

INSTRUCTIONS: Write your NAME on the front of the blue exam booklet. The exam is closed book, and you may have only pens/pencils and a calculator (no stored equations or programs and no graphing). Show all of your work in the blue book. For problems II-V, an answer alone is worth very little credit, even if it is correct – so show how you get it.

Suggestions: Draw a diagram when possible, circle or box your final answers, and cross out parts which you do not want us to consider.

Multiple Choice Questions (4 points each) Please write the letter corresponding to your answer for each question in the grid stamped on the first inside page of your blue book. No partial credit is given for these questions.

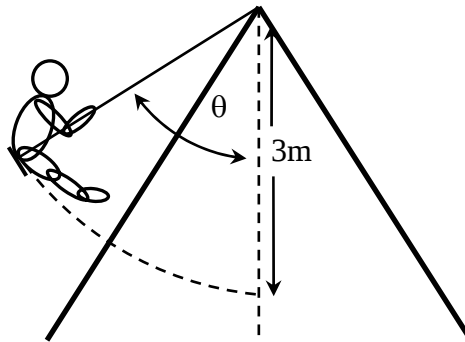
1. A simple pendulum swings back and forth. Consider the force of gravity, F_g , air resistance, F_A , and the tension in the string, T . Which of the following correctly gives the relationship among the work done by each of the three forces during *one full swing* of the pendulum?
 - a) $W(F_g) = 0$, $W(F_A) > 0$, $W(T) = 0$
 - b) $W(F_g) > 0$, $W(F_A) < 0$, $W(T) = 0$
 - c) $W(F_g) = 0$, $W(F_A) < 0$, $W(T) = 0$
 - d) $W(F_g) = 0$, $W(F_A) < 0$, $W(T) > 0$
 - e) The work cannot be determined unless the initial angle is given.
 2. A Yugo accelerates from 0 to a speed v in 10s. A Mazzerati accelerates from 0 to a speed $2v$ in the same time period. What is the ratio of the power expended by the Yugo's engine to that of the Mazzerati? Assume both cars have the same mass and ignore air resistance and other internal friction.
 - a) 1:1
 - b) 1:2
 - c) 1:3
 - d) 1:4
 - e) 1:8
 3. A tennis player returns a shot that arrives traveling horizontally at 50.0 m/s. The outgoing return is again horizontal, directly back along the original direction, at a velocity of 40.0 m/s. If the mass of a tennis ball is 0.06 kg, the impulse delivered by the tennis racket is:
 - a) 0.6 kg m/s
 - b) 5.4 kg m/s
 - c) -0.6 kg m/s
 - d) 2.4 kg m/s
 - e) 3.0 kg m/s
 4. In an elastic collision, two identical carts interact on an air track. If cart 1 is moving with a velocity $v/2$ and the other (cart 2) enters with velocity v , what will be the final velocity of cart 2 after the collision? Both carts are moving in the same direction before the collision.
 - a) $-v/2$
 - b) $v/2$
 - c) v
 - d) $-v$
 - e) $3/2 v$
 5. For the situation in Question 4, above, what is the velocity of the center of mass of the two-cart system? Use the sign of the velocities given there.
 - a) v
 - b) $2v$
 - c) $3/4v$
 - d) $v/2$
 - e) $-3/4v$
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Problems (20 points each)

II. A spherical cannonball of mass $2M$ is launched with an initial velocity V at an angle of 45° above the horizontal. There is an explosive charge between the two halves of the cannonball which is detonated when the cannonball has reached the highest point of its trajectory. One half of the cannonball (mass M) is propelled backwards exactly along the original trajectory and lands back in the cannon (good trick!). Ignore air resistance for this problem.

- Assuming level terrain, find the range of the center of mass of the system, *i.e.*, how far away from the cannon does the center of mass of the system land?
- How far away from the cannon does the second half of the cannonball land?
- Find the velocity of the second half of the cannonball (the one that doesn't land back in the cannon) immediately after the explosion.
- What is the change in kinetic energy of the system due to the explosive charge? Give the magnitude and sign of the change.

III. In a classic “Mythbusters™” episode, Adam and Jamie explore the myth that a person on a child’s swing set can go sufficiently fast that they can swing all of the way around in a vertical circle without falling. The setup is shown in the figure, below, where we define the angle θ to be the angle between the chains holding the swing and the vertical direction. The chains have length $3m$.



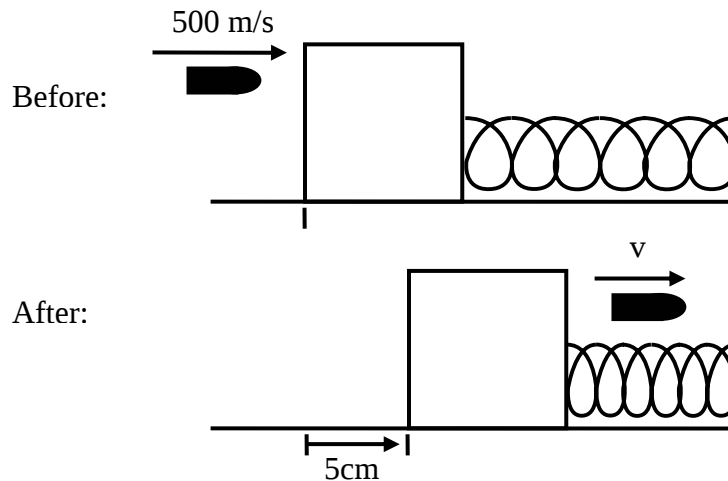
- Answer the following question in words: Theoretically, what is the maximum angle θ that a person can achieve with non-zero tension in the chains merely by swinging themselves on the swing in the standard manner? (*i.e.*, without someone pushing) Why?

True to form, the Mythbusters decided that they would see what it really takes to go all of the way around. To do this, they attached a rocket to their favorite crash-test dummy Buster and put him on the swing. The rocket produces a constant thrust of 2000 N perpendicular to the chains (always tangent to the circle). Buster has a mass of 70 kg . Assume Buster starts his trip from $\theta = 0^\circ$.

- Find Buster’s speed at the top of the circle. Do *not* neglect gravity.
- Find the total tension in the chains at the top of the circle.

IV. A 5.00-g bullet moving with an initial speed of 500 m/s is fired into and passes instantaneously through a 2.00-kg block, as shown in the figure. The block, initially at rest on a frictionless horizontal surface, is connected to a spring of force constant 900 N/m. If the block moves 5.00 cm to the right after impact before coming to rest, find

- The speed of the block right after the collision,
- The speed at which the bullet emerges from the block, and
- The energy lost in the collision



V. The Rusty Atwood's Machine: Two masses are suspended from a pulley attached to the ceiling. One mass, m_2 is heavier than the other, m_1 , i.e., $m_2 > m_1$. Mass m_2 is released a distance h from the floor, and falls while m_1 is lifted up. Ignore the heights of the blocks in all cases.

- First, assume there is no friction in the pulley. Using conservation of energy, write an expression for the speed of mass m_2 when it is a distance d above the floor.
- In this frictionless case, at what speed does m_2 hit the floor?

Now, assume that there is a constant force of friction caused by rust on the pulley's axle. The rusty axle exerts a constant force F in opposition to the direction of motion of the rope as the wheel turns.

- Incorporating this dissipative force, write a new expression for the speed of mass m_2 when it is a distance d above the floor.
- In this case, at what speed does m_2 hit the floor?

