Midterm 1 - Problem 1

Midterm 1 - Problem 1

Due: 12:22pm on Sunday, November 15, 2020

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Problem 1

Consider the vector $\vec{A} = 2.0\hat{i} - 4.0\hat{k}$.

Part A

Construct a unit vector that is parallel to $\vec{A}$.

Enter the x, y, and z components of the vector separated by commas.

ANSWER:

a_x , a_y, a_z = $\frac{Ax}{\sqrt{(Ax^2+Az^2)}}, 0, \frac{Az}{\sqrt{(Ax^2+Az^2)}}$ = 0.45, 0, -0.89

Also accepted: $\frac{Ax}{\sqrt{(Ax^2+Az^2)}}, 0, \frac{Az}{\sqrt{(Ax^2+Az^2)}}$ = 0.447, 0, -0.894, $\frac{Ax}{\sqrt{(Ax^2+Az^2)}}, 0, \frac{Az}{\sqrt{(Ax^2+Az^2)}}$ = 0.45, 0, -0.89

Part B

Construct a unit vector that is antiparallel to $\vec{A}$.

Enter the x, y, and z components of the vector separated by commas.

ANSWER:

b_x, b_y, b_z = $\frac{-Ax}{\sqrt{(Ax^2+Az^2)}}, 0, \frac{-Az}{\sqrt{(Ax^2+Az^2)}}$ = -0.45, 0, 0.89

Also accepted: $\frac{-Ax}{\sqrt{(Ax^2+Az^2)}}, 0, \frac{-Az}{\sqrt{(Ax^2+Az^2)}}$ = -0.447, 0, 0.894, $\frac{-Ax}{\sqrt{(Ax^2+Az^2)}}, 0, \frac{-Az}{\sqrt{(Ax^2+Az^2)}}$ = -0.45, 0, 0.89

Part C

Construct two unit vectors that are perpendicular to $\vec{A}$ and that have no y-component.

Enter the x, y, and z components of the vectors separated by commas.

ANSWER:

$c_x, c_y, c_z, d_x, d_y, d_z$ = $\frac{Az}{\sqrt{(Ax^2+Az^2)}}, 0, \frac{-Ax}{\sqrt{(Ax^2+Az^2)}}, \frac{-Az}{\sqrt{(Ax^2+Az^2)}}, 0, \frac{Ax}{\sqrt{(Ax^2+Az^2)}}$ = -0.89, 0, -0.45, 0.89, 0, 0.45

Also accepted: $\frac{-Az}{\sqrt{(Ax^2+Az^2)}}, 0, \frac{Ax}{\sqrt{(Ax^2+Az^2)}}, \frac{Az}{\sqrt{(Ax^2+Az^2)}}, 0, \frac{-Ax}{\sqrt{(Ax^2+Az^2)}}$ = 0.89, 0, 0.45, -0.89, 0, -0.45, $\frac{Az}{\sqrt{(Ax^2+Az^2)}}, 0, \frac{-Ax}{\sqrt{(Ax^2+Az^2)}}, \frac{-Az}{\sqrt{(Ax^2+Az^2)}}, 0, \frac{Ax}{\sqrt{(Ax^2+Az^2)}}$ = -0.894, 0, -0.447, 0.894, 0, 0.447, $\frac{-Az}{\sqrt{(Ax^2+Az^2)}}, 0, \frac{Ax}{\sqrt{(Ax^2+Az^2)}}, \frac{Az}{\sqrt{(Ax^2+Az^2)}}, 0, \frac{-Ax}{\sqrt{(Ax^2+Az^2)}}$ = 0.894, 0, 0.447, -0.894, 0, -0.447, $\frac{Az}{\sqrt{(Ax^2+Az^2)}}, 0, \frac{-Ax}{\sqrt{(Ax^2+Az^2)}}, \frac{-Az}{\sqrt{(Ax^2+Az^2)}}, 0, \frac{Ax}{\sqrt{(Ax^2+Az^2)}}$ = -0.89, 0, -0.45, 0.89, 0, 0.45, $\frac{-Az}{\sqrt{(Ax^2+Az^2)}}, 0, \frac{Ax}{\sqrt{(Ax^2+Az^2)}}, \frac{Az}{\sqrt{(Ax^2+Az^2)}}, 0, \frac{-Ax}{\sqrt{(Ax^2+Az^2)}}$ = 0.89, 0, 0.45, -0.89, 0, -0.45

