UIC: Physics 105

1st Midterm Exam

Fall 2014

Thursday, October 2

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LAST Name (print) ______________________________

FIRST Name (print) ______________________________

Signature: ______________________________

UIN #: ______________________________

Giving or receiving aid in any examination is cause for dismissal from the University. Any other violation of academic honesty can have the same effect.

MCQ/LP/SP	POINTS	SCORE
Multiple Choice	**50**	
Short Problem SP1	**11**	
Short Problem SP2	**10**	
Short Problem SP3	**14**	
Short Problem SP4	**15**	
Total	**100**	

MULTIPLE CHOICE QUESTIONS

Clearly circle the letter of the best answer

MCQ01 [2 points]: A sphere with a radius of 1.7 cm has a surface area of:

(A) 2.1×10^{-5} m^2

(B) 9.1×10^{-4} m^2

(C) 3.6×10^{-3} m^2

(D) 0.11 m^2

(E) 36. m^2

Answer (C):
$A = 4\pi R^2$ where $R = 1.7$ cm $= 0.017$ m $\Rightarrow A = 4\pi \times 0.017^2 = 3.6 \times 10^{-3}$ m^2

MCQ02 [2 points]: Suppose A = B·C, where A has the dimension L/M and C has the dimension L/T. Then B has the dimension:

(A) T/M

(B) L^2/TM

(C) TM/L^2

(D) L^{2}T/M

Answer (A):
$A = BC \Rightarrow B = A \times \frac{1}{C} \Rightarrow [B] = \frac{L}{M} \times \frac{T}{L} = \frac{T}{M}$

MCQ03 [2 points]: The average speed of a moving object during a given interval of time is always:

(A) the magnitude of its average velocity over the interval

(B) the distance covered during the time interval divided by the time interval

(C) one-half its speed at the end of the interval

(D) its acceleration multiplied by the time interval

(E) one-half its acceleration multiplied by the time interval.

Answer (B): The average speed of an object is defined as the distance traveled divided by the time elapsed

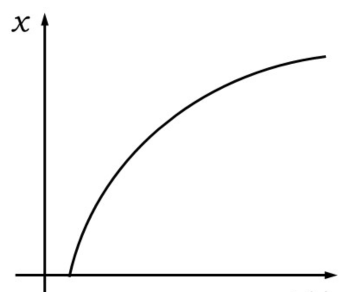
MCQ04 [2 points]: The graph of position vs. time for a car is given in the figure to the right. What can you say about the velocity of the car over time?

(A) it speeds up all the time

(B) it slows down all the time

(C) it moves at constant velocity

(D) sometimes it speeds up and sometimes it slows down



Answer (B): The slope of the x vs. t graph is continuously diminishing as time goes on $\Rightarrow$ the car slows down all the time.

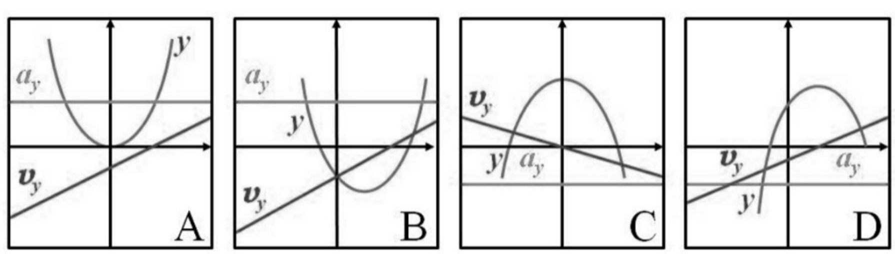
MCQ05 [3 points]: A ball is dropped from a high tower and falls freely under the influence of gravity only – no air drag. Consider the 4 sketches below showing position, velocity and acceleration (on the vertical axis) as functions of time (on the horizontal axis). If gravity is downwards, and we take upwards as the positive y-direction, which of the sketches is the only correct display of y, υ_y and a_y versus time? Circle the letter of the best answer.

