Physics 1A - Lecture 3 Midterm 2

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TOTAL POINTS

24 / 36

QUESTION 1

1 Problem 1 (6 / 6)

+ 0 Click here to replace this description.
+ 1 Recognize that there is no net external force in the x-direction.
+ 2 Recognize that no external force in the x-direction implies that the acceleration of the center of mass in that direction is zero.
+ 2 Reason that since the center of mass acceleration in the x-direction is zero, and since it falls from rest, it falls straight down
+ 1 Diagram of the trajectory

QUESTION 2

2 Problem 2 (11 / 15)

+ 3 (a) Correct use of energy conservation or kinematics to get equation relating initial velocity and height of monkey
+ 3 (a) Correct use of momentum conservation when acrobat grabs monkey
+ 3 (a) Correct use of energy conservation or kinematics to get equation relating velocity right after the grab to final height reached by acrobat and monkey
+ 2 (a) Solve for maximum height correctly
+ 1 (b) Mechanical Energy is not conserved during grab
+ 3 (b) Compute the change in mechanical energy by finding the difference in kinetic energies before and after the grab.
+ 2 (c) Using physical reasoning and no math, correctly state the limiting behavior of the answer to part (a) in the given limits.
+ 2 Show that the mathematical answer agrees with the expected limiting behavior.
+ 2 Physical reasoning and math for limiting behavior in one of the two cases.
+ 1 Physical reasoning or math for limiting behavior in one of the two cases
+ 0 Click here to replace this description.

QUESTION 3

3 Problem 3 (7 / 15)

+ 3 (a) Correct momentum conservation equation for the first burst.
+ 3 (a) Correct momentum conservation equation for the second burst.
+ 2 (a) Correct solution for the velocity after both bursts by simultaneously solving momentum conservation equations.
+ 2 (b) State or prove the correct expression for the velocity as a function of time for the rocket using the given speed variable.
+ 1 (b) Correctly identify the initial and final mass of the rocket + fuel to solve for the final velocity of the rocket.
+ 2 (c) Correct calculation of final velocity in the case of two, consecutive mass bursts in the given limit.
+ 2 (c) Correct calculation of the final velocity in the case of continuous mass flow in the given limits.
+ 4 (d) Correct computation of Taylor expansion to first, non-vanishing order and correct statement of the relationship between the velocities in this limit.
+ 2 (a)for first burst, only make mistake in writing the velocity of fuel
+ 2 (a)for second burst, only make mistake in writing the velocity of fuel
- 1 (a) calculation mistake
+ 1 (a)for first burst, use conservation law but make many mistakes
+ 1 (a) for second burst, use conservation law but

make many mistakes
- 2 (a) wrong masses of fuel
+ 1 (a) get the correct solution for first burst
+ 1 (b)consider gravity
- 1 (b)calculation mistakes
+ 1 (b) write something related but make many mistakes
- 1 (b)mixing scalars and vectors
+ 1 (c) know how to calculate
- 1 (c) don't give a correct result for strategy 1
- 1 (c) calculation mistakes
+ 1 (c)give a correct result without calculations
+ 2 (c)give a correct answer with some explanations (but not enough or not correct)
+ 1 (d) have done some calculations
+ 2 (d) have done some calculations
+ 0 Click here to replace this description.

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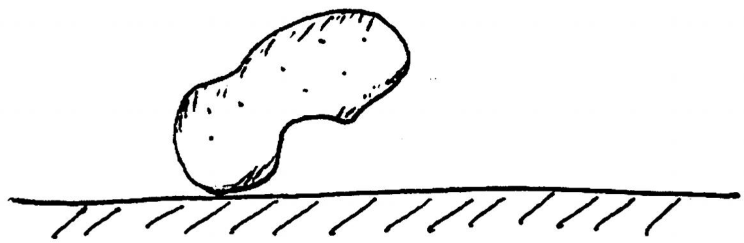
Physics 1A - Winter 2016

MIDTERM EXAM #2

Advice. 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.

Problem 1. (6 points)

A perfectly smooth but irregularly-shaped rock is placed on a perfectly smooth, planar table on Earth as shown. The coefficient of friction between the rock and the surface is zero. For times $t < 0$, the rock is at rest in an unbalanced orientation, but at $t = 0$ it is released.



Describe the motion of the center of mass of the rock as a function of time for $t > 0$. Justify your description mathematically, with a diagram of the trajectory, and in words.

If you consider the center of mass a height h above the planar surface

$$\vec{R} = \frac{m_1 x_1 + m_2 x_2 \cdots m_n x_n}{m_1 + m_2 \cdots m_n}$$

It will fall directly downwards as a function of $V_i = -2gd$

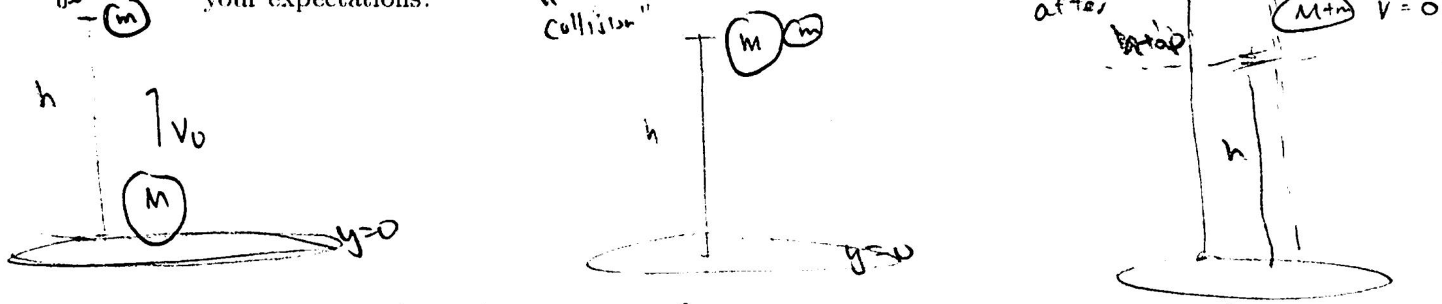
Problem 2. (15 points)

A circuis acrobat of mass M leaps straight up with initial velocity v_0 from a trampoline. As he rises up, he quickly takes a trained monkey of mass m off a perch at height h above the trampoline.

