Physics 141, Midterm Exam #2

Thursday November 12, 2013

8.00 am – 9.30 am

Do not turn the pages of the exam until you are instructed to do so.

Exam rules: You may use *only* a writing instrument while taking this test. You may *not* consult any calculators, computers, books, nor each other.

1. Answer the multiple-choice questions (problems 1 – 10) by marking your answer on the scantron form. For each multiple-choice question (problems 1 – 10), select only one answer. Questions with more than one answer selected will be considered incorrect. **If your student ID is not listed properly on the Scantron form (in the bubbles on the top-left corner), the form will not be processed and you loose points for all multiple-choice questions.**
2. Problems 11, 12, and 13 must be answered in the blue exam booklets **(answer questions 11 and 12 in booklet 1 and question 13 in booklet 2.)** The answers need to be well motivated and expressed in terms of the variables used in the problem. You will receive partial credit where appropriate, but only when we can read your solution. Answers that are not motivated will not receive any credit, even if correct.

At the end of the exam, you need to hand in your exam, the blue exam booklets, and the scantron form. All items must be clearly labeled with your name, your student ID number, and the day/time of your recitation. **If any of these items are missing, we will not grade your exam, and you will receive a score of 0 points.**

Name: ____

ID number: ____

Recitation Day/Time: __________________________________

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Useful Relations:

$$\cos(30^\circ)=\frac{1}{2}\sqrt{3} \quad \sin(30^\circ)=\frac{1}{2} \quad \tan(30^\circ)=\frac{1}{3}\sqrt{3}$$

$$\cos(45^\circ)=\frac{1}{2}\sqrt{2} \quad \sin(45^\circ)=\frac{1}{2}\sqrt{2} \quad \tan(45^\circ)=1$$

$$\cos(60^\circ)=\frac{1}{2} \quad \sin(60^\circ)=\frac{1}{2}\sqrt{3} \quad \tan(60^\circ)=\sqrt{3}$$

$$\cos\left(\frac{1}{2}\pi-\theta\right)=\sin(\theta) \quad \sin\left(\frac{1}{2}\pi-\theta\right)=\cos(\theta)$$

$$\cos(2\theta)=1-2\sin^2(\theta) \quad \sin(2\theta)=2\sin(\theta)\cos(\theta)$$

	Circle	Sphere
circumference	$2\pi r$	
(surface) area	πr^2	$4\pi r^2$
volume		$\frac{4}{3}\pi r^3$

