Physics 1A: Mechanics

Winter 2016

1st Midterm Review

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(Alternatively, just e-mail me your questions.)

Problem 1

This is a Corbin midterm problem.

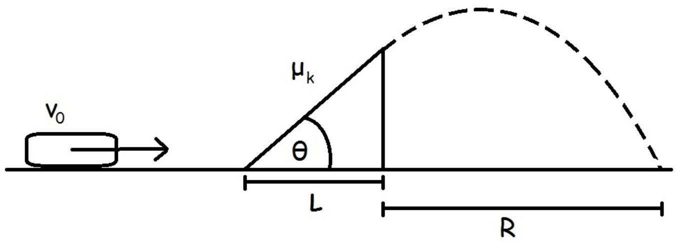
A block slides (with a large speed v_0) over a frictionless horizontal surface towards an immovable ramp. The ramp is inclined at an angle θ, its length is L, and is covered by a material that presents a coefficient of kinetic friction μ_k to the block.

a) What speed will the block have at the top of the ramp?

b) What does it mean if the speed you calculated in part a) is imaginary? What can you deduce from this?

c) What happens to the answer in part a) in the limit $\theta \to 0$? Is this what you'd expect? Explain/resolve any discrepancy.

d) How far from the vertical edge of the ramp will the block land? Evaluate your answer in the limit v_0 is very large (compared to...?) and interpret the result.



Problem 2

This is a Corbin midterm problem.

Every year aficionados of air-guns, catapults, trebuchets and the like gather on the East Coast to participate in a charity fund-raising event called *Pumpkin Chunkin'*. The goal is simple - launch a pumpkin into the air and try to achieve a greater range than anyone else. The current record appears to be about 4695 ft (or nearly a mile!). I have seen unofficial claims of shots (outside the event) well in excess of a mile.

Let's say a pumpkin is launched from a height h. It achieves a maximum height H and a range R. In terms of these quantities find

a) The time of flight of the pumpkin.

b) The x- and y-components of the pumpkin's initial velocity.

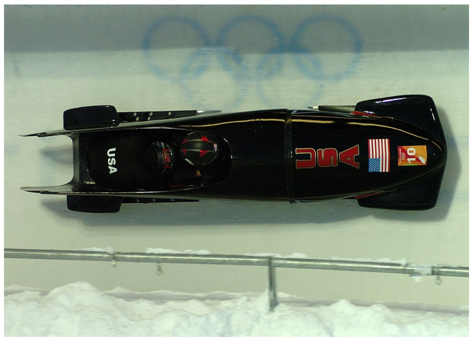
c) The speed the pumpkin was traveling with and the direction it was traveling in when it returned to the ground.

d) Evaluate your answers to part c) in the limit $h \to 0$ and discuss the result.

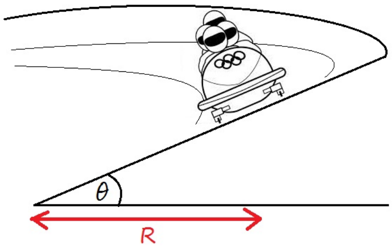
Problem 3

In bobsleigh (a winter sport) teams of two or four teammates make timed runs down narrow, twisting, banked, iced tracks in a gravity-powered sled. It's an Olympic sport of long tradition - below you can see (left to right) the Swiss bobsleigh team in 1910, an East German bobsleigh in 1950 and team USA in 2006:





Let us consider the motion of such a bobsleigh when it's riding along a banked curve of radius R, inclined at an angle θ to the horizontal as shown:



You can assume that the coefficients of friction between the bobsleigh and the track are negligibly small.

a) At what speed should the bobsleigh travel in order to make it safely around the curve (that is, without slipping up or down)?

b) One of the team members has a true weight given by W. What is her apparent weight if the bobsleigh travels safely around the curve?