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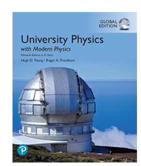

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Midterm 1 - Problem 2

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Midterm 1 - Problem 2

Due: 12:47pm on Sunday, November 15, 2020

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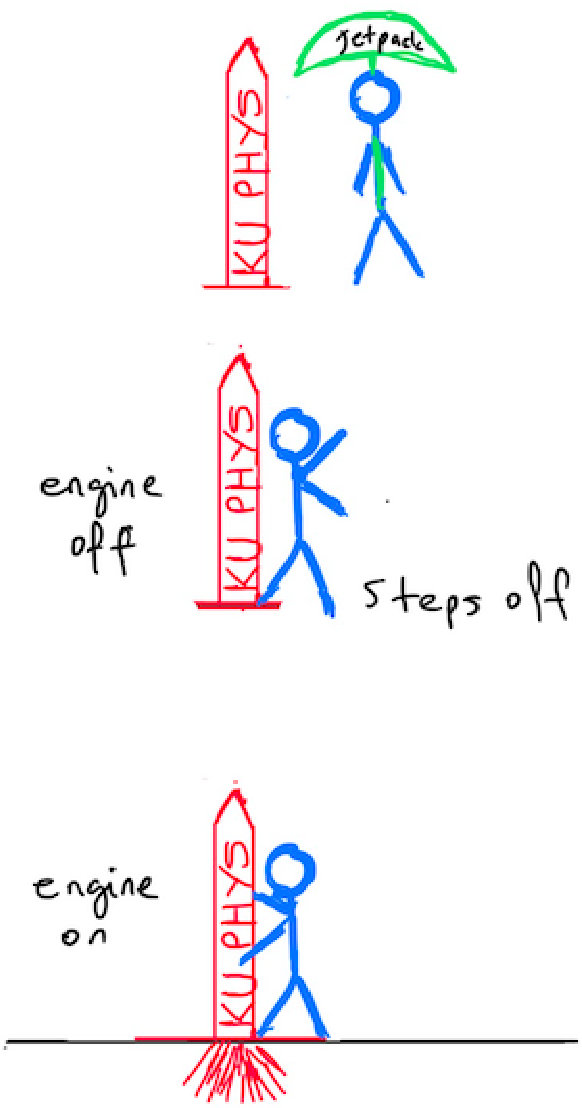
Problem 2

Description:

Suppose you are inside a rocket on the ground at t = 0 s. The rocket is fired from the ground with a constant upward acceleration of 6.0 $\mathrm{m/s^2}$. Suppose you shut the engine off after 10.8 s, and step off the rocket. Assume that the rocket is in free fall after its engine is shut off, and ignore the effects of air resistance.



Part A

What is the maximum height above ground reached by the rocket?

Express your answer with the appropriate units.

ANSWER:

$h = \frac{{t_1}^2}{2}\left(a_1 + \frac{{a_1}^2}{9.8}\right) = 564\,\mathrm{m}$

Also accepted: $\frac{{t_1}^2}{2}\left(a_1 + \frac{{a_1}^2}{9.8}\right) = 564\,\mathrm{m}$, $\frac{{t_1}^2}{2}\left(a_1 + \frac{{a_1}^2}{9.8}\right) = 564\,\mathrm{m}$

Part B

After the engine is shut off, how much time it takes for the rocket to crash into the ground?

Express your answer with the appropriate units.