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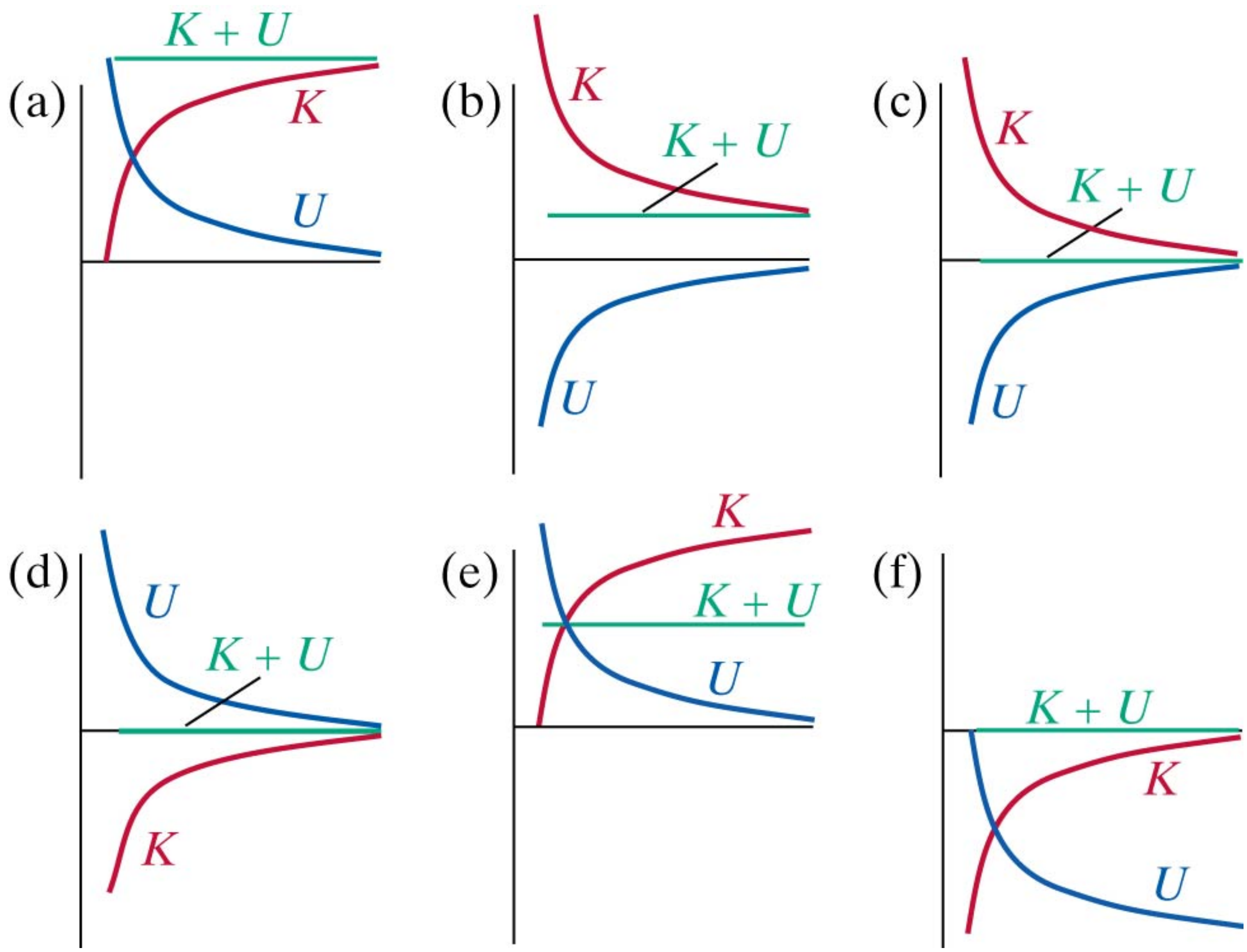
Problem 1 (2.5 points)

Which of the diagrams in the following Figure corresponds to a system of two electrons that start out far apart, moving straight toward each other with nonzero initial velocities?



1. (a)
2. (b)
3. (c)
4. (d)
5. (e)
6. (f)

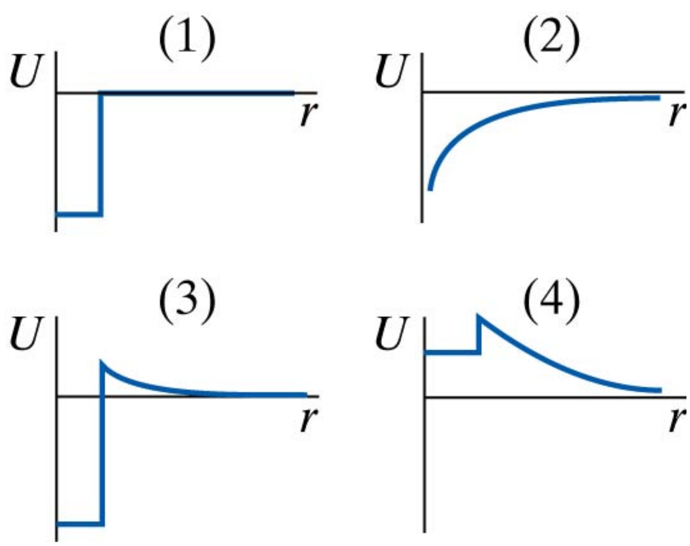
Problem 2 (2.5 points)

One of the thermonuclear or fusion reactions that take place inside a star such as our Sun is the production of ^{3}He and a high-energy photon in a collision between a proton (^{1}H) and a deuteron (^{2}H, the nuclear us "heavy" hydrogen, consisting of a proton and a neutron):

$$^{1}H + {}^{2}H \rightarrow {}^{3}He + \gamma$$

The rest mass of a proton is 1.0073 u (where u is the unified mass unit), the rest mass of the deuteron is 2.0136 u, the rest mass of ^{3}He is 3.0155 u, and the mass of a photon is 0 u.

