8.01L Fall 2005 Exam 2 Samples

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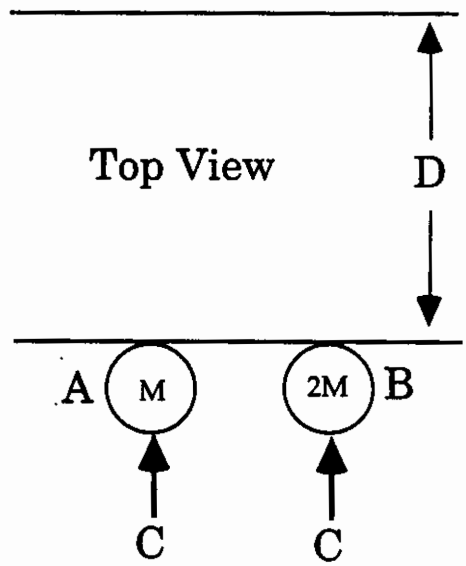
For each question, your answer will be one of the following:

a) Object A b) Object B

c) Both are the same d) Can't answer without further information

Chose answer (d) if you can't answer without further information (i.e. you need other parameters or you need to know the numerical values of the parameters).

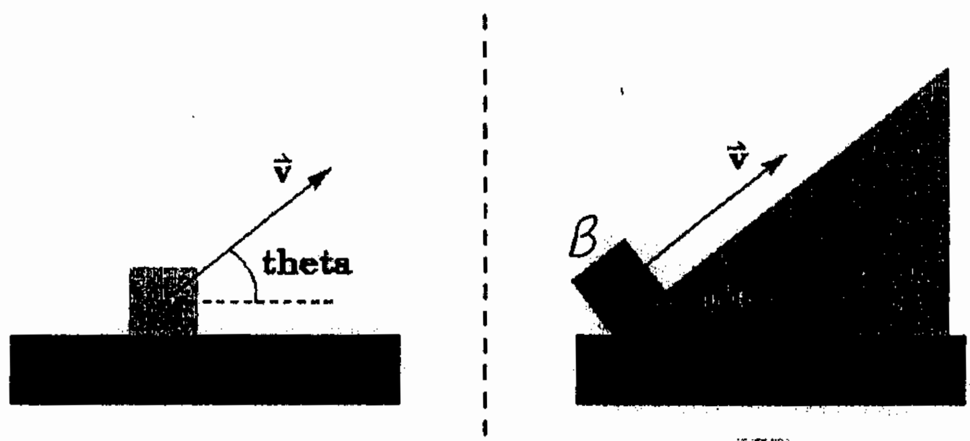
Two objects (Object A with mass M and object B with mass 2M) are each acted on by a force of magnitude C. Both objects start at rest and they both move a distance D along a horizontal, frictionless surface.



i) Which object moves the distance D in the smallest time?

ii) When they reach the distance D, which object has the larger kinetic energy?

iii) Suppose we now add kinetic friction with coefficient μ to the surface. Now, which object has the larger kinetic energy at the distance D?



Now consider the situation shown in the figure. Object A is launched as a projectile with initial speed v at an angle theta above the horizontal. Object B has exactly the same initial speed at exactly the same angle as object A but object B is sliding up a frictionless incline. As before, object A has mass M and object B has mass 2M.

iv) During the subsequent motion, each object will reach a maximum height above the starting location. At its maximum height, which object has the larger kinetic energy?

v) During the subsequent motion, each object will reach a maximum height above the starting location. Which object has the larger maximum height?

A) A student is pushing a large crate across a rough floor at constant velocity. Which of the following is true:

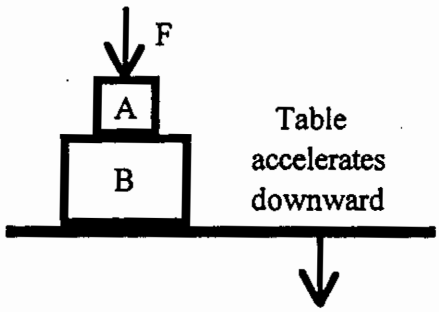
i) The motion is at constant velocity so no force acts between the student and the crate.

ii) Because of friction, the crate pushes harder on the student than the student pushes on the crate.

iii) To overcome friction, the student pushes harder on the crate than the crate pushes on the student.

iv) The crate pushes on the student with the same magnitude of force that the student pushes on the crate.

