\theta \times \frac{2v_0 \sin\theta}{g} = \frac{2v_0^2 \sin\theta \cos\theta}{g}$$

For $\theta = 50^\circ$, the distances are

$$(x_1)_{\text{earth}} = \frac{2v_0^2 \sin\theta \cos\theta}{g_{\text{earth}}} = \frac{2(10 \text{ m/s})^2 \sin 50^\circ \cos 50^\circ}{9.80 \text{ m/s}^2} = 10.0 \text{ m}$$

$$(x_1)_{\text{moon}} = \frac{2v_0^2 \sin\theta \cos\theta}{g_{\text{moon}}} = \frac{2v_0^2 \sin\theta \cos\theta}{g_{\text{earth}}/6} = 6 \times \frac{2v_0^2 \sin\theta \cos\theta}{g_{\text{earth}}} = 6(x_1)_{\text{earth}} = 60.3 \text{ m}$$

The golf ball travels $60.3 \text{ m} - 10.0 \text{ m} = 50.2 \text{ m} \approx 50 \text{ m}$ farther on the moon than on earth.

Part B

For how much more time was the ball in flight?

Express your answer with the appropriate units.

Hint 1. How to approach the problem

Now that you know the horizontal range, you can use either of your equations from the previous part, $x(t)$ and $y(t)$, to solve for the time.

Hint 2. Simplify: time equation

Given that the initial and final positions of the ball are at the same height, derive the expression for the flight time in terms of the ball's initial velocity v_0, the launch angle θ, and the free-fall acceleration g.

Express your answer in terms of v_0, θ, and g.

ANSWER:

$t = \frac{2v_0 \sin(\theta)}{g}$

Hint 3. Simplify: flight time on the moon

Calculate the flight time of the ball on the moon.

Express your answer in seconds.

ANSWER:

$t_{\text{moon}} = \frac{6 \cdot 2v \sin(\theta)}{9.8} = 9.38 \ \text{s}$

ANSWER:

$t = \frac{10v \sin(\theta)}{9.8} = 7.8 \text{s}$

The flight times are

$$(t_1)_{\text{earth}} = \frac{2v_0 \sin\theta}{g_{\text{earth}}} = \frac{2(10 \text{ m/s}) \sin 50^\circ}{9.80 \text{ m/s}^2} = 1.56 \text{ s}$$

$$(t_1)_{\text{moon}} = \frac{2v_0 \sin\theta}{g_{\text{moon}}} = \frac{2v_0 \sin\theta}{g_{\text{earth}}/6} = 6(t_1)_{\text{earth}} = 9.38 \text{ s}$$

The ball spends $9.38 \text{ s} - 1.56 \text{ s} = 7.82 \text{ s} \approx 7.8 \text{ s}$ longer in flight on the moon.

Problem 4.21 - Enhanced - with Hints and Feedback

Description: A kayaker needs to paddle north across a 100-m-wide harbor. The tide is going out, creating a tidal current that flows to the east at 2.0 m/s. The kayaker can paddle with a speed of 3.0 m/s. (a) In which direction should he paddle in order to travel...

A kayaker needs to paddle north across a 100-m-wide harbor. The tide is going out, creating a tidal current that flows to the east at 2.0 m/s. The kayaker can paddle with a speed of 3.0 m/s.

Part A

In which direction should he paddle in order to travel straight across the harbor?

Express your answer in degrees measured north of east.

Hint 1. How to approach the question

Use the Galilean transformation of velocity to express the kayaker's velocity with respect to the earth in terms of his direction angle. In order to go straight north in the earth frame, the component of the kayaker's velocity in the east-west direction must equal 0.

ANSWER:

$\theta =$ 132 $^\circ$ north of east

Part B

How long will it take him to cross?

Express your answer in seconds.

Hint 1. How to approach the question

After you determine the direction in which the kayaker needs to paddle, calculate the northward component of his velocity. Knowing the distance and velocity, it's quite simple to find the corresponding time.

ANSWER:

$t =$ 45 s

Also accepted: 44.7, 45

Problem 4.22

Description: Susan, driving north at ## mph, and Shawn, driving east at ## mph, are approaching an intersection. (a) What is Shawn's speed relative to Susan's reference frame?

Susan, driving north at 48 mph , and Shawn, driving east at 65 mph , are approaching an intersection.

Part A

What is Shawn's speed relative to Susan's reference frame?

Express your answer with the appropriate units.