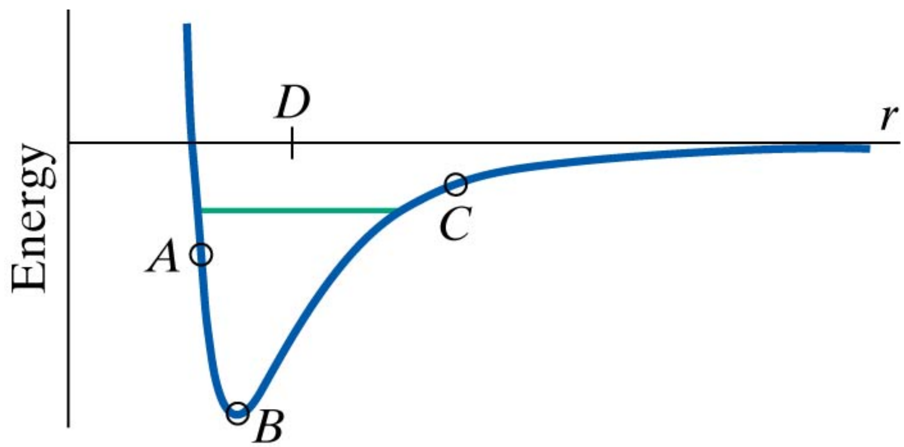
Which of the potential energy curves in the following Figure is a reasonable representation of the interaction in this fusion reaction?



1. (1)
2. (2)
3. (3)
4. (4)

Problem 3 (2.5 points)

The Figure below shows a graph of the potential energy versus the interatomic distance for a particular molecule.



Rank the magnitude of the force at locations A, B, and C in order from strongest to weakest.

1. $|\vec{F}_A| \geq |\vec{F}_B| \geq |\vec{F}_C|$
2. $|\vec{F}_A| \geq |\vec{F}_C| \geq |\vec{F}_B|$
3. $|\vec{F}_B| \geq |\vec{F}_A| \geq |\vec{F}_C|$
4. $|\vec{F}_B| \geq |\vec{F}_C| \geq |\vec{F}_A|$
5. $|\vec{F}_C| \geq |\vec{F}_B| \geq |\vec{F}_A|$
6. $|\vec{F}_C| \geq |\vec{F}_A| \geq |\vec{F}_B|$

Problem 4 (2.5 points)

What is so important about the number 42? Note that more than one answer may be correct.

1. That is the number that follows 41.
2. That is the number that precedes 43.
3. That is the number of points I hope to get on this exam.
4. That is the number of Mariano Rivera, the last person who was able to use this number.
5. That is the number that was retired in 1997 to honor Jackie Robinson.
6. That is the number of airplanes your Physics 141 instructor owns.

Problem 5 (2.5 points)

Which energy diagram in the following Figure is appropriate for the following situations?

a) Hadronic.

b) Vibrational states of a diatomic molecule such as O_2.

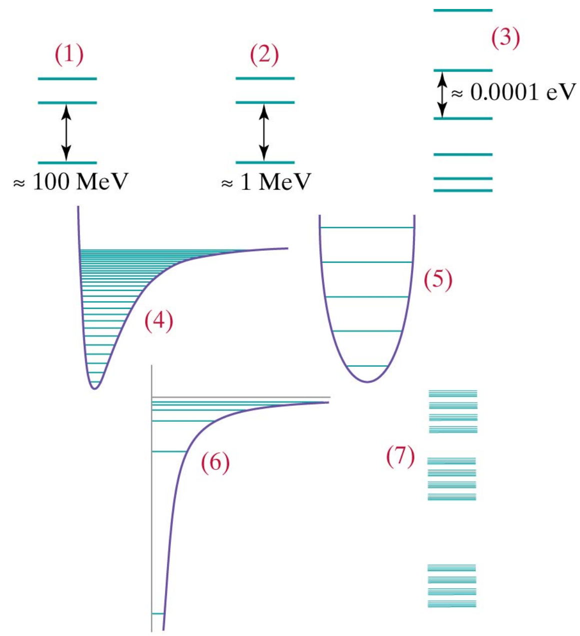
c) Idealized quantized spring-mass oscillator.

d) Nuclear.

e) Vibrational and rotational states of a diatomic molecule such as O_2.

f) Rotational states of a diatomic molecule such as O_2.

g) Electronic states of a single atom such as hydrogen.