B) Block A sits on top of block B which sits on a table. An external force of magnitude F pushes down on the top of block A. If the table is accelerating downward, the magnitude of the Normal force of block B on block A is:



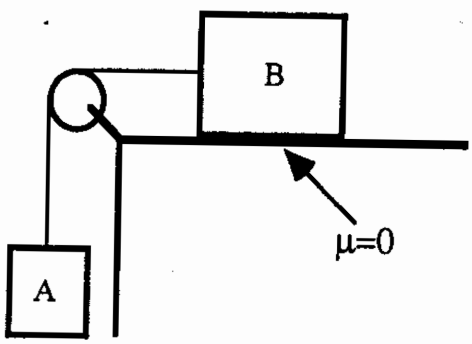
i) Equal to the magnitude of the force of gravity on block A.

ii) Equal to the magnitude of the force of gravity on block A plus the external force F.

iii) Greater than the magnitude of the force of gravity on block A plus the external force F.

iv) None of the above.

C) A block of mass M_A hangs from a string which passes over a light, frictionless pulley and connects to another block of mass M_B which sits on a frictionless horizontal surface. The system is released from rest. During the subsequent motion, which of the following is true.



i) The tension in the string is always $(M_A)g$.

ii) The tension in the string is zero.

iii) The tension in the string is less than $(M_A)g$ but not zero.

iv) The tension in the string is greater than $(M_A)g$.

D) A box of mass M_A is sitting on the floor of an elevator which is moving up at a constant speed, v. Which of the following is true?

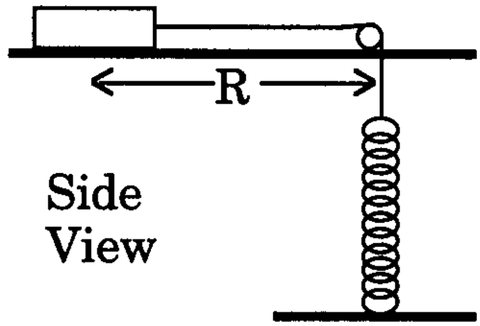
i) Kinetic energy of the box is being converted into gravitational potential energy.

ii) The normal force does work on the box, creating gravitational potential energy.

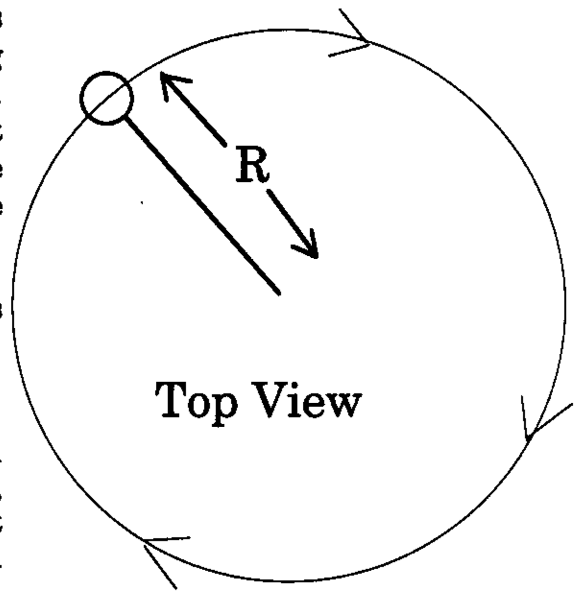
iii) The normal force must be larger than $(M_A)g$ in order to overcome gravity and create the upward energy.

iv) None of the above.

