Physics 1A - Spring 2016

Lecture 1
Midterm Exam #1

Rules and Advice

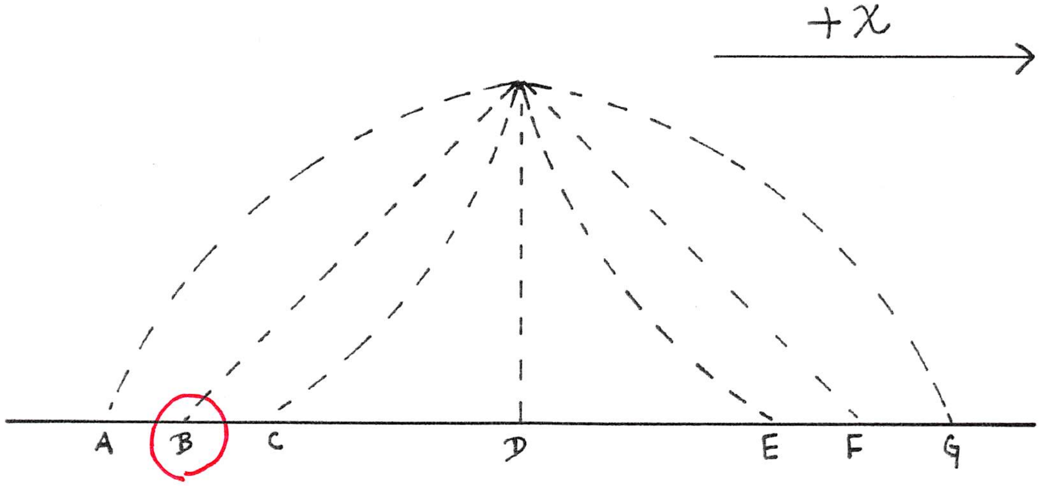
Multiple Choice Questions. For each of the multiple choice questions that follow, write the letter of the correct answer. If your answer is correct, you will receive 5 points, regardless of whether you include any reasoning. If your answer is incorrect but you include some good reasoning, you will receive some partial credit. If your answer is incorrect with no reasoning, you will receive no credit. Reasoning can include diagrams, mathematics, or complete English sentences.

Short Answer Problems. On short answer problems, your answers will be graded to a large extent on how convincing your reasoning is. A correct answer without good reasoning won't get much credit. Often convincing reasoning is a mixture of mathematics, explanations, and diagrams. *Try to make sure you work is neat and well-spaced so that the grader can follow it!*

1 Multiple Choice

Question 1. (5 points)

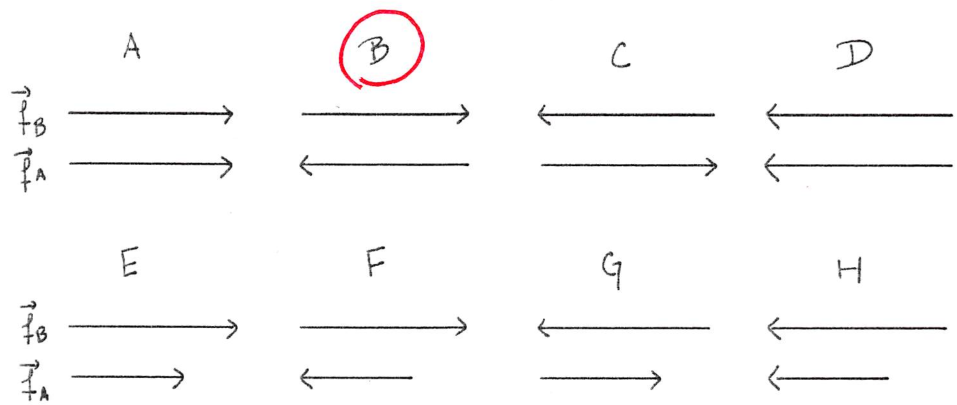
Jarevil is standing on a train that is free to move along a straight track in the positive x-direction. At time $t = 0$, the train is stationary and two things happen. The train begins to accelerate with the same magnitude of gravity, g, in the positive x-direction. Simultaneously, Jarevil drops a marble which falls with acceleration g from a certain height above the floor of the train. Which of the following represents what the path of the marble would look like from Jarevil's perspective?