1. (1=a), (2=c), (3=d), (4=e), (5=g), (6=f), (7=b)
2. (1=a), (2=d), (3=f), (4=b), (5=c), (6=g), (7=e)
3. (1=b), (2=a), (3=f), (4=d), (5=c), (6=g), (7=e)
4. (1=b), (2=a), (3=c), (4=g), (5=d), (6=f), (7=e)
5. (1=c), (2=d), (3=a), (4=b), (5=e), (6=f), (7=g)
6. (1=c), (2=d), (3=a), (4=g), (5=f), (6=e), (7=b)
7. (1=d), (2=a), (3=f), (4=b), (5=c), (6=g), (7=e)
8. (1=d), (2=b), (3=f), (4=a), (5=c), (6=g), (7=e)

Problem 6 (2.5 points)

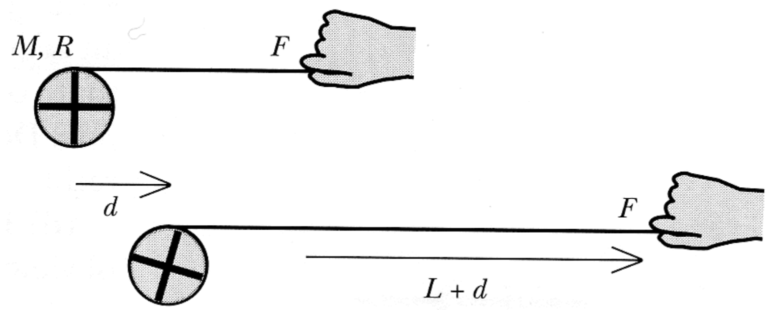
You are given two carts, A and B. They look identical, and you are told that they are made of the same material. You place A at rest on an air track and give B a constant velocity directed to the right so that it collides elastically with A. After the collision, both carts move to the right, the velocity of B being smaller than what it was before the collision. What do you conclude?

1. Cart A is hollow.
2. The two carts are identical.
3. Cart B is hollow.
4. Need more information.

Problem 7 (2.5 points)

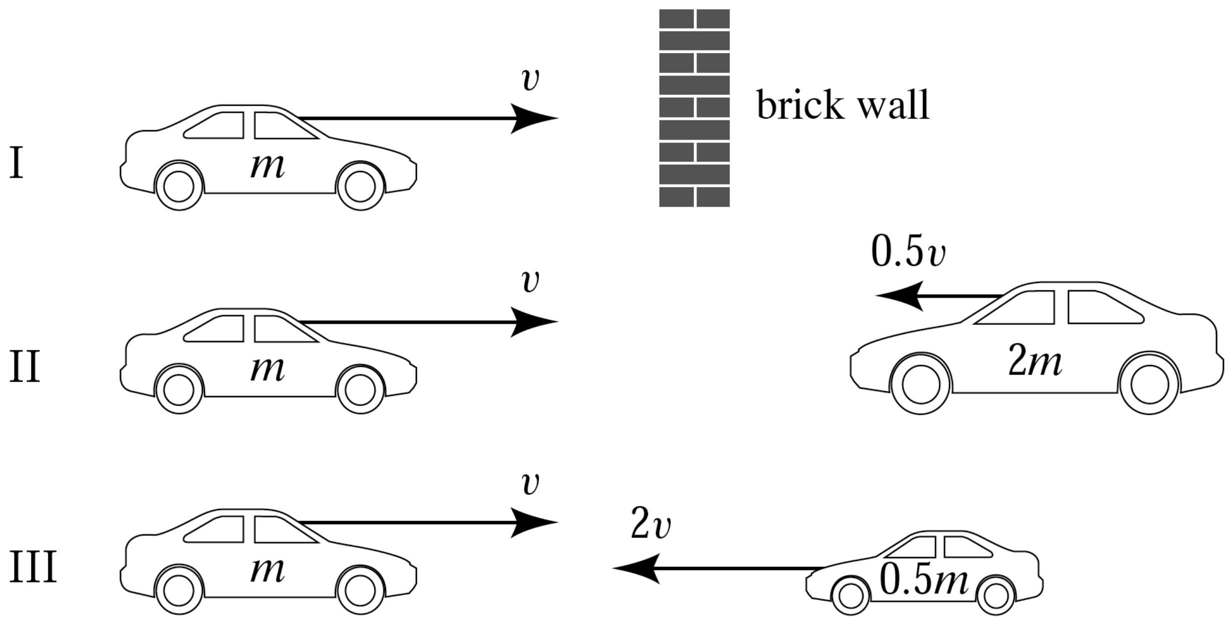
A string is wrapped around a disk of mass M and radius R. Starting from rest, you pull the string with a constant force F along a nearly frictionless surface. At the instant when the center of the disk has moved a distance d, a length L has unwound of the disk. At this instant what is the speed of the center of mass of the disk?