Problem 3 (20 points)



This is a variation on a lecture demonstration. A disk of mass M is held by a string and is moving in a circle on a horizontal, frictionless table. The string passes through a hole in the center of the table on a frictionless pulley. In the lecture demonstration, a hanging weight provided the string tension. In this problem, a spring with spring constant k is attached to the end of the string as shown. The other end of the spring is connected to the floor. Both the string and spring are very light so you can ignore their masses. Assume that the length of the string is such that the spring is just beginning to stretch when the disk is at R=0. The disk completes one full circle every τ seconds (this is the period of the motion).

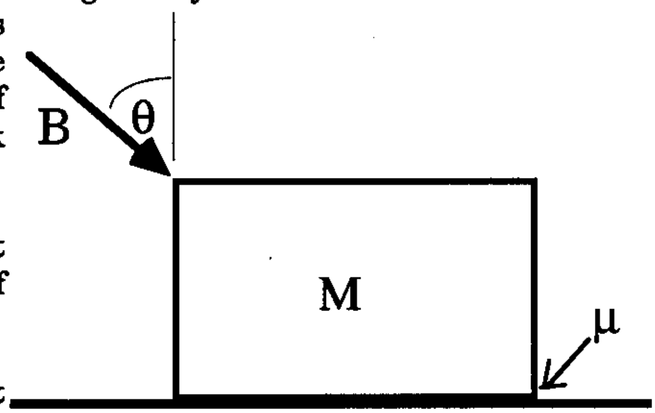


a) Draw a clear diagram showing all the forces acting on the block and its acceleration (if any).

b) Find the value of τ in terms of numerical constants and the given quantities (M, g, k, and R). [Hint: Surprisingly, the correct answer depends on only two of the given quantities.]

Problem 4 (25 points)

An astronaut is pushing a block of mass M that is sitting on a surface as shown. The magnitude of the force exerted by the astronaut is given by B and the direction is shown by the angle θ in the drawing. This experiment is done is *outer space* where *gravity can be neglected.* The coefficients of static and kinetic friction between the block and the surface are both equal to μ.

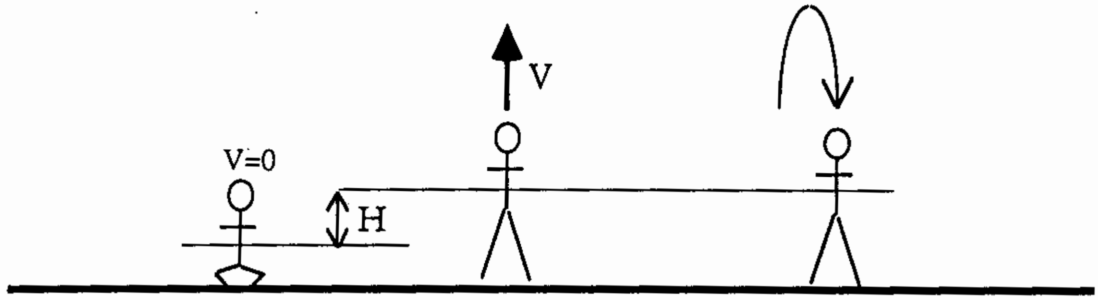


a) Assume initially that the block does **not** move. Draw a clear diagram showing all of the forces acting on the block.

b) Still assuming that the block does **not** move, find the magnitude of all the forces acting on the block (other than the astronaut's hand) in terms of the given quantities.

c) Now assume that the astronaut wants the block to start moving. She will accomplish this by pushing harder (changing B) or by pushing at a different angle (changing θ) or by changing both angle and magnitude. Find the requirements for B and θ in order for the block to just barely start to move. If there are no restrictions on the value of either B or θ, or both, clearly explain why that is the case.