c) A bobsleigh competition is being organized in high mountains, where one can use naturally occurring embankments along with artificial ones. The organizers are considering the following problem: when a bobsleigh leaves such a naturally shaped track, that bobsleigh is headed straight towards a precipice. Bobsleighs have brakes that will stop them well before the precipice, however, the organizers are considering safety measures in case brakes in one of the bobsleighs break down. At this particular point in track an average speed of a bobsleigh is V, and the precipice is a distance D away. By comparing the amount of friction required to stop the bobsleigh while it's headed straight towards the abyss to the amount of friction required to turn the bobsleigh away (while maintaining a constant speed), determine the safest course of action for bobsleigh teams.

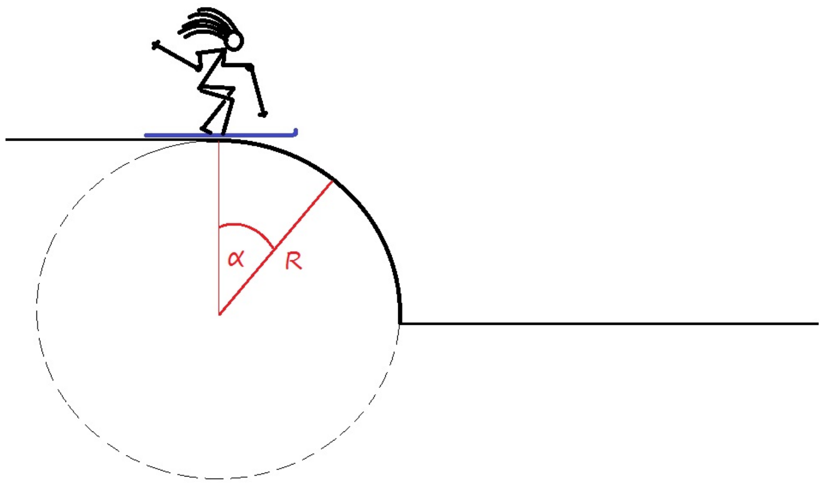
Problem 4

A group of students gets bored on a skiing trip and decides to try something new. They plan to ski down a perfectly spherical part of the hill (see figure).

a) First, a coy student starts at the top of the "sphere" with very small initial speed - barely a push to get him going (meaning you can assume the initial velocity is zero). He then skids down the side of the ball. At what angle α does he lose contact with the hill and fly off at a tangent?

b) Another student is much braver: she approaches the spherical part of the hill with an initial speed v_0. And what angle does she lose the contact with the ground?

c) What initial speed must the next student have to shoot off the top of the hill without ever touching the spherical surface?



Problem 5

Victor is on the 100th floor of an office building. At each of times $t_1 = 0$ and $t_2 > 0$ he drops a metal ball from a window. While the balls are falling, will the distance between them increase, decrease, or stay the same? Explain your answer using kinematics. You may neglect air resistance.

Problem 6

This is a Corbin midterm problem.

A small hot-air balloon slowly rises from the surface of the Earth at a constant speed v_b. Nearby a young child holds a loaded slingshot above his head, pointed straight up. When the balloon reaches a height H above the slingshot, the child fires a marble with a large velocity v_m along a vertical path adjacent to that of the balloon.

a) How fast is the marble moving (relative to the child) when it first overtakes the balloon?

b) How far above the balloon will the marble appear to go?