1. $v_{cm} = \sqrt{\frac{2F}{M} d}$
2. $v_{cm} = \sqrt{\frac{2F}{M} L}$
3. $v_{cm} = \sqrt{\frac{2F}{M}(L + d)}$
4. $v_{cm} = \sqrt{\frac{2F}{M} R}$
5. $v_{cm} = \sqrt{\frac{2F}{M} \frac{2\pi R}{d} L}$



Problem 8 (2.5 points)

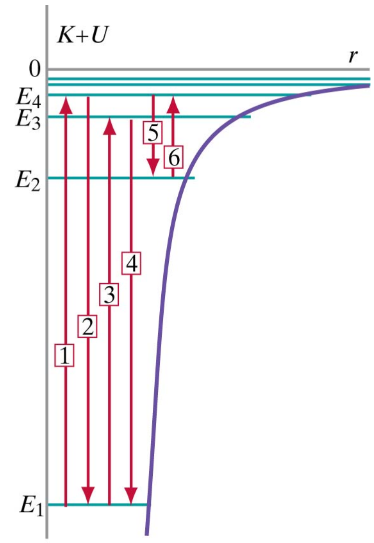
If all three collisions in the figure shown below are totally inelastic, which collisions cause(s) the most damage?



1. I.
2. II.
3. III.
4. I and II.
5. I and III.
6. II and III.
7. All three.

Problem 9 (2.5 points)

An energy diagram of the hydrogen atom with several transitions is shown in the Figure below.



Assuming that the hydrogen is maintained at extremely low temperatures, which transition shown in the Figure represents an absorption transition that is extremely unlikely to be observed?

1. Transition 1
2. Transition 2
3. Transition 3
4. Transition 4
5. Transition 5
6. Transition 6

Problem 10 (2.5 points)

Consider a head-on collision between two objects. Object 1, which has mass m_1, is initially in motion and collides head-on with object 2, which has mass m_2 and is initially at rest. Which of the following statements about the collision are true?

A. $\vec{p}_{1,initial} = \vec{p}_{1,final} + \vec{p}_{2,final}$

B. $\left|\vec{p}_{1,initial}\right| > \left|\vec{p}_{1,final}\right|$

C. If $m_2 \gg m_1$, then $\left|\Delta\vec{p}_1\right| > \left|\Delta\vec{p}_2\right|$.

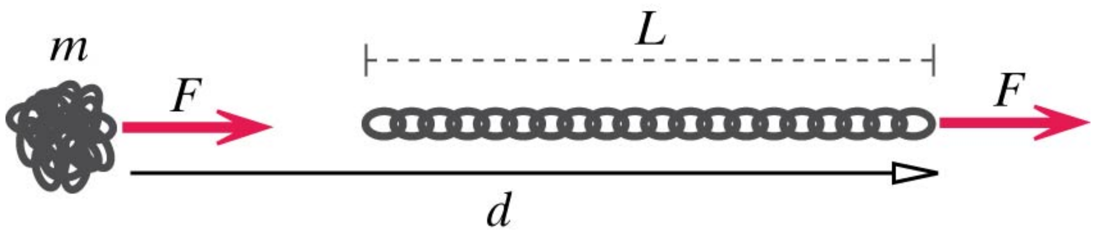
D. If $m_1 \gg m_2$, then the final speed of object 2 is less than the initial speed of object 1.

E. If $m_2 \gg m_1$, then the final speed of object 1 is greater than the final speed of object 2.

1. A
2. A B
3. A B C
4. A B D
5. A B E
6. A C
7. A C D
8. A C E
9. *A D*
10. *A E*

Problem 11 (25 points)

A chain of metal links is coiled up in a tight ball on a frictionless table. The mass of the chain is m. You pull on a link at one end of the chain with a constant force F. Eventually the chain straightens out to its full length L, and you keep pulling until you have pulled your end of the chain a total distance d.