ANSWER:

$T = \frac{a_1 t_1}{9.8}\left(1 + \sqrt{\left(1 + \frac{9.8}{a_1}\right)}\right) = 17.3\,\mathrm{s}$

Part C

Suppose you deploy a jet pack strapped on your back 6.8 s after leaving the rocket, and then you have a constant downward acceleration with magnitude 2.8 $\mathrm{m/s^2}$. How far are you above the ground when the rocket crashes into the ground?

Express your answer with the appropriate units.

ANSWER:

$h = \frac{9.80 - a_2}{2}\left(\frac{a_1 t_1 + \sqrt{{a_1}^2 {t_1}^2 + 9.80 a_1 {t_1}^2}}{9.80} - t_2\right)^2$ = 389m

Also accepted: $\frac{9.80 - a_2}{2}\left(\frac{a_1 t_1 + \sqrt{{a_1}^2 {t_1}^2 + 9.80 a_1 {t_1}^2}}{9.80} - t_2\right)^2$ = 389m, $\frac{9.80 - a_2}{2}\left(\frac{a_1 t_1 + \sqrt{2 \cdot 9.8 sigdig\left(\frac{{t_1}^2}{2}\left(a_1 + \frac{{a_1}^2}{9.8}\right), 2\right)}}{9.80} - t_2\right)^2$ = 386m, $\frac{9.80 - a_2}{2}\left(\frac{a_1 t_1 + \sqrt{2 \cdot 9.8 sigdig\left(\frac{{t_1}^2}{2}\left(a_1 + \frac{{a_1}^2}{9.8}\right), 2\right)}}{9.80} - t_2\right)^2$ = 386m, $\frac{9.80 - a_2}{2}\left(\frac{a_1 t_1 + \sqrt{{a_1}^2 {t_1}^2 + 9.80 a_1 {t_1}^2}}{9.80} - t_2\right)^2$ = 389m

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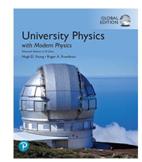

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Midterm 1 - Problem 3

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Midterm 1 - Problem 3

Due: 1:12pm on Sunday, November 15, 2020

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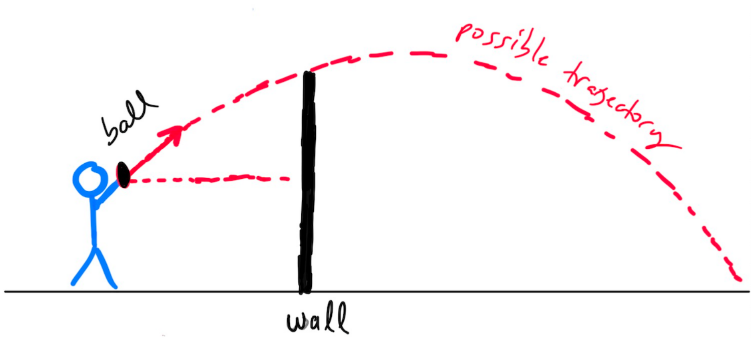
Problem 3

Suppose you are standing at a horizontal distance of 14 m from a high wall. The height of the wall is 6.0 m above the ground. You want to throw a ball over the wall. The ground is level, and the width of the wall is small enough to be ignored. You throw the ball from a height of 1.4 m above the ground and at an angle of 44.0° above the horizontal.



Part A

What minimum initial speed must the ball have as it leaves your hand to go over the wall?

Express your answer with the appropriate units.

ANSWER:

$$v_0 = \sqrt{\frac{dist^2 \cdot 9.8}{(dist\tan(\theta) - (fence - height)) \cdot 2(\cos(\theta))^2}} = 14.5 \frac{\mathrm{m}}{\mathrm{s}}$$

Also accepted: $\sqrt{\frac{dist^2 \cdot 9.81}{(dist\tan(\theta) - (fence - height)) \cdot 2(\cos(\theta))^2}} = 14.5 \frac{\mathrm{m}}{\mathrm{s}}$, $\sqrt{\frac{dist^2 \cdot 9.8}{(dist\tan(\theta) - (fence - height)) \cdot 2(\cos(\theta))^2}} = 14.5 \frac{\mathrm{m}}{\mathrm{s}}$

Part B

For the initial velocity calculated in the previous part, what horizontal distance beyond the wall will the ball land on the ground?

