University of California at Berkeley
Department of Physics
Physics 7A, Fall 2017

Midterm 1
Sep. 26, 2017

You will be given 120 minutes to work this exam. No books are allowed, but you may use a 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 answers in a blue book (or green book), and do not use any extra scratch paper. Please BOX your answers. Good luck!

1) (25 points) Cal Volleyball

The Berkeley women's volleyball team is ahead by one point over Stanford near the end of a grueling contest; a two point lead is needed to win. During the final play of the match, a Cal player dives for the ball and hits the ball from a height of h_o above the ground with an initial speed of v_o at an angle θ above the horizontal, as shown in the diagram. The top of the volleyball net is at a height h_n above the ground and the net is a horizontal distance D from the Cal player. You may neglect wind resistance and the finite size of the ball.

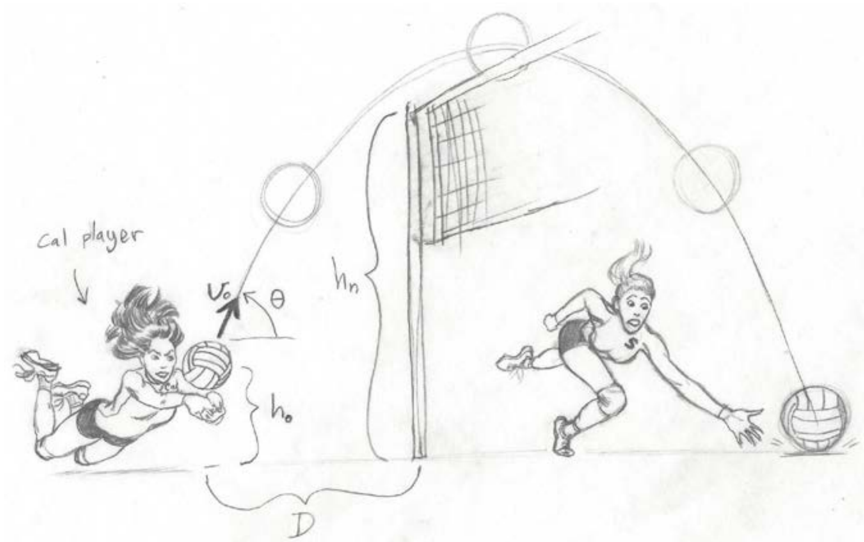
a) How much time does it take for the ball to reach a point directly over the net? Express your answer as a function of D, v_o, and θ. As always, show your work and/or justify your answer.

b) What is the magnitude of the ball's acceleration at the highest point of its trajectory?

c) What is the minimum speed of the ball over its trajectory?

d) How much time does it take for the ball to hit the ground? Express your answer as a function of v_o, h_o, θ, and any relevant physical constants.

e) What is the minimum value for the initial speed v_o to ensure that the ball makes it over the net? Express your answer as a function of h_o, h_n, θ, D, and any relevant physical constants. (You may assume that $\tan(\theta) > (h_n - h_o)/D$.)



2) (25 points) Two blocks, an incline, and a pulley

Two blocks are tied together by an ideal rope that passes over an ideal pulley so that one block of mass M_1 hangs from one end of the rope and the other block of mass M_2 rests on an incline making an angle θ with respect to the horizontal, as shown in the diagram. The static and kinetic coefficients of friction for the interface between the ramp and the bottom surface of the second block are μ_s and μ_k, respectively.

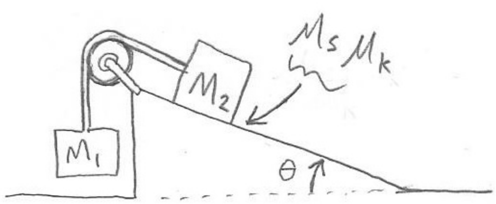
a) Draw 2 free body diagrams, one showing all forces acting on the hanging block alone, and a second diagram for the block on the incline by itself. Assume that the blocks are not moving.

b) What is the magnitude of the normal force acting on M_2? Express your answer in terms of θ, M_2, and any relevant physical constants.