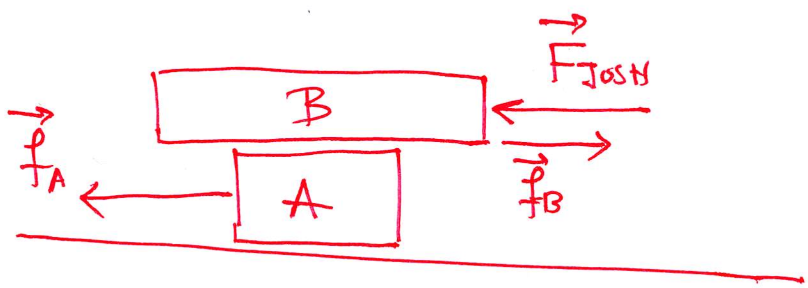


$$\left.\begin{aligned} x(t) &= -\tfrac{1}{2}gt^2 \\ y(t) &= h - \tfrac{1}{2}gt^2 \end{aligned}\right\} \Rightarrow \underbrace{y = h + x}_{\text{line w/ slope } +1}$$

Question 2. (5 points)

Block A is free to slide on a frictionless surface, while block B slides on top of block A. The mass of block A is less than the mass of block B. The interface between the surfaces of the blocks is not frictionless. Josh pushes block B to the left by exerting a horizontal force on its right-hand vertical side. Let $\vec{f}_A$ denote the force of friction exerted by block B on block A, and let $\vec{f}_B$ denote the force of friction exerted by block A on block B. Which of the following diagrams accurately represents these two friction vectors?

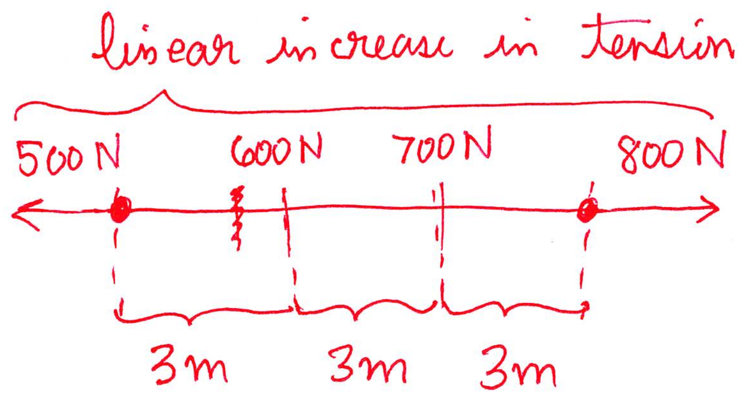




$|\vec{f}_A| = |\vec{f}_B|$ by Newton's 3rd Law.

Question 3. (5 points)

Two astronauts, Alex and Herb, are playing tug o' war in space with a rope of mass 10 kg and length 9 m having uniform mass density. Alex pulls to the left with a force 500 N, and Herb pulls to the right with a force 800 N. What is the tension in the rope at a point 6 m away from Alex?



(A) 500 N

(B) 550 N

(C) 600 N

(D) 650 N

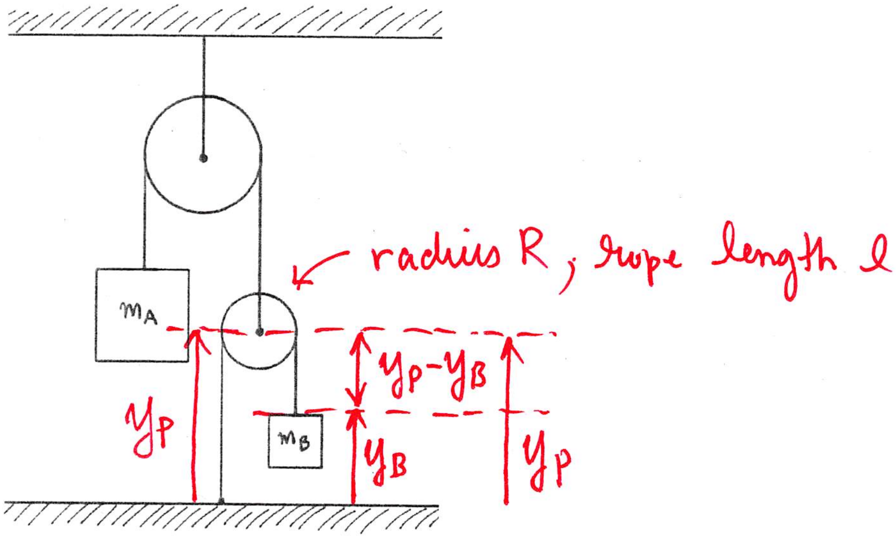
(E) 700 N

(F) 750 N

(G) 800 N

Question 4. (5 points)

In the following diagram, all ropes are of constant length, and the circles are pulleys. The opposite end of the rope attached to mass B is fastened to the ground. What is the constraint relating the y-components of the accelerations of masses A and B provided they move only up or down?