Express your answer with the appropriate units.

ANSWER:

$$d = \left(\left(\sqrt{\frac{dist^2\cdot 9.8}{(dist\tan(\theta)-(fence-height))\cdot 2(\cos(\theta))^2}}\right)\cos(\theta)\,\frac{\left(\sqrt{\frac{dist^2\cdot 9.8}{(dist\tan(\theta)-(fence-height))\cdot 2(\cos(\theta))^2}}\right)\sin(\theta)+\sqrt{\left(\sqrt{\frac{dist^2\cdot 9.8}{(dist\tan(\theta)-(fence-height))\cdot 2(\cos(\theta))^2}}\right)^2(\sin(\theta))^2+2\cdot 9.8 height}}{9.8}\right)-dist$$

= 8.51 m

Also accepted:

$$\left(\left(\sqrt{\frac{dist^2\cdot 9.81}{(dist\tan(\theta)-(fence-height))\cdot 2(\cos(\theta))^2}}\right)\cos(\theta)\,\frac{\left(\sqrt{\frac{dist^2\cdot 9.81}{(dist\tan(\theta)-(fence-height))\cdot 2(\cos(\theta))^2}}\right)\sin(\theta)+\sqrt{\left(\sqrt{\frac{dist^2\cdot 9.81}{(dist\tan(\theta)-(fence-height))\cdot 2(\cos(\theta))^2}}\right)^2(\sin(\theta))^2+2\cdot 9.81 height}}{9.81}\right)-dist$$

= 8.51 m,

$$\left(\left(\sqrt{\frac{dist^2\cdot 9.8}{(dist\tan(\theta)-(fence-height))\cdot 2(\cos(\theta))^2}}\right)\cos(\theta)\,\frac{\left(\sqrt{\frac{dist^2\cdot 9.8}{(dist\tan(\theta)-(fence-height))\cdot 2(\cos(\theta))^2}}\right)\sin(\theta)+\sqrt{\left(\sqrt{\frac{dist^2\cdot 9.8}{(dist\tan(\theta)-(fence-height))\cdot 2(\cos(\theta))^2}}\right)^2(\sin(\theta))^2+2\cdot 9.8 height}}{9.8}\right)-dist$$

= 8.51 m

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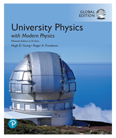

All Assignments

Midterm 1 - Problem 4

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Midterm 1 - Problem 4

Due: 1:37pm on Sunday, November 15, 2020

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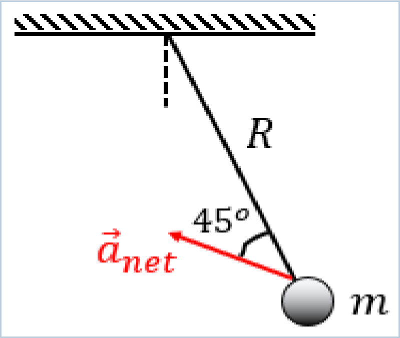
Phys101F20Mt1Q4

Description:

The figure shows a simple pendulum consisting of a ball of mass $m = 500$ grams, suspended by a light string of length $R = 55$ cm . At the instant shown, the net acceleration of the ball makes an angle 45 degrees with the string and has a magnitude 1.0 $\mathrm{m/s^2}$.



Part A - Calculate the speed of the ball.