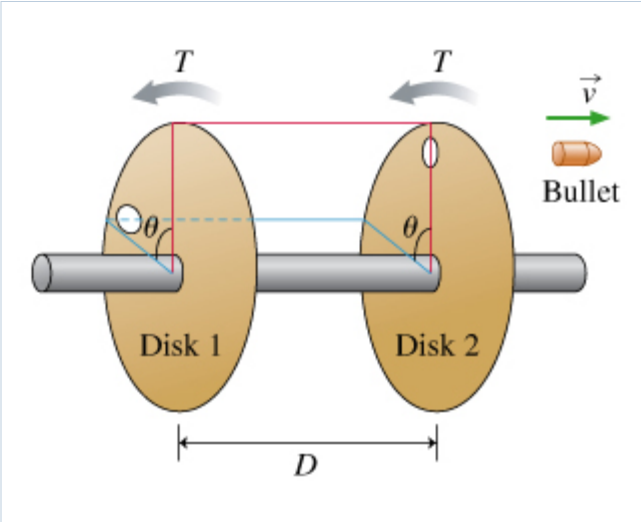
ANSWER:

$v_{relative} =$ $\sqrt{(v1^2+v2^2)}$ = 81mph

Speed of a Bullet

Description: This problem reviews speed from the angle between bullet holes in two disks following a standard experiment.

A bullet is shot through two cardboard disks attached a distance D apart to a shaft turning with a rotational period T, as shown.



Part A

Derive a formula for the bullet speed v in terms of D, T, and a measured angle θ between the position of the hole in the first disk and that of the hole in the second. If required, use π, not its numeric equivalent. Both of the holes lie at the same radial distance from the shaft. θ measures the angular displacement between the two holes; for instance, $\theta = 0$ means that the holes are in a line and $\theta = \pi$ means that when one hole is up, the other is down. Assume that the bullet must travel through the set of disks within a single revolution.

Hint 1. Consider hole positions

The relative position of the holes can be used to find the bullet's speed. Remember, the shaft will have rotated while the bullet travels between the disks.

Hint 2. How long does it take for the disks to rotate by an angle θ?

The disks rotate by 2 π in time T. How long will it take them to rotate by θ?

Give your answer in terms of T, θ, and constants such as π.

Hint 1. Checking your formula

If your formula is correct, when you plug 2 π in for θ, your answer will be T.

ANSWER:

$$T_\theta = \frac{T\theta}{2\pi}$$

You know that the bullet went a distance D in the time it took for the disks to rotate by θ.

ANSWER:

$$v = \frac{2\pi D}{\theta T}$$

Problem 4.33 - Enhanced - with Hints and Feedback

Description: The radius of the earth's very nearly circular orbit around the sun is 1.5 * 10^11 (m). (a) Find the magnitude of the earth's velocity. Assume a year of 365 days. (b) Find the magnitude of the earth's angular velocity. (c) Find the magnitude of...

The radius of the earth's very nearly circular orbit around the sun is $1.5 \times 10^{11}\ \mathrm{m}$.

Part A

Find the magnitude of the earth's velocity. Assume a year of 365 days.

Express your answer with the appropriate units.

Hint 1. How to find the earth's velocity

Recall the relationship between velocity, displacement, and time. In this case, displacement is the length of the earth's orbit around the sun, and time is the period of the earth's motion.

ANSWER:

$v = 3.0\times10^{4}\ \frac{\mathrm{m}}{\mathrm{s}}$

Also accepted: $2.99\times10^{4}\ \frac{\mathrm{m}}{\mathrm{s}}$, $3.0\times10^{4}\ \frac{\mathrm{m}}{\mathrm{s}}$

Part B

Find the magnitude of the earth's angular velocity.

Express your answer in radians per second.

Hint 1. How to find the earth's angular velocity

Angular velocity is the rate at which a particle's angular position is changing as it moves around a circle. To calculate it, you only need to know angular displacement and period, not the radius of motion.

ANSWER:

$\omega = 2.0\times10^{-7}\ \mathrm{rad/s}$

Also accepted: 1.99×10^{-7}, 2.0×10^{-7}

Part C

Find the magnitude of the earth's centripetal acceleration as it travels around the sun.

Express your answer with the appropriate units.

Hint 1. How to find the earth's centripetal acceleration

After you solve the previous parts, you can use the expression for centripetal acceleration either in terms of linear velocity and radius or in terms of angular velocity and radius.