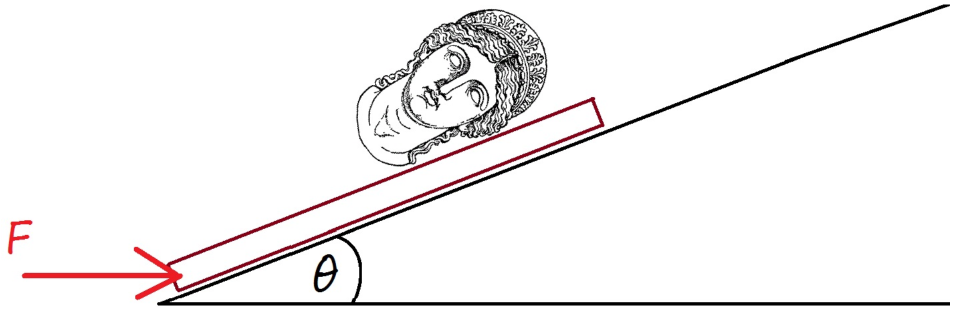
c) How fast is the marble moving (relative to the child) when the marble reaches its greatest distance above the balloon? Explain.

d) How much time will elapse between the marble's first encounter with the balloon and its last?

Problem 7

This is a Corbin midterm problem.

After robbing the museum, the thieves need to carry a very unwieldy art piece (of mass M_1) up a hill to their hideout. Instead of risking tripping and falling down the hill with their hands full, they place the sculpture on a wooden plank (of mass M_2) and lay the plank on the hill. Then they apply a horizontal force F to the bottom of the plank, as shown below. The coefficients of friction between the art piece and the plank are given as μ_{s1} and μ_{k1}, while the coefficients of friction between the plank and the ground are given as μ_{s2} and μ_{k2}.



a) Assume the art piece stays at rest relative to the plank as the plank slowly rises up the plane. Sketch the coordinate system you intend to use on the figure above, then below draw free-body diagrams for the sculpture and the plank. For full credit you need to label each diagram and clearly identify (correctly and unambiguously) each of the forces that act on the objects and the directions in which they act.

b) What is the magnitude and direction of the sculpture's acceleration?

c) How large is the force of friction acting on the art piece?

d) How large would the horizontal force have to be in order to cause the skull to begin to slide?

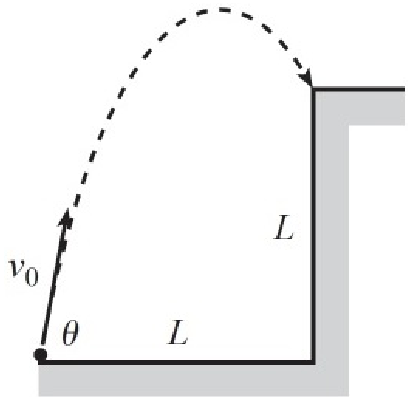
Problem 8

A small ball is launched from the ground onto the corner of a cliff as shown.

a) For which launch angles θ in the range $[0, \pi]$ is it possible for the ball to hit the corner? Explain.

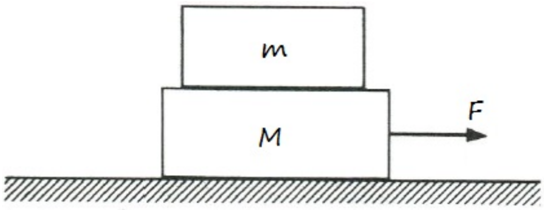
b) For a given angle θ belonging to the above range, what launch speed v_0 is necessary for the ball to hit the corner?

c) Examine the limiting cases $\theta \to \frac{\pi}{2}$ and $\theta \to \frac{\pi}{4}$. What happens to the required launch speed in each of these cases according to the formula you derived in part b)? Does the behavior of your formula make sense in these limiting cases? *(Hint: if this behavior makes little sense then examine the formula carefully - is it correct? [Probably not - either that or you have rather poor physical intuition ;).])*



Problem 9

A block of mass m rests on top of a block of mass M, which rests on a frictionless table. The coefficient of friction between the two blocks is such that the blocks start to slip when the horizontal force applied to the lower block is equal F. Suppose that now a horizontal force is applied only to the upper block, what is the maximum value of this force for the blocks to slide on the table without slipping relative to each other?



Problem 10

A block of mass m rests on a frictionless wedge of mas M, which itself rests on a frictionless floor. What external force must be applied to prevent block from sliding down?