(A) A

(B) B

(C) C

(D) D



Answer (C):
position-time graph must be an open-down parabola
velocity-time graph must be a line with a negative slope
acceleration-time graph must be a horizontal line with zero slope in the negative region, i.e. (C)

MCQ06 [2 points]: A car, initially at rest, travels 20.0 m in 4.0 s along a straight line with constant acceleration. The acceleration of the car is:

(A) 0.40 m/s^2
(B) 1.3 m/s^2
(C) 2.5 m/s^2
(D) 4.9 m/s^2
(E) 9.8 m/s^2

Answer (C): $\Delta x = v_0 t + \frac{1}{2}at^2$ where Δx = 20. m, v_0 = 0 m/s and t = 4.0 s
$\Rightarrow a = \frac{2\Delta x}{t^2} = 2 \times 20./4.0^2$ = 2.5 m/s^2

MCQ07 [2 points]: A ball rolls up a slope. At the end of three seconds its velocity is 20. cm/s; at the end of eight seconds its velocity is 0. What is the average acceleration from the third to the eighth second?

(A) – 4.0 cm/s^2
(B) – 2.5 cm/s^2
(C) + 2.5 cm/s^2
(D) + 4.0 cm/s^2

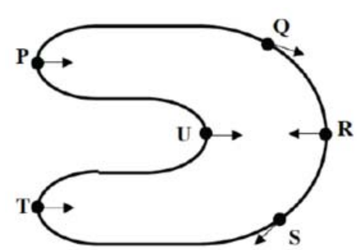
Answer (A): Average acceleration over time interval $a_{avg} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i} = \frac{0-20}{8-3} = -4$ cm/s^2

MCQ08 [2 points]: A freely falling body has a constant acceleration of 9.8 m/s^2. This means that:

(A) the body falls 9.8 m during each second
(B) the body falls 9.8 m during the first second only
(C) the velocity of the body changes by 9.8 m/s during each second
(D) the acceleration of the body increases by 9.8 m/s^2 during each second
(E) the acceleration of the body decreases by 9.8 m/s^2 during each second

Answer (C): Acceleration is the rate at which an object changes its velocity $\Rightarrow$ (C)

MCQ09 [3 points]: Which of the arrows correctly indicates the direction of the acceleration of a particle that moves clockwise at a constant speed around the path shown in the figure to the right?



(A) P, R and T
(B) P, R, T and U
(C) Q and S
(D) R and U
(E) None of the arrows correctly indicates the direction of acceleration

Answer (A): The acceleration points to the inside of the curve (which is not the same as the inside of the shape). Therefore only P, R and T are correct.

MCQ10 [3 points]: A stone is tied to the end of a string and is swung with constant speed around a horizontal circle with a radius of 1.52 m. If it makes two complete revolutions each second, the magnitude of its acceleration is:

(A) 0.24 m/s^2
(B) 2.4 m/s^2
(C) 24. m/s^2
(D) 240 m/s^2
(E) 2400 m/s^2

Answer (D):
$a = v^2/R$ where $v = 2 \times 2\pi R/t$, t = 1 s and R = 1.5 m $\Rightarrow a = \frac{16\pi^2 R}{t^2} = \frac{16\pi^2 \cdot 1.52}{1^2}$ = 240 m/s^2

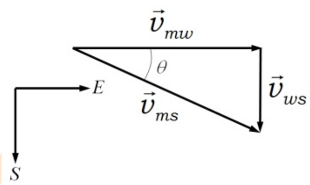
MCQ11 [3 points]: A river flows due south with a speed of 4 m/s. A man steers a motorboat across the river. His velocity relative to the water is 3 m/s due east. The river is 600 m wide. What is the magnitude and direction of his velocity relative to the shore? Use the coordinate system where the *y-axis* is *north* and the *x-axis* is *east*.

(A) 5 m/s 53° below x-axis
(B) 1 m/s 47° below x-axis
(C) 1 m/s 53° above x-axis
(D) 5 m/s 47° above x-axis

Answer (A):
$|\vec{v}_{mw}|$ = 3 m/s is speed of motorboat with respect to water
$|\vec{v}_{ws}|$ = 4 m/s is speed of water with respect to the shore
So, the speed of the motorboat relative to the shore

$$|\vec{v}_{ms}| = \sqrt{v_{mw}^2 + v_{ws}^2} = \sqrt{3^2 + 4^2} = 5 \text{ m/s}$$

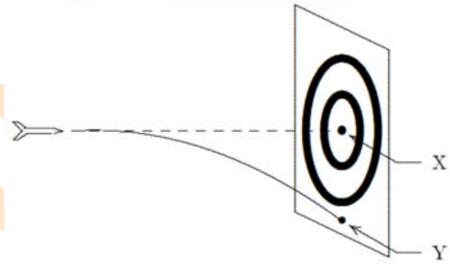
and $\theta = \tan^{-1}(4/3) = 53°$ below x-axis