(A) $a_A + a_B = 0$

(B) $a_A - a_B = 0$

(C) $2a_A + a_B = 0$

(D) $2a_A - a_B = 0$

(E) $a_A + 2a_B = 0$

(F) $a_A - 2a_B = 0$

(G) $3a_A + a_B = 0$

(H) $3a_A - a_B = 0$

(I) $a_A + 3a_B = 0$

(J) $a_A - 3a_B = 0$

$$y_P + \pi R + y_P - y_B = \ell$$

$$\Rightarrow \quad 2a_P - a_B = 0$$

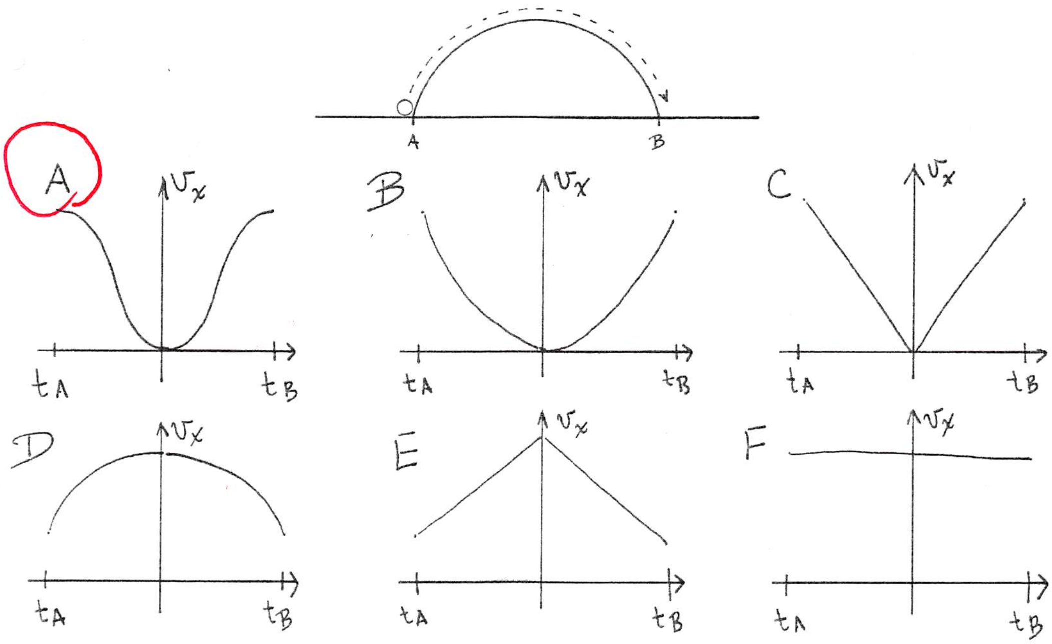
Note also that $-a_A = a_P$, so

$$-2a_A - a_B = 0$$

$$\Rightarrow 2a_A + a_B = 0$$

Question 5. (5 points)

A ball starts at the bottom of the hill as shown and is given the minimum initial speed to the right allowing it to barely make it over the hill. For the period of time during which the ball rolls between points A and B indicated on the diagram, which of the following could represent the x-component of the ball's velocity plotted as a function of time?



velocity zero halfway between t_A and t_B: $\cancel{D}, \cancel{E}, \cancel{F}$

$a_x = 0$ halfway between t_A, t_B: $\cancel{C}$

TRICKY { normal force nearly 0 at t_A and t_B (or possibly exactly zero) $\Rightarrow a_x \approx 0$ at t_A, t_B : $\cancel{B}$

B accepted as well

2 Short answer

Problem 1.

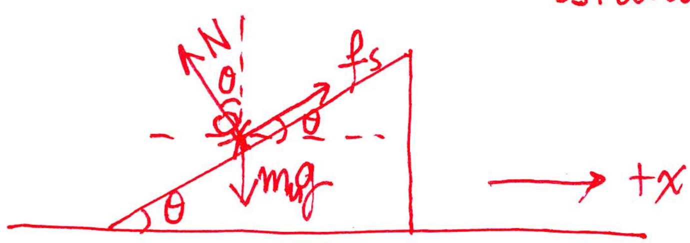
Usain Bolt is running up a wedge whose slanted surface has length ℓ and makes an angle $\pi/4$ radians with the horizontal. The bottom of the wedge slides frictionlessly on the ground but there is a coefficient of static friction μ_s between Usain's shoes and the slanted surface on which he runs. Usain has mass m_U and the wedge has mass m_W. Usain runs hard enough that his feet are just barely about to slip, but not quite.

