University of California at Berkeley
Department of Physics
Physics 7A, Spring 2019

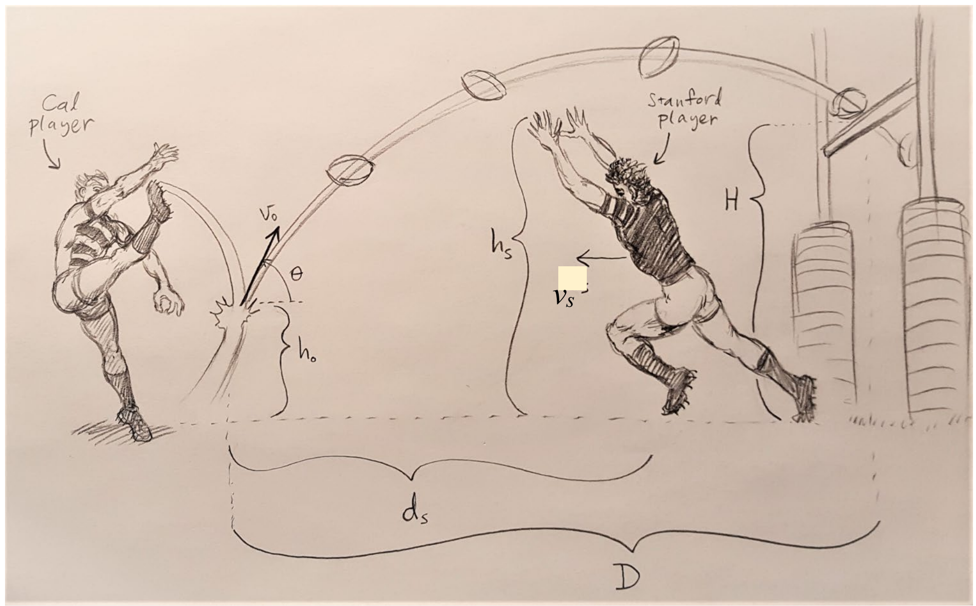
Midterm 1
Feb. 26, 2019

You will be given 110 minutes to work this exam. There are 4 problems total worth 25 points each. No books are allowed, but you may use one single-sided, handwritten formula sheet no larger than an 8 ½" by 11" sheet of paper. No calculators or other electronics are allowed (wouldn't help much anyhow…). Your description of the physics involved in a problem is worth significantly more than the final answer by itself. Show all work, be careful with signs, and take particular care to explain what you are doing. Please express your answers using the symbols provided in the problem descriptions or define any new symbols you use, tell us why you're writing any new equations, and clearly label any drawings that you make. Write your solutions on the exam itself and do not use any scratch paper. Please $\boxed{\text{BOX}}$ your answers. Good luck!

1) (25 points) Men's Rugby match against Stanford.

In the final seconds of the Cal vs. Stanford rugby match, Stanford leads by 2 points, but Cal has the ball and the ball carrier attempts a "drop-goal", which is worth 3 points if successful. The Cal player kicks the ball with an initial speed of v_o at an initial angle θ above the horizontal, as shown in the diagram. The ball is kicked from a height of h_o above the ground, and the goal posts are a horizontal distance D from the Cal player, and a height H above the ground.

a) How high above the ground does the ball get before it begins to fall back down? Please express your answer as a function of any subset of h_o, v_o, θ, and any relevant physical constants. As always, show your work and/or justify your answer.
b) How long does it take for the ball to reach its highest point?
c) What is the relative velocity of the goal posts with respect to the ball just as the ball reaches its highest point? Express your answer as a vector and clearly label your axes.
d) If the ball successfully passes over the horizontal cross bar between the goal posts, then what is the minimum possible value for v_o? Express your answer in terms of h_o, θ, H, D, and any relevant physical constants.
e) A Stanford player charges the Cal player but he is not quick enough to knock the ball down with his upraised hands, which are at a height h_S above the ground. If the Stanford player runs directly towards the Cal player at a constant speed of v_S, then what was the minimum possible horizontal distance d_S between the two players when the ball was kicked?



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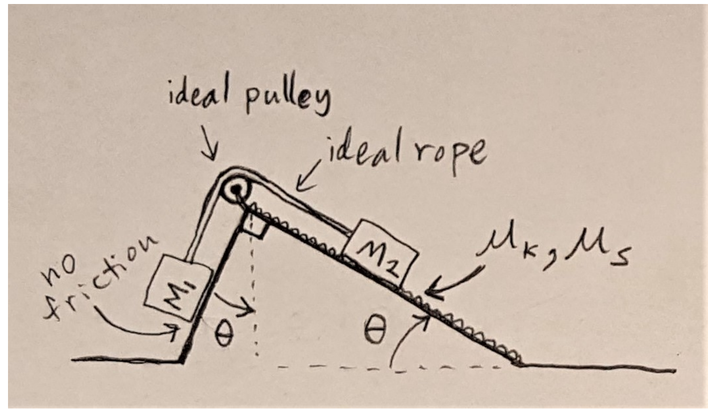
2) (25 points) Two blocks on inclines