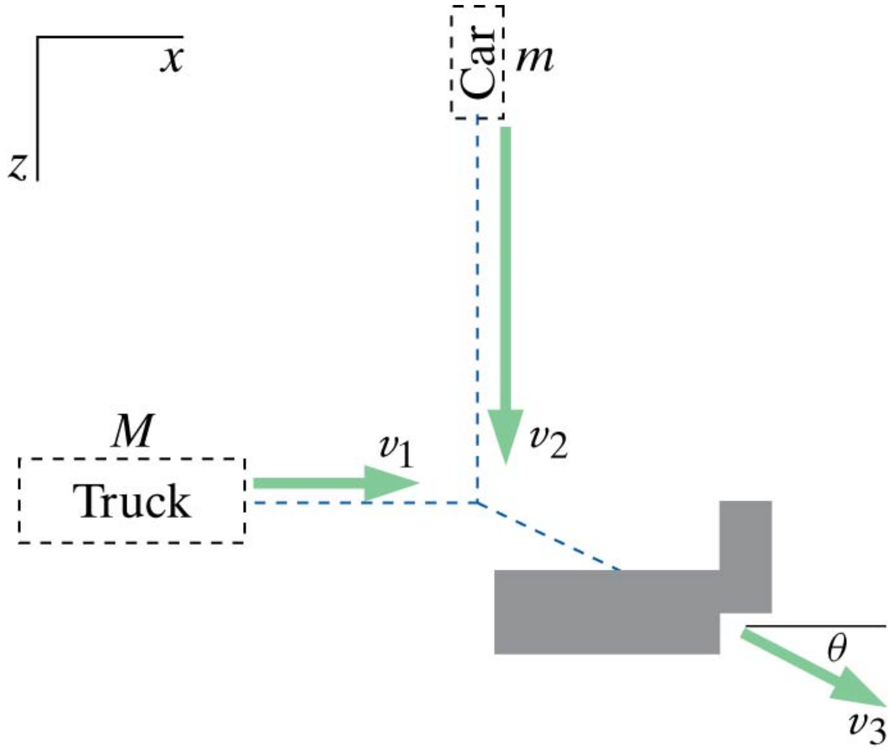
a. What is the speed of the chain at this instant?

b. When the chain straightens out, the links of the chain bang against each other, and their temperature rises. Calculate the increase in thermal energy of the chain, assuming that the process is so fast that there is insufficient time for the chain to lose much thermal energy to the table.

Express all your answers in terms of the variables provided. Your answers must be well motivated.

Problem 12 (25 points)

Consider an inelastic collision in which a truck of mass *M* and a car of mass *m* collide in an icy intersection and stick together, as shown in the Figure below.



a) Let v_1 be the initial speed of the truck, v_2 the initial speed of the car, and v_3 the final speed of the car and the truck when they are stuck together. What are the final speed v_3 and the angle θ between the direction of the car and truck after the collision and the *x* axis?

b) How much energy is lost in this collision?

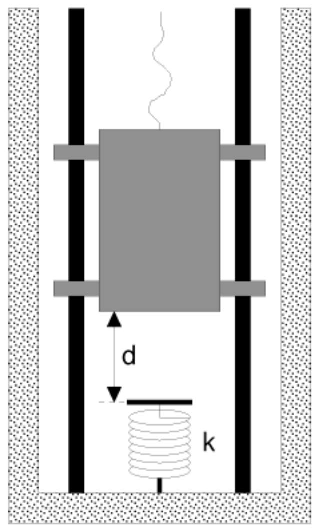
c) What is the velocity of the center of mass before the collision (specify both the direction and the magnitude or the *x* and *z* components of the center-of-mass velocity)?

d) What is the velocity of the center of mass after the collision (specify both the direction and the magnitude or the *x* and *z* components of the center-of-mass velocity)?

Express all your answers in terms of the variables provided. Your answers must be well motivated.

Problem 13 (25 points)

The cable of an elevator of mass M snaps when the elevator is a rest at one of the floors of a skyscraper. At this point the elevator is a distance d above a cushioning spring with spring constant k. A safety device clamps the elevator against the guide rails so that a constant frictional force f opposes the motion of the elevator. Find the maximum distance by which the cushioning spring will be compressed.



Express all your answers in terms of the variables provided. Your answers must be well motivated.

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