MCQ12 [3 points]: A dart is thrown horizontally toward X at 20 m/s as shown to the right. It hits Y 0.1 s later. The distance XY is:

(A) 2m
(B) 1m
(C) 0.5m
(D) 0.1m
(E) 0.05m

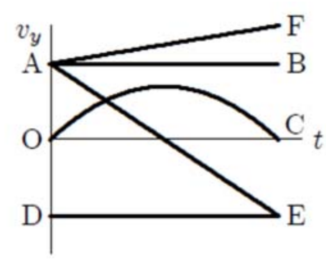
Answer (E): $|XY| = \frac{gt^2}{2} = 9.81 \times 0.1^2/2 = 0.049$ m ≈ 0.05 m



MCQ13 [3 points]: Which of the curves on the graph below best represents the vertical component v_y of the velocity versus the time t for a projectile fired at an angle of 45° above the horizontal?

A. OC
B. DE
C. AB
D. AE
E. AF

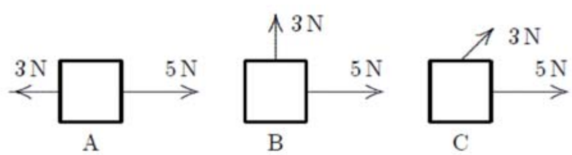
Answer (D): Vertical component $v_y = v_{y,0} - gt$ is a straight line with a negative slope and positive intercept, i.e. (D) AE

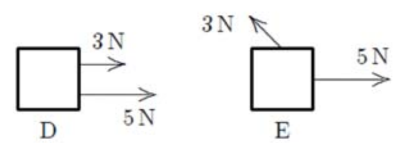


MCQ14 [3 points]: Two forces, one with a magnitude of 3N and the other with a magnitude of 5N, are applied to an object. For which orientations of the forces shown in the diagrams to the right is the magnitude of the acceleration of the object the least?

(A) A
(B) B
(C) C
(D) D
(E) E

Answer (A): $\vec{a} = \frac{\vec{F}_{net}}{m} = \frac{\vec{F}_1 + \vec{F}_2}{m}$. The forces shown in the diagram "A" corresponds to the smallest net force $\vec{F}_{net} = \vec{F}_1 + \vec{F}_2$

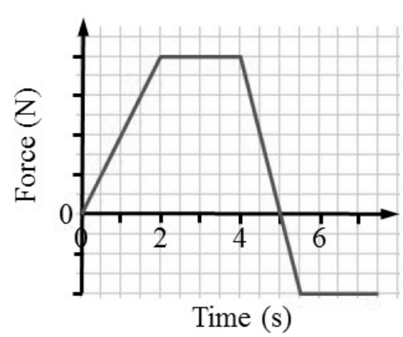




MCQ15 [2 points]: Refer to the force-time curve for an object of constant mass m shown in the figure to the right. When was the object at rest?

(A) at $t = 0$ s
(B) from $t = 2$ s to $t = 4$ s
(C) at $t = 5$ s
(D) from $t = 5$ s to $t = 9$ s
(E) not enough information given

Answer (E): To answer the question, the object's mass, its velocity at $t = 0$ s and scale of the force on the diagram must be given



MCQ16 [2 points]: A ball with a weight of 1.5N is thrown at an angle of 30° above the horizontal with an initial speed of 12m/s. At its highest point, the net force on the ball is:

(A) zero
(B) 1.5N, down
(C) 9.8N, up
(D) 9.8N, down
(E) 9.8N, 30° below horizontal

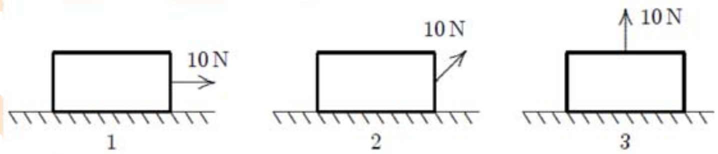
Answer (B): A single force acts on a ball, $F = mg = 1.5$ N directed down

MCQ17 [3 points]: A 90-kg man stands in an elevator that has a downward acceleration of 1.4 m/s^2. The magnitude of the force exerted by him on the floor is about:

(A) zero
(B) 90N
(C) 760N
(D) 880N

Answer (C): The magnitude of the force exerted by man on the floor is equal to the normal force $N = m(g - a) = 90(9.81 - 1.4) = 757 \text{ N} \approx 760 \text{ N}$

MCQ18 [3 points]: A crate rests on a horizontal surface and a woman pulls on it with a 10-N force. Rank the situations shown below according to the magnitude of the normal force exerted by the surface on the crate, least to greatest.