ANSWER:

v = $\sqrt{\frac{0.01Ra}{\sqrt{2}}}$ = 0.624 $\mathrm{m/s}$

Part B - Calculate the tension on the string

ANSWER:

$$T = 0.5 \cdot 9.81 \left(\frac{a\sqrt{2}}{2 \cdot 9.81} + \sqrt{1 - \left(\left(\frac{a\sqrt{2}}{2 \cdot 9.81} \right)^2 \right)} \right) = 5.25 \text{ N}$$

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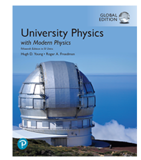

All Assignments

Midterm 1 - Problem 5

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Midterm 1 - Problem 5

Due: 2:02pm on Sunday, November 15, 2020

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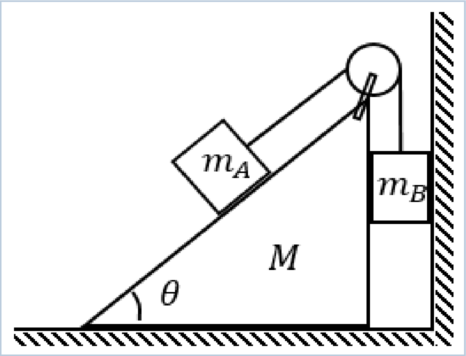
Phys101F20Mt1Q5

In the figure block A has a mass $m_A = 5.0\ \mathrm{kg}$ and placed on the inclined surface of a wedge shaped block of mass M (a numerical value of M is not required for this problem). Another block B with mass m_B is attached to block A by an ideal (massless) string-pulley system and suspended between the vertical side of the wedge and a wall. All adjacent surfaces are in contact during motion. Only the ground is frictionless. The coefficient of kinetic friction at all other surfaces is $\mu = 0.35$. The wedge angle is $\theta = 55$ degrees. It is observed that blocks A and B move with constant speed (block B moves down), while the wedge block remains stationary.



Part A - Calculate the tension on the string.

Draw free body diagram.

ANSWER:

T = $m_A \cdot 9.81\left(\mu\cos\left(\frac{\theta\pi}{180}\right)+\sin\left(\frac{\theta\pi}{180}\right)\right)$ = 50.0 N

Part B - Calculate the net normal force on block B.

Draw free body diagram.

ANSWER:

N_{netonB} = $0\ \mathrm{N}$

Part C - Calculate the mass of the block B.

Draw free body diagram.

ANSWER:

m_{B} = $m_A\left(\mu\cos\left(\frac{\theta\pi}{180}\right)+\sin\left(\frac{\theta\pi}{180}\right)\right)\left(1+2\mu\cos\left(\frac{\theta\pi}{180}\right)\right)$ = 7.15 kg

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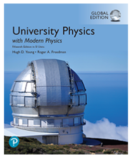


Problem 1

a) $\vec{A} = 2\hat{i} - 5\hat{k}$

First find the length of $\vec{A}$

$$|\vec{A}| = \sqrt{2^2 + 5^2} = \sqrt{4+25} = \sqrt{29}$$

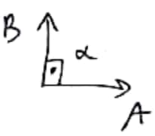
$$\hat{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k} = \frac{\vec{A}}{|\vec{A}|} = \frac{2}{\sqrt{29}}\hat{i} - \frac{5}{\sqrt{29}}\hat{k} =$$

$$= \boxed{0{,}37\,\hat{i} - 0{,}93\,\hat{k} = \hat{a}}$$

Dividing the vector with its own norm (length) gives the unit vector.

b) The vector $\vec{B} = b_1\hat{i} + b_2\hat{j} + b_3\hat{k}$ to be perpendicular to $\vec{A}$, means that:

$$\vec{A} \cdot \vec{B} = |\vec{A}||\vec{B}| \cos\alpha$$



$\cos 90° = 0$

$$\vec{A} \cdot \vec{B} = 0 = 2b_1 - 5b_3$$

$$2b_1 = 5b_3$$

$$b_1 = \frac{5}{2}b_3$$

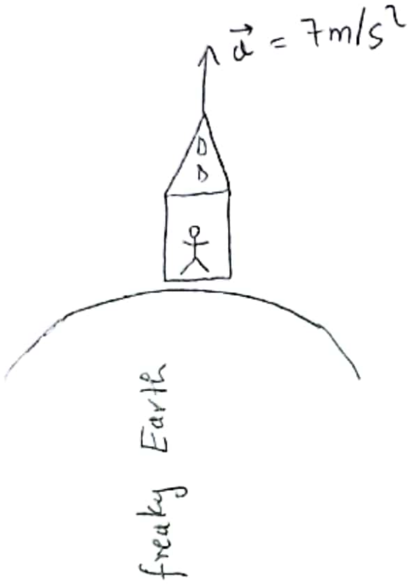
$\vec{B} = \frac{5}{2}b_3\,\hat{i} + b_3\hat{k}$, there are infinite such vectors, we choose one just for fun, $b_3 = 2 \Rightarrow \vec{B} = 5\hat{i} + 2\hat{k}$

c) the unit vector antiparallel to $\vec{A}$ means that it points in the opposite direction from $\hat{a}$.

$$\hat{a}_{antiparallel} = -\hat{a} = -0{,}37\,\hat{i} + 0{,}93\,\hat{k}$$

Problem 2

This is similer to what we have solved so far !



* for 11 s the distance travelled is

$$d_1 = \frac{1}{2} a t^2 + v_0 = 0 + \frac{1}{2} a t^2 = \frac{1}{2} 7 \cdot 11^2 = 423,5 .$$

When the engine turns off, it already moves with velocity

$$v = at = 7 \cdot 11 = 77 \; m/s^2$$

It will keep moving upward until the Earth's gravity pulls it, $t = \frac{v}{g} = \frac{77}{10} = 7,7 \; s$

So the distance travelled during deccelaration is

$$d_2 = v_0 t - \frac{g t^2}{2} = 77 \cdot 7,7 - \frac{10}{2} \cdot (7,7)^2 = 296,45 \; m$$

total distance is $d = d_1 + d_2 = 296,45 + 423,5 = 726 \; m$

B) $d = \frac{1}{2} g t^2 \Rightarrow t = \sqrt{\frac{2d}{g}} = \sqrt{\frac{2 \cdot 726}{9,8}} = \sqrt{148} = 12,16$ s

t is the time from the highest distance to the ground;

to reach the maximum hightness, we need 7,7 s

total time from the engine power off to land crash is: $t + t_1 = 12,16 + 7,7 \approx 20$ s

C) at time t_1

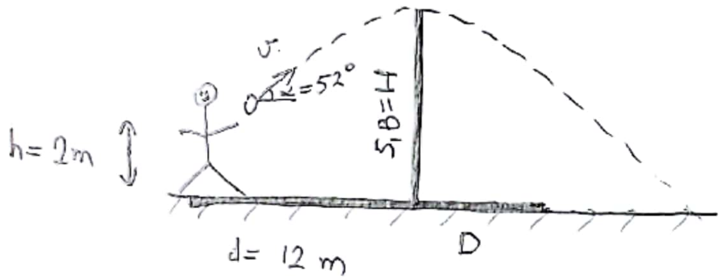
$h_2 = h_1 + a_1 t_1 t_2 - \frac{1}{2} g t^2$

$v_2 = v_1 - g t_2 = a_1 t_1 - g t_2$

$h_{fe}^{men} = h_2 + (a_1 t_1 - g t_2)(t_{fe} - t_2) - \frac{1}{2} a_2 (t_{fe} - t_2)^2$