Two blocks are tied together by an ideal rope that passes over an ideal pulley that is mounted to the top of a pair of stationary ramps, as shown in the diagram. The block on the left has a mass M_1, and it rests on an incline that forms an angle of θ with respect to the vertical, whereas the block on the right has a mass M_2, and it rests on an incline that forms an angle θ with respect to the horizontal. The static and kinetic coefficients of ***friction*** between block M_2 and the ramp on the ***right*** are μ_s and μ_k, respectively. There is ***no friction*** between the block M_1 and the ramp on the ***left***. Throughout the problem, assume there is non-zero tension in the rope.



a) Assuming that the blocks are ***not sliding***, draw ***2*** free body diagrams, one showing all forces acting on the left block alone, and a second diagram for the right block alone.
b) What is the magnitude of the normal force acting on the left block M_1?
c) If the blocks are ***not sliding***, at what angle θ will there be no force of static friction on the right block? Express your answer in terms of M_1, M_2, and any relevant physical constants.
d) If the left block M_1, is sliding ***down the ramp*** to the left, then what is the tension in the rope?
e) If the left block M_1, is sliding ***down the ramp*** to the left, then what is the maximum possible value of the mass M_2 such that the blocks will not slow down as they slide? Express your answer in terms of M_1, μ_k, θ.

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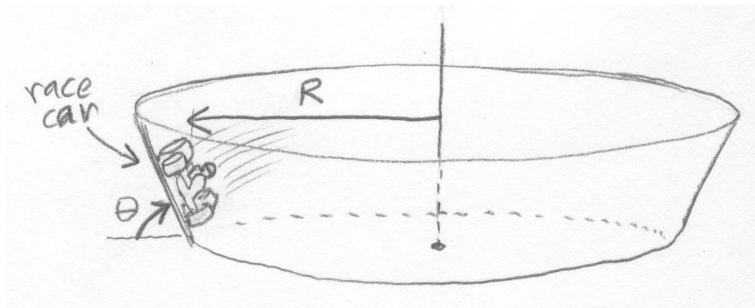
3) (25 points) Rounding the bend

A racecar is traveling around a circular track at a constant speed of v. The track is banked at an angle of θ with respect to the horizontal. As shown in the diagram, the race car is moving out of the page towards the viewer on the left side of the circular racetrack. The car has mass M, and it is traveling in a horizontal circle with a radius of R. All 4 of the wheels wheels are rolling without slipping.

a) Make a free body diagram of the car.
b) What is the magnitude and direction of the acceleration of the car as viewed in the diagram? Express your answer in terms of R and v.
c) What is the magnitude of the combined force of static friction from the road acting on all the tires? Express your answer in terms of R, v, θ, m, and any relevant physical constants.
d) If $\theta = 45°$, so that $\sin(45°) = \cos(45°) = (½)^{1/2}$, then what is the condition that results in the force of static friction pointing down the hill? Express your answer in terms of R, v, and any relevant physical constants.
e) If the car comes to a stop so $v = 0$ m/s, then what is the smallest possible value of the coefficient of static friction μ_s necessary for the car to not slide down towards the middle of the racetrack? Again assume that $\sin(45°) = \cos(45°) = (½)^{1/2}$. (Even for racecar tires, this gives a pretty high value for μ_s.)



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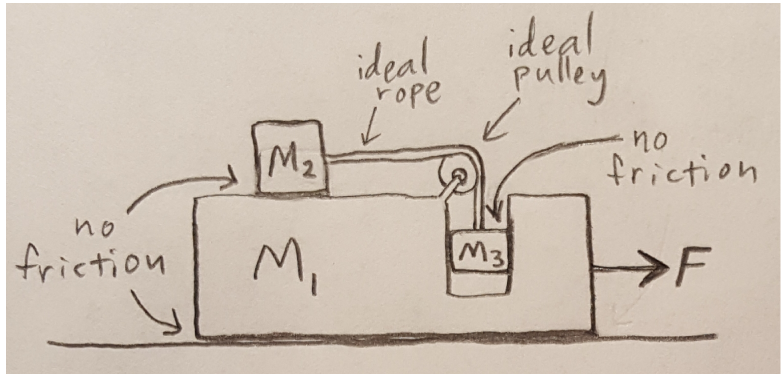
4) (25 points) Pedagogical machine

A "pedagogical machine" consists of a large block of mass M_1 that is resting on a horizontal frictionless surface with two other masses, M_2 and M_3, connected to each other by an ideal rope that passes over an ideal pulley that is attached to the large block, as shown in the diagram. M_2 can slide horizontally on the top of the large block, and M_3 can slide vertically with respect to the large block. You may neglect friction on all surfaces in this entire problem.



a) If a constant external force F pointing to the right in the diagram is applied to the large block of mass M_1 so that the hanging mass M_3 does not accelerate upward or downward, then what is the tension in the rope? Express your answer in terms of any combination of M_1, M_2, M_3, and any relevant physical constants.
b) In that case, what is the magnitude of the acceleration of the block M_2? Express your answer in terms of any combination of M_1, M_2, M_3, and any relevant physical constants.
c) In that case, what is the magnitude of the external horizontal force F being applied to the large block M_1? Express your answer in terms of any combination of M_1, M_2, M_3, and any relevant physical constants. (hint: Note that the rope exerts forces on both the pulley and the two smaller blocks.)
d) For the rest of this problem, consider the case in which there is NO external horizontal force acting on the Pedagogical machine. What is the ***direction*** and ***magnitude*** of the acceleration of the large block M_1?
e) In that case, what is the tension in the rope?

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