(A. 1, 2, 3
(B. 2, 1, 3
(C) 2, 3, 1
(D) 1, 3, 2
(E) 3, 2, 1

Answer (E):
1. $N_{(1)} = mg$
2. $N_{(2)} = mg - 10 \times \cos(\theta)$ where θ is the angle above the horizontal
3. $N_{(3)} = mg - 10$

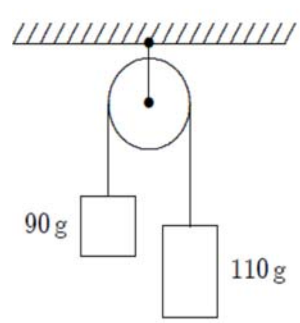
$\Rightarrow N_{(3)} < N_{(2)} < N_{(1)}$

MCQ19 [2 points]: A forward horizontal force of 12 N is used to pull a 24-kg crate at constant velocity across a horizontal floor. The coefficient of friction is:

(A) 0.51
(B) 0.051
(C) 2.5
(D) 0.25
(E) 25.

Answer (B): $f_k = \mu_k N$ where $N = mg$. $F_{net} = F - f_k = 0 \Rightarrow f_k = F$. So, $\mu_k = \frac{F}{mg} = \frac{12}{24 \cdot 9.81} = 0.051$

MCQ20 [3 points]: Two blocks are connected by a string and pulley as shown. Assuming that the string and pulley are massless, the magnitude of the acceleration of each block is:



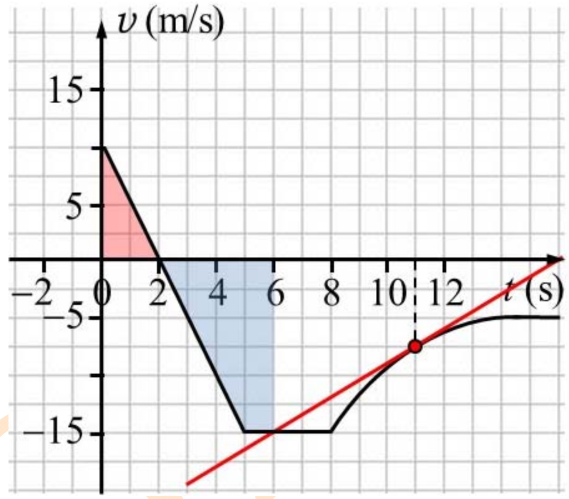
(A) 0.049m/s^2
(B) 0.020m/s^2
(C) 0.0098m/s^2
(D) 0.54m/s^2
(E) 0.98m/s^2

Answer (E):
m_1: $m_1 a = T - m_1 g$ (1)
m_2: $m_2 a = m_2 g - T$ (2)
From (1) and (2) $\Rightarrow a = \frac{m_2 - m_1}{m_2 + m_1} g = 0.98$ m/s^2

SHORT PROBLEMS

You must show your work and write your answers clearly and legibly

SP1: The motion of a particle along a straight line is represented by the velocity versus time graph shown to the right. At $t = 0$ the particle has position $x_0 = +27.5$ m.



(a) [4 points] Find the instantaneous acceleration of the particle at $t = 11$ s.

__Solution:__ From the given v-vs-t graph we can determine the instantaneous acceleration at $t = 11$ s which is just the slope of the tangent line to the curve at the given time ($t = 11$ s). Picking, for instance, two points $t_1 = 6$ and $t_2 = 11$ s we can find a as

$$a = \frac{\Delta v}{\Delta t} = \frac{-7.5-(-15)}{11-6} = 1.5\ \text{m/s}^2$$

(b) [7 points] At what time does the particle pass through the origin?