(a) **(7 points)** Make a convincing physical argument as to what the x-component of Usain's acceleration relative to the ground would be in the limit $m_U/m_W \to 0$. You will likely still need a bit of math along with your physical reasoning for this question.

(b) **(17 points)** Compute an expression for the x-component of Usain's acceleration relative to the ground in terms of the given variables.

(c) **(6 points)** Compare your physical prediction from part (a) to your mathematical result from part (b). Are they consistent? If not, there is an error either in your physical reasoning, or in your mathematical result, or both. Try to find and explain the error in this case.

(a) $\frac{m_u}{m_W} \to 0 \Rightarrow a_{W,x} \to 0$, so treat wedge as stationary,



NSL x: $f_s \cos\theta - N \sin\theta = m_u a_x$

NSL y: $f_s \sin\theta + N\cos\theta - m_u g = m_u a_y$

max static friction: $f_s = \mu_s N$

constraint: $a_y = a_x \tan\theta$

$\theta = \frac{\pi}{4} \Rightarrow \cos\theta = \sin\theta = \frac{1}{\sqrt{2}},\ \tan\theta = 1$

$\Rightarrow$ $\frac{\mu_s - 1}{\sqrt{2}} N = m_u a_x$

$\frac{\mu_s + 1}{\sqrt{2}} N - m_u g = m_u a_x$

(OVER)

$$(\mu_s+1)\frac{\cancel{m_u} a_x}{\mu_s-1} - \cancel{m_u} g = \cancel{m_u} a_x$$

$$(\mu_s+1)a_x - g(\mu_s-1) = (\mu_s-1)a_x$$

$$2a_x = g(\mu_s-1)$$

$$\boxed{a_x = \frac{\mu_s-1}{2} g}$$

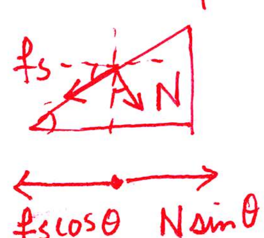
(b) NSL equations for Usain same as part (a),

NSLx: (Usain) $\quad (\mu_s-1)\frac{N}{\sqrt{2}} = m_u a_{u,x}$

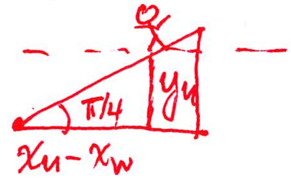
NSLy: (Usain) $\quad (\mu_s+1)\frac{N}{\sqrt{2}} - m_u g = m_u a_{u,y}$

But now we need NSL in x-dir. for wedge:

NSLx: (Wedge) $\quad (1-\mu_s)\frac{N}{\sqrt{2}} = m_w a_{w,x}$



and different constraint:



constraint: $a_{u,x} - a_{w,x} = a_{u,y}$

4 eqs, 4 unknowns: $N, a_{u,x}, a_{u,y}, a_{w,x}$, solve! (OVER)

$$\frac{N}{\sqrt{2}} = \frac{m_u a_{u,x}}{\mu_s - 1} \Rightarrow a_{u,y} = \frac{(\mu_s+1)}{\cancel{m_u}} \cdot \frac{\cancel{m_u} a_{u,x}}{\mu_s - 1} - g$$

$$= \frac{\mu_s+1}{\mu_s-1} a_{u,x} - g$$

$$\Rightarrow a_{w,x} = \frac{(1-\mu_s)}{m_w} \cdot \frac{m_u a_{u,x}}{\mu_s - 1}$$

$$= \frac{-m_u}{m_w} a_{u,x}$$

plug into constraint

$$a_{u,x} + \frac{m_u}{m_w} a_{u,x} = \frac{\mu_s+1}{\mu_s-1} a_{u,x} - g$$

$$a_{u,x}\left(\frac{\mu_s+1}{\mu_s-1} - 1 - \frac{m_u}{m_w}\right) = g$$

$$\boxed{a_{u,x} = \frac{g}{\frac{2}{\mu_s-1} - \frac{m_u}{m_w}}}$$

(c) $\frac{m_u}{m_w} \to 0$ in part (b) answer gives $a_{u,x} \to \frac{g}{\frac{2}{\mu_s-1}} = \frac{(\mu_s-1)g}{2}$

which agrees w/part (a)!