$= 743$ m

Problem 3



[A] There is a difference $5{,}8 - 2 = 3{,}8\,m$

$$d = (v\cos\alpha)t$$

$$H = h + v\sin\alpha\, t - \frac{1}{2} g t^2 = h + v(\cos\alpha)t\, \frac{\sin\alpha}{\cos\alpha} - \frac{1}{2} g \left(\frac{d}{v\cos\alpha}\right)^2$$

$$H - h - d\tan\alpha = -\frac{1}{2} g \left(\frac{d}{v\cos\alpha}\right)^2$$

$$\frac{2}{g}(h + d\tan\alpha - H) = \left(\frac{d}{v\cos\alpha}\right)^2 \Rightarrow v^2 = \frac{d^2}{\cos^2\alpha}\,\frac{g}{2}(h + d\tan\alpha - H)$$

$$v = \frac{d}{\cos\alpha}\left(\frac{g}{2}(h + d\tan\alpha - H)\right)^{1/2}$$

$$v = \frac{12}{\cos 52}\left(\frac{10}{2}(2 + 12\tan 52 - 5{,}8)\right)^{1/2} = 12{,}7\ m/s$$

[B] $d + D = v\cos\alpha\, t_1$

$0 = h + v\sin\alpha\, t_1 - \frac{1}{2} g t_1^2$

$D = v\cos\alpha\, t_1 - d$

$\frac{1}{2} g t_1^2 - v\sin\alpha\, t_1 + h = 0$

$\Delta = b^2 - 4ac = v^2\sin^2\alpha - 2gh$

$$t_1 = \frac{v\sin\alpha + \sqrt{v^2\sin^2\alpha + 2gh}}{g} =$$

$$= \frac{v}{g}\sin\alpha + \sqrt{\left(\frac{v\sin\alpha}{g}\right)^2 + \frac{2h}{g}}$$

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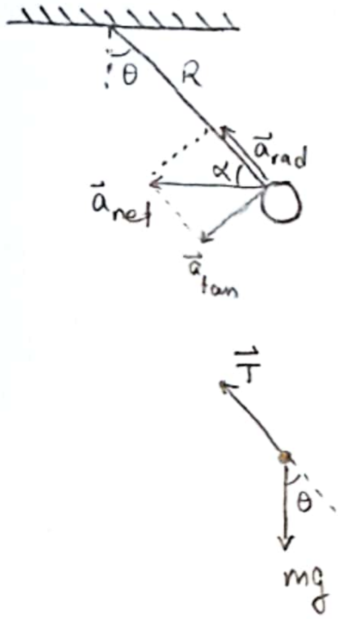
$$D = v_0 \cos\alpha \left(\frac{v_0}{g} \sin\alpha + \sqrt{\left(\frac{v}{g} \sin\alpha\right)^2 + \frac{2h}{g}} \right) - d$$

$$D = 12{,}7 \cos 52 \left(\frac{12{,}7}{10} \sin 52 + \sqrt{\left(\frac{12{,}7}{10} \sin 52\right)^2 + \frac{2 \cdot 2}{10}} \right) - 12 = 5{,}38 m$$

Q.4



Identify: The ball of the pendulum makes a non-uniform circular motion.

Setup : $\vec{a}_{net} = \vec{a}_{rad} + \vec{a}_{tan}$

$a_{rad} = a_{net}\cos(\alpha) \quad a_{tan} = a_{net}\sin(\alpha)$

$\alpha = 45^\circ \quad \cos(\alpha) = \sin(\alpha) \Rightarrow a_{rad} = a_{tan}$

$a_{rad} = \frac{v^2}{R}$

Apply Newton's 2nd law through FBD

$ma_{rad} = T - mg\cos(\theta)$

$ma_{tan} = mg\sin(\theta)$

Execute:

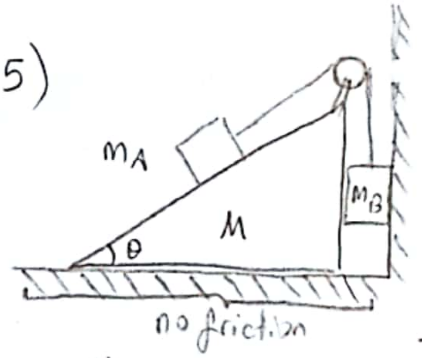
PART-A : $v = \sqrt{a_{rad}R} = \sqrt{a_{net}R\cos(45^\circ)} = \sqrt{\frac{a_{net}R}{\sqrt{2}}}$