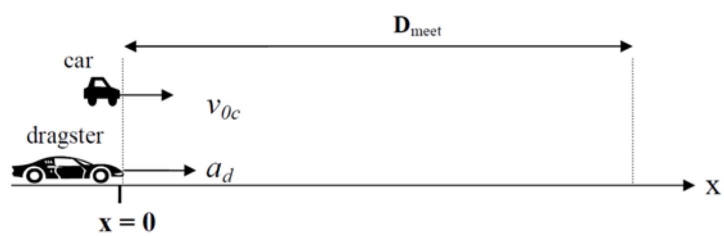
__Solution:__ From the graph the first 2 seconds the particle moves in the positive x-direction, then it stops and turns to go in the opposite direction

At $t = 2$ s the particle is $x = x_0 + \Delta x$ away from the origin.

From the graph, 1 square = (2.5 m/s)×(1 s) = 2.5 m, so $\Delta x = \frac{1}{2} v \cdot \Delta t = \frac{1}{2} 10 \cdot (2-0) = 10$ m (area under curve shaded in red), and $x = 27.5 + 10 = 37.5$ m

The particle will pass the origin when it will move 37.5 m (area = 15 squares under t axis, shaded in blue) in the opposite direction, i.e. at $t = 6$ s

SP2: You drive in a car at a constant velocity of v_{0c} on a straight road past a stopped dragster. The dragster accelerates from rest (at $t = 0$) at the exact instant that the front bumpers of the cars are at $x = 0$ as shown in the figure to the right.



(a) [6 points] Find the time when the dragster's front bumper again matches up with the car. Use values of v_{0c}=25.0 m/s and acceleration of dragster $a_d = 30.0$ m/s^2.

__Solution:__ Eq. of motion for the car: $x_c = x_{0,c} + v_{0,c}t + \frac{1}{2}a_c t^2$, $x_{0,c} = 0$ m and $a_c = 0$ m/s^2 $\Rightarrow x_c = 0 + v_{0,c}t = v_{0,c}t$

Eq. of motion for the dragster: $x_d = x_{0,d} + v_{0,d}t + \frac{1}{2}a_d t^2$, $x_{0,d} = 0$ m and $v_{0,c} = 0$ m/s

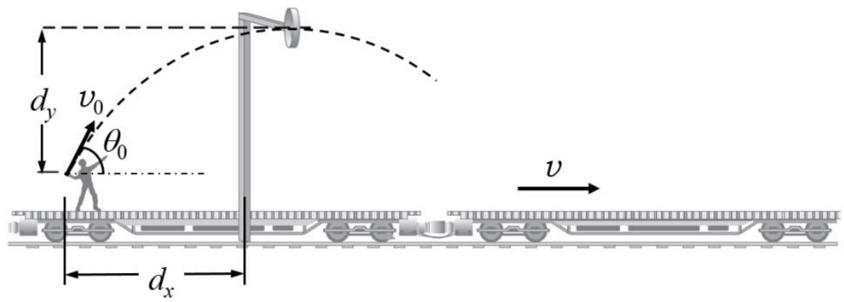
$\Rightarrow x_d = 0 + 0t + \frac{1}{2}a_d t^2$

Bumpers match up again when $x_c = x_d$, $v_{0,c}t = \frac{1}{2}a_d t^2 \Rightarrow t = \frac{2v_{0,c}}{a_d}$ = 2×25.0/30.0 = 1.67 s ≈ 1.7 s

(b) [4 points] Find the velocity of the dragster when they meet at time t, found in part (a).

__Solution:__ For the car $v_d = a_d t$ = 30.0 × 1.7 = 51 m/s

SP3: A man is riding on a flatcar traveling at a constant speed $v = 9.10$ m/s. He wishes to throw a ball through a hoop a distance $d_y = 4.90$ m above the height of his hands in such a manner that the ball will move horizontally as it passes through the hoop as shown in the figure to the right. The hoop is stationary with respect to the ground, and the ball is thrown toward the hoop with a speed $v_0 = 10.8$ m/s with respect to the flatcar.



(a) [8 points] At what angle θ_0 above the horizontal with respect to the flatcar does he throw the ball?