Problem 5 (25 points) The physics of Michael Jordan



A basketball player wants to jump straight up. He starts the motion crouched down at rest (left picture) and first pushes against the ground, raising his center of mass by a distance **H**. Assume that during this motion, the force his legs exert is a constant equal to **B**. At the point where he has moved up a distance **H**, his feet leave the ground and he has an upward velocity of **V** (middle picture). Answer the following questions in terms of the distance, **H**, the player's mass, **M**, the velocity **V**, the force magnitude **B**, and the acceleration due to gravity, **g**.

a) How long does it take for the player to return to the ground (i.e. when is his center of mass again at a height of H, right picture, assuming that he started at that same height)? Assume that the motion is straight up and down, no horizontal movement at all.

b) What was the normal force on his feet due to the floor right before he left the ground?

c) What was the normal force on his feet due to the floor right after he left the ground?

d) Find the magnitude of B in terms of the other variables.

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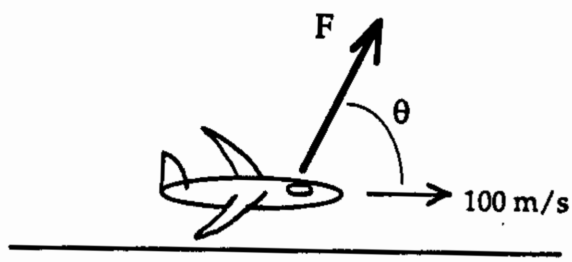


A jet is moving horizontally down a runway. At the instant that it leaves the runway, it is moving at a speed of $v_0 = 100\ m/s$. The combination of the thrust of the jet engine and the lift of the wings produce a force on the plane that makes an angle θ with the horizontal as shown. Use $g = 10\ m/s^2$ to solve this problem. Using M for the mass of the plane, assume that the magnitude of the force is given by:

$$F = \frac{2Mg}{\sin\theta}$$

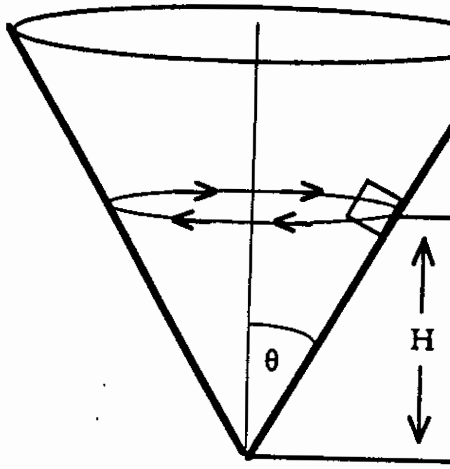
a) (15 pts) Assume that the magnitude and direction of this force doesn't change after the plane leaves the runway. Find the horizontal and vertical distance that the plane has moved in a time of 12 seconds after taking off.

b) (10 pts) Find the magnitude and direction of the velocity of the jet at a time of 12 seconds after takeoff. For this part of the problem only, use $\theta = 60°$.

Initials ____________

Problem 7 (35 points)

A small car is driving in a horizontal circle on the inside surface of a cone as shown. The car has mass, M, and is moving with a constant speed of V. Assume that there is no friction acting on the car. The horizontal circle is located at a height, H, above the point of the cone as shown on the drawing. The angle between the center of the cone and the side (the half-angle) is θ as shown.



a) Draw a free-body diagram showing all the forces acting on the car. Also, draw an arrow indicating the direction of any acceleration.

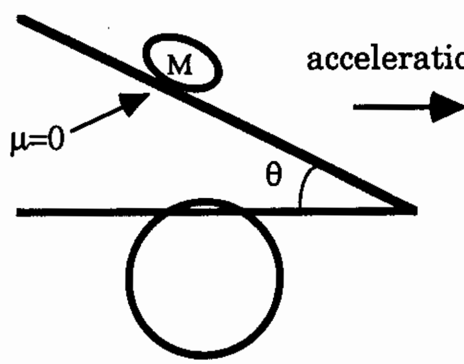
b) In terms of the given quantities and the acceleration of gravity, g, find the value of the normal force acting on the car.

c) In terms of the given quantities and the acceleration of gravity, g, find the value of the constant speed, V, for which the car can continue to move in a horizontal circle at a height, H, with no friction acting along the incline. (Hint: If you do the physics, trigonometry, and algebra correctly, the trig functions all cancel and the answer is independent of θ)

Initials ____________

Problem 8 (20 points)

A bead of water of mass **M** sits on the sloped hood of a car. The hood is at an angle θ from the horizontal and the car is accelerating to the right as shown. Assume that air resistance on the bead and friction between the bead and the hood of the car are both so small that they can be ignored. As the car accelerates, the bead moves along with the car but it does not move up or down the slope of the hood.