PART-B $T = \underbrace{ma_{rad}}_{= ma_{tan}} + mg\cos(\theta) = mg(\sin\theta + \cos\theta)$

$\sin\theta = \frac{a_{tan}}{g} = \frac{a_{net}}{\sqrt{2}g} \qquad \cos\theta = \sqrt{1-\sin^2\theta} = \sqrt{1-\left(\frac{a_{net}}{\sqrt{2}g}\right)^2}$

$$T = mg\left(\frac{a_{net}}{\sqrt{2}g} + \sqrt{1-\left(\frac{a_{net}}{\sqrt{2}g}\right)^2}\right)$$

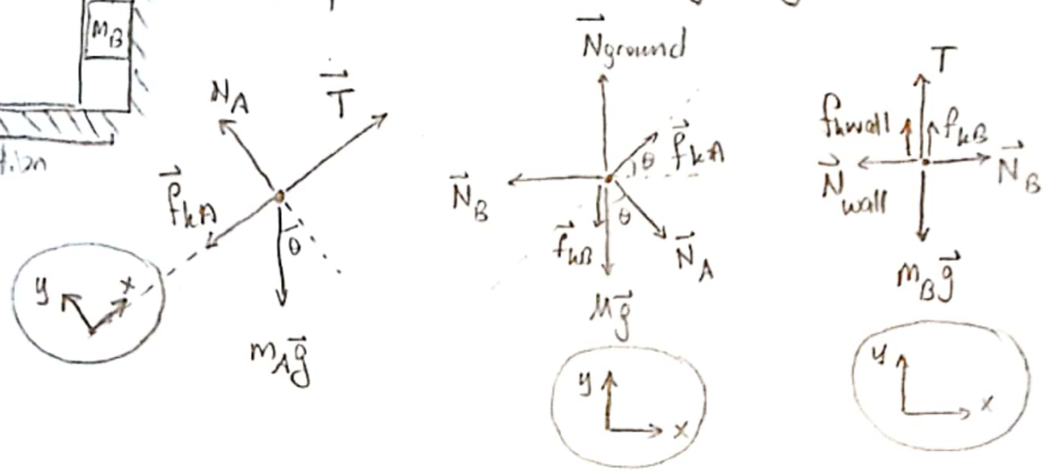
Q.5)



μ_k on all surfaces except ground

Identify: Motion with constant speed. Apply Newton's 1st Law.

Setup: Draw free body diagrams



In each FBD, use the encircled coordinate systems.

Execute: m_A: $\sum F_x = T - f_{kA} - m_A g \sin\theta = 0$ (1)

$\sum F_y = N_A - m_A g \cos\theta = 0$ (2)

$f_{kA} = \mu_k N_A$ (3)

M: $\sum F_x = -N_B + f_{kA}\cos\theta + N_A \sin\theta = 0$ (4)

$\sum F_y = N_{ground} + f_{kA}\sin\theta - f_{kB} - N_A\cos\theta - Mg = 0$ (5)

m_B: $\sum F_x = N_B - N_{wall} = 0$ (6)

$\sum F_y = T + f_{kB} + f_{kwall} - m_B g = 0$ (7)

$f_{kB} = \mu_k N_B$ (8)

$f_{kwall} = \mu_k N_{wall}$ (9)

PART-A: Use equations (1, 2, 3): $T = m_A g(\sin\theta + \mu_k\cos\theta)$ (10)

PART-B: Use (6) Net normal force on B $= N_B - N_{wall} = 0$

PART-C: Use (4) $N_B = N_A(\mu_k\cos\theta + \sin\theta) = \mu_k m_A g\cos\theta\,(\mu_k\cos\theta + \sin\theta)$ (11)

Use (6,8,9) $f_{kB} = \mu_k N_B$ $f_{kwall} = f_{kB}$

Use (7) $m_B = \frac{1}{g}(T + 2\mu_k N_B)$ (put T & N_B from (10), (11))