ANSWER:

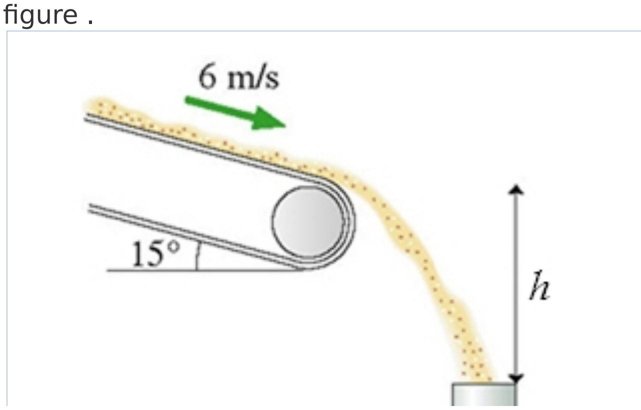
$a_r = 6.0\times10^{-3}\ \frac{\mathrm{m}}{\mathrm{s}^2}$

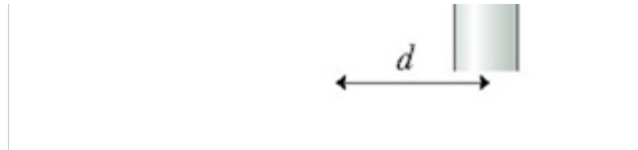
Also accepted: $5.95\times10^{-3}\ \frac{\mathrm{m}}{\mathrm{s}^2}$, $6.0\times10^{-3}\ \frac{\mathrm{m}}{\mathrm{s}^2}$

Problem 4.56

Description: Sand moves without slipping at 6.0 m/s down a conveyer that is tilted at 15 degree(s). The sand enters a pipe h=## m below the end of the conveyer belt, as shown in the figure . (a) What is the horizontal distance d between the conveyer belt and the...

Sand moves without slipping at 6.0 $\mathrm{m/s}$ down a conveyer that is tilted at 15°. The sand enters a pipe h = 4.9 m below the end of the conveyer belt, as shown in the figure .





Part A

What is the horizontal distance d between the conveyer belt and the pipe?

Express your answer with the appropriate units.

ANSWER:

d = $0.5914\left(-1.55+4.427\sqrt{0.1226+h}\right)$ = 5.0m

Problem 4.65 - Enhanced - with Hints and Feedback

Description: A typical laboratory centrifuge rotates at w rpm. Test tubes have to be placed into a centrifuge very carefully because of the very large accelerations. (a) What is the acceleration at the end of a test tube that is 10 cm from the axis of...

A typical laboratory centrifuge rotates at 3400 rpm. Test tubes have to be placed into a centrifuge very carefully because of the very large accelerations.

Part A

What is the acceleration at the end of a test tube that is 10 cm from the axis of rotation?

Express your answer with the appropriate units.

Hint 1. How to approach the question

Use the expression for radial acceleration in terms of angular velocity and the radius of rotation. Note that you need to convert angular velocity to radians per second.

ANSWER:

a = $\frac{w^2}{10}$ = $1.3\times10^4 \frac{\mathrm{m}}{\mathrm{s}^2}$

Also accepted: $\frac{w^2}{10}$ = $1.27\times10^4 \frac{\mathrm{m}}{\mathrm{s}^2}$, $\frac{w^2}{10}$ = $1.3\times10^4 \frac{\mathrm{m}}{\mathrm{s}^2}$

Part B

For comparison, what is the magnitude of the acceleration a test tube would experience if dropped from a height of $1.0\ \mathrm{m}$ and stopped in a 1.3-ms-long encounter with a hard floor?

Express your answer with the appropriate units.

Hint 1. How to approach the question

The tube is undergoing free-fall motion. Use the appropriate kinematic equations. Note that you need to convert time from milliseconds to seconds.

ANSWER:

$a = \frac{4.43}{t} \cdot 10^3 = 3400 \frac{\mathrm{m}}{\mathrm{s}^2}$

Also accepted: $\frac{4.43}{t} \cdot 10^3 = 3410 \frac{\mathrm{m}}{\mathrm{s}^2}$, $\frac{4.43}{t} \cdot 10^3 = 3400 \frac{\mathrm{m}}{\mathrm{s}^2}$

< All Assignments

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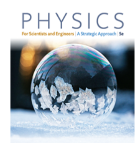

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