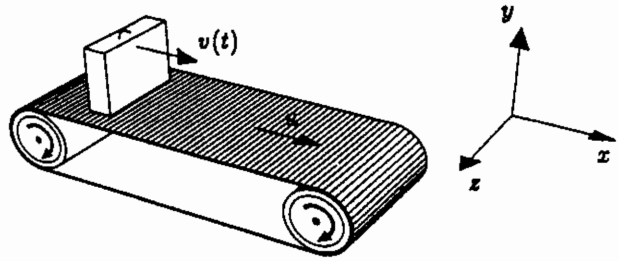
a) Draw a free-body diagram for the bead showing all of the forces acting on it.

b) Pick a choice of X and Y axes, show them on your diagram, and write F=ma equations for the two directions.

c) Find the magnitudes of the normal force of the hood on the bead and the acceleration of the car. Express your answers in terms of **M**, **g**, and θ, noting that the results may depend on only one or two of these values.

Problem 9: A suitcase placed on a conveyor belt (*25 points*)

A suitcase of mass M is placed on a level conveyor belt at an airport. The coefficient of static friction between the suitcase and the conveyor belt is μ_s, and the coefficient of kinetic friction is μ_k, with $\mu_k < \mu_s$. The conveyor belt moves with constant speed u, and at time $t = 0$ the suitcase is placed on the conveyor with speed $v = 0$.



(a) (*6 points*) At $t = 0$, what is the total force $\vec{\mathbf{F}}$ acting on the suitcase?

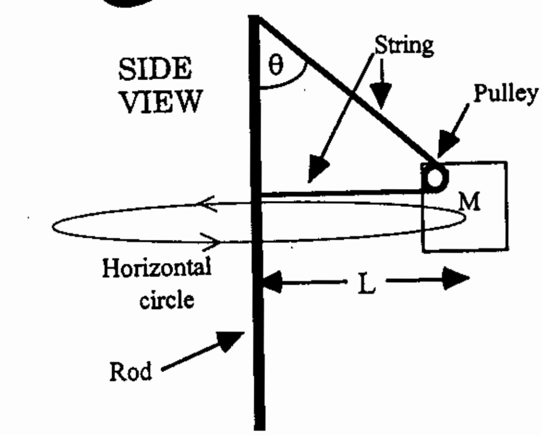
(b) (*6 points*) How long does the suitcase take to reach the speed of the conveyor belt (i.e. at what time t does $v(t) = u$)?

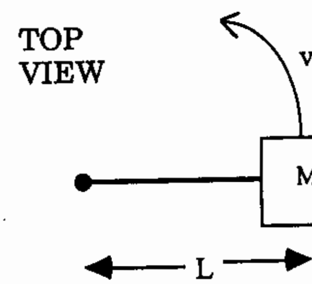
(c) (*7 points*) What is the work done by friction on the suitcase during this time? Be sure that you give the sign as well as the magnitude.

(d) (*6 points*) After the suitcase reaches the speed of the conveyor belt, what is the force of friction that acts on it?

Initials __________

Problem 10 (8 points)





A block of mass M is attached to a vertical rod by a single string which passes around a pulley attached to the block as shown. The entire system rotates so that the block is moving in a horizontal circle with constant speed, v. Assume that the pulley is very light and has negligible friction and also that the string has very little mass.

a) Draw a free-body diagram for the block showing all of the forces acting on it.

b) Pick a choice of X and Y axes, show them on your diagram, and write F=ma equations for the two directions. You do not need to solve these equations.

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Problem 13 Young & Freedman 7.65 Page 279