(a) What is the maximum height attained by the pair?

(b) Is mechanical energy of the acrobat-monkey system conserved in this process? If so, prove it. If not, compute the mechanical energy lost.

(c) **Extra Credit. (4 extra points possible)** What would you expect the answer to be in the limits $M/m \to 0$ and $m/M \to 0$? Does you mathematical answer agree with your expectations?



Energy

from the initial leap to the perch

$\frac{1}{2}Mv_0^2 = \frac{1}{2}Mv_f^2 + Mgh$

$\frac{1}{2}v_0^2 = \frac{1}{2}v_f^2 + gh$

$\sqrt{v_0^2 - 2gh} = v_{f_1}$

Momentum

is an inelastic collision

before after

$M\left(\sqrt{v_0^2 - 2gh}\right) = (M+m)v_{f_2}$

$v_{f_2} = \frac{M\left(\sqrt{v_0^2-2gh}\right)}{(M+m)}$

at max height the velocity of the system will be 0

$E_{perch} = E_{top}$

$(m+M)gh + \frac{1}{2}(M+m)v_{f_2}^2 = mgh_{top}$

$(m+M)gh + \frac{1}{2}(m+M)\left(\frac{(v_0^2-2gh)}{(M+m)}\right) = mgh_{top}$

$(m+M)gh + \frac{1}{2}(v_0^2 - 2gh) = mgh_{top}$

$h_{top} = \frac{(m+M)}{m}h + \frac{\frac{1}{2}(v_0^2-2gh)}{mg}$

3

b)

It's an inelastic collision → energy is not conserved

energy just before collision (grabbing the monkey)

$\frac{1}{2} M v_{f1}^2 + Mgh + mgh =$

$\frac{1}{2} M (v_0^2 - 2gh) + mgh$

energy just after

$\frac{1}{2} (M+m) v_{f2}^2 + (M+m)gh$

$\frac{1}{2} (M+m) M^2 (v_0^2 - 2gh) + (M+m)gh$

$\frac{1}{2} (M+m) M^2 (v_0^2 - 2gh) + (M+m)gh - \frac{1}{2} M (v_0^2 - 2gh) - mgh$

c) If the mass m approaches 0 → no energy should be lost and height should just be $\frac{v_0^2}{2gh}$

If $\frac{M}{m}$ approaches 0 then all energy should be lost, and height should be limited to h

Extra Space

Problem 3. (15 points)

no gravity

Lonestar is a space rocket engineer attempting to design a rocket that can break the Andromeda rocket speed record. The rocket she designs has mass m_R and can hold a mass of fuel m_F. To break the record, Lonestar needs to launch her rocket from rest. She is considering the following propulsion strategies:

Strategy 1. The fuel is expelled in two mass bursts with the first burst expelling half as much mass as the second and with both bursts having speed u relative to the rocket.

Strategy 2. The fuel is expelled continuously at speed u relative to the rocket.

(a) What will be the final speed of the rocket for strategy 1?

(b) What will be the final speed of the rocket for strategy 2?

(c) If the mass of fuel m_F is much larger than the mass of the rocket m_R, then which strategy will yield a larger final rocket speed?

(d) **Extra Credit. (4 extra points possible)** Use Taylor expansions in the variable $x = m_F/m_R$ to determine the final rocket speed for each strategy when the mass of fuel m_R is much smaller than the mass of the rocket m_R. Which strategy yields a larger final rocket speed in this case?

a) burst 1 $\frac{1}{3} m_F$ burst 2 $\frac{2}{3} m_F$

first blast

momentum before

$$0 = (m_R + \tfrac{2}{3}m_f)(v) - \tfrac{1}{3}m_f(v-u)$$

$$= V m_R + \tfrac{2}{3}m_f V - \tfrac{1}{3}m_f V + \tfrac{1}{3}m_f u$$

$$-\tfrac{1}{3}m_f u = V(m_R + \tfrac{1}{3}m_f)$$

$$V = \frac{-m_f u}{3(m_R + \frac{1}{3}m_f)}$$

Second blast

$$(m_R + \tfrac{2}{3}m_f)\left(\frac{-m_f u}{3(m_R + \frac{1}{3}m_f)}\right) = (m_R)V_f - \tfrac{2}{3}m_f(V_f - u)$$

$$= (m_R)V_f - \tfrac{2}{3}m_f V_f - \tfrac{2}{3}m_f u$$

$\frac{2}{3}m_f u$

② Strategy 2

$$F_{ext} = M(t)\frac{dv}{dt} - \frac{dM}{dt}u(t)$$

at the end it's just m_R

rocket equation

$$v(t) = u \ln\left(\frac{M(t)}{M}\right)$$

at fuel is all out

$$v = u \ln\left(\frac{m_R}{m_R + m_f}\right)$$

③ If m_f is much greater than m_f

two mass bursts b/c ln levels off while m_f is in mune

Extra Space

Problem	Score
1	
2	
3	
Total	
Extra Credit 2	
Extra Credit 3	