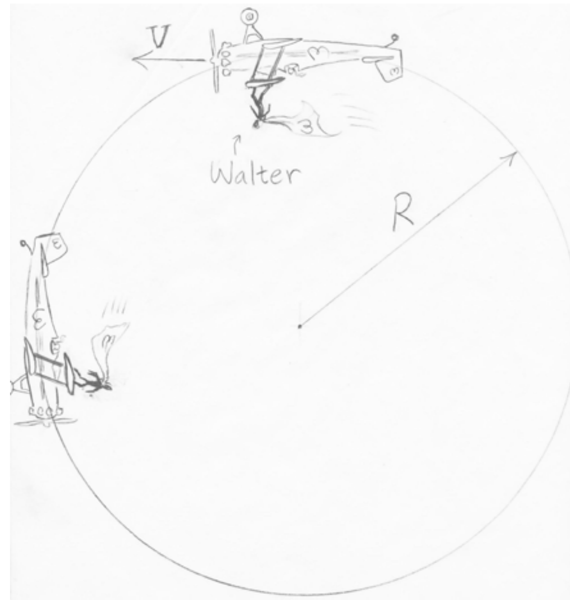
c) What is the ***maximum*** possible value for the mass M_1 of the hanging block if the blocks are ***not moving***? Express your answer in terms of θ, μ_s, and M_2.

d) Now consider the situation in which the second block is ***sliding up the ramp***. In that case, what is the acceleration of the hanging block? Express your answer in terms of M_1, M_2, μ_k, θ and any relevant physical constants.

e) If the second block is ***sliding up the ramp***, then what is the tension in the rope? Express your answer in terms of M_1, M_2, μ_k, θ and any relevant physical constants.



3) (25 points) Wing walker



A stuntman named Walter the Wing Walker of mass M stands on the top wing of an old fashioned biplane as the pilot performs various maneuvers.

a) For the first stunt, the pilot makes a vertical circle with radius R at **constant speed** V, as shown in the diagram. What is the magnitude of the ***vertical*** component of the force from the ***plane*** acting downward on Walter at the ***highest point*** of the circle? Express your answer in terms of M, R, V, and any relevant physical constants.

b) While the plane is still executing a vertical circle at constant speed, what is the magnitude of the net force acting on Walter at the moment the plane is traveling straight ***downward*** including all forces from the plane and wind ***but excluding the force of gravity***? Express your answer in terms of M, R, V, and any relevant physical constants.

c) Now the pilot breaks out of the circular path and performs a different maneuver so that the plane's ***speed*** in units of m/s obeys the formula $v = A + Bt^3$ and the plane's height in m above the ground obeys the formula $h = Ct - Dt^2$, where A, B, C, and D are all positive constants. What are the physical ***units*** of the constants A, B, C, and D?

d) What is the ***speed*** of the plane at its ***highest*** point along its trajectory? Express your answer in terms of A, B, C, and D.

e) If the numerical values of the constants are $A = 100$, $B = 0.1$, $C = 200$, and $D = 10$ (with the units you found for each of them above), then what is the magnitude of the ***horizontal*** component of the plane's ***acceleration*** at its highest point? Please give a numerical answer with correct physical units.

4) (25 points) Lifting a slug

A weight called a "slug" of mass M is suspended by two ideal ropes, each tied to the top of the slug. The two ropes are at potentially different angles θ_1 and θ_2 from the horizontal, as shown in the diagram.

a) If the slug is not moving over some extended period of time, then what is the tension T_1 in the first rope during this time? Express your answer in terms of M, θ_1, θ_2, and any relevant physical constants.

b) For the rest of this problem, assume that the two angles are the same, $\theta_1 = \theta_2 = \theta$. If the slug is not accelerating, what is the relationship between T_1 and T_2? Please show your work or justify your answer.

c) If the two angles are the same, $\theta_1 = \theta_2 = \theta$, then what is T_1 if the slug and both ropes are ***accelerating*** straight ***upwards*** with an acceleration of magnitude a? Express your answer in terms of M, θ, and a, and any relevant physical constants.

d) If the two angles are the same, $\theta_1 = \theta_2 = \theta$, then what is T_1 if the slug and both ropes are ***accelerating horizontally*** to the ***right*** as viewed in the diagram with an acceleration of magnitude a'? Express your answer in terms of M, θ, a', and any relevant physical constants.

e) Just as in part d), if the two angles are the same, $\theta_1 = \theta_2 = \theta$, then what is the maximum value a'_{max} for the magnitude of purely horizontal acceleration for the slug and ropes? Express your answer in terms of θ and any relevant physical constants.