Solution:

$\theta_0 = \tan^{-1}\left(\frac{v_{0,y}}{v_{0,x}}\right)$ (1)

By using the eq. $v_y^2 - v_{0,y}^2 = 2a_y d_y$ (2) we can find y-component of the ball's initial velocity

In eq. (2), $v_y = 0$, $a_y = -9.81$ m/s^2 and $d_y = 4.90$ m $\Rightarrow v_{0,y} = \sqrt{2gd_y} = \sqrt{2 \times 9.81 \times 4.90} = 9.81$ m/s

The initial velocity v_0 and its components, $v_{0,x}$ and $v_{0,y}$ form the right, i.e. $v_0^2 = v_{0,x}^2 + v_{0,y}^2$

$\Rightarrow v_{0,x} = \sqrt{v_0^2 - v_{0,y}^2} = \sqrt{10.8^2 - 9.81^2} = 4.52$ m/s with respect to the flatcar

So, $\theta_0 = \tan^{-1}\left(\frac{9.81}{4.52}\right) = 65.3°$

(b) [6 points] At what horizontal distance in front of the hoop must he release the ball?

Solution:

The x-component of the ball's velocity with respect to the ground is $v_x = v_{0,x} + v = 4.52 + 9.1 = 13.6$ m/s.

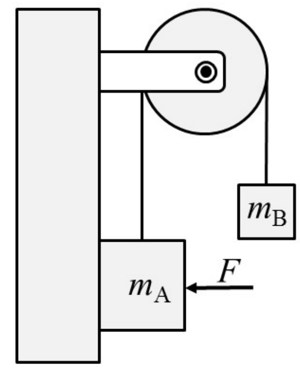
Because the v_x is constant, $d_x = v_x t$ where t is the time the ball takes to reach the hoop (maximum height)

We can find the time t from the eq. describing the change in the ball's velocity along y-axis, $v_y = v_{0,y} - gt$

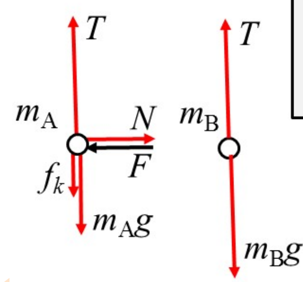
$\Rightarrow t = \frac{v_{0,y}}{g} = 9.81/9.81 = 1$ s

So, $d_x = (13.6\ m/s) \times (1s) = 13.6$ m

SP4: A Block A of mass $m_A = 3$ kg and block B of unknown mass m_B are attached to a rope, which passes over a pulley. A force $F = 20$ N is applied horizontally to block A, keeping it in contact with a rough vertical wall as shown in the figure to the right. The coefficients of static and kinetic friction between the wall and block A are $\mu_s = 0.40$ and $\mu_k = 0.30$. The pulley is light and frictionless. The mass of block B is set so that block A ascends at constant velocity when it is set into motion.



(a) [8 points] Draw a free-body diagram for block A and block B, and find the mass of block B, m_B.



Solution:

m_A, along x-axis: $F_{x,i} = N - F = 0$ (1)

m_A, along y-axis: $F_{y,i} = T - f_k - m_A g = 0$ (2)

where $f_k = \mu_k N$ (3)

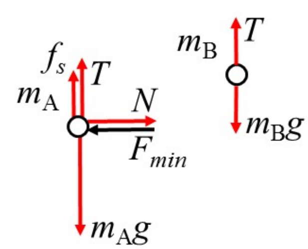
m_B, along y-axis: $F_{y,i} = T - m_B g = 0$ (4)

From (4) $\Rightarrow T = m_B g$

From (1) and (3) $\Rightarrow N = F$, so $f_k = \mu_k F$

By plugging T and f_k into (2) we can solve for m_B: $m_B = m_A + \frac{\mu_k}{g} F = 3 + \frac{0.30}{9.81} 20 = 3.6$ kg

(b) [7 points] If the given mass m_B is replaced by the mass equal to one-half the m_A, what is the minimum value of the horizontal force F required to keep the block A from slipping down the wall. Draw a free-body diagram.



Solution:

m_A, along x-axis: $F_{x,i} = N - F_{min} = 0$ (1)

m_A, along y-axis: $F_{y,i} = T + f_s - m_A g = 0$ (2) where $f_s = \mu_s N$ (3)

m_B, along y-axis: $F_{y,i} = T - m_B g = 0$ (4)

From (4) $\Rightarrow T = m_B g$

From (1) and (3) $\Rightarrow N = F_{min}$, so $f_s = \mu_s F_{min}$

By plugging T and f_s into (2) we can solve for F_{min}: $F_{min} = \frac{m_A g}{2\mu_s} = \frac{3 \cdot 9.81}{2 \cdot 0.4} = 36.8$ N