Final F=ma prep

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1 Introduction

Hi everyone, F=ma is next Tuesday !! In each section, we have 1-2 problems on various topics in mechanics. We hope this will help you identify anything you aren't comfortable with, and we can work on it together. Even if you aren't taking F=ma, a solid background in mechanics is essential for future (and harder) physics. Also, you can get a 5 on the AP Physics Mechanics Exam and feel very smart.

2 Collisions

Collisions are scenarios where one object crashes into another. Since there is no external forces, we can always conserve momentum. For elastic collisions, there is a useful 'trick' where we change frames for easier calculations. The steps are as follows:

1. Change the frame so the total momentum is originally 0.
2. After the collision, the velocities are simply reversed.
3. Reverse the original change, and you have the final velocities after a collision.

Example (will be done on board): Arnold (mass: 8 kg) is traveling at 3 m/s when he crashes into Jeremy (mass: 4 kg), who is originally at rest.
Elastic collision: Momentum *and* energy are conserved.
Inelastic (sticky) collision: Momentum is conserved.

3 Collision Problems

1. Arnold is originally to the left of Jeremy. Arnold (mass: 8 kg) is moving at 5 m/s to the right, while Jeremy (mass: 4 kg) is moving at a speed of 2 m/s to the left. After they collide elastically, what are Arnold and Jeremy's velocities?
2. Arnold is moving at a speed of 5 m/s. He travels 3 m, when he then collides elastically with Jeremy, who is at rest. If the coefficient of kinetic friction between both Arnold and Jeremy and the surface is 0.2, how far will Jeremy travel before stopping? Use the same masses from the previous problem.

4 Motion

1. Arnold (5 m tall) is on an elevator accelerating upwards at 3 m/s^2. If Arnold drops his phone when the elevator is 10 meters above the ground, what will the phone's velocity be when it hits the bottom of the elevator?

2. Arnold shoots a rock with his rock gun at an angle θ with respect to the horizontal. Find the horizontal distance D the rock travels, and the maximum height H it reaches during the flight. What is the value of H/D?

5 Rotation

The moment of inertia of a filled disk about its center is $\frac{1}{2}MR^2$. The parallel-axis theorem says: $I_{\text{parallel}} = I_{COM} + mr^2$.

1. Calculate the moment of inertia of a disk of uniform density, mass $4M$, and radius $2R$ about its center.

2. Calculate the moment of inertia of the same disk about a point on its circumference.

3. Calculate the new moment of inertia of the resultant disk after a circle of radius R is cut out from the middle of it.

4. Calculate the moment of inertia of the resultant disk after a circle of radius R is cut out in a Pac-man like shape (the cutout is between the circumference and the center).

5. Order the last 4 objects from easiest to rotate to hardest to rotate.

6 Energy

1. What are the units of energy in terms of the base SI units? (kg, m, s, etc.)

2. A block of mass m is moving on a horizontal table surface at v_o. It then moves smoothly onto a sloped big block of mass M. The big block can also move on the table surface. Assume that everything moves without friction. How high is the small block before it falls back down the ramp? What is the speed of the small block after it leaves the slope?

7 Orbits and Gravity

1. Four masses m are arranged at the vertices of a tetrahedron of side length a. What is the gravitational potential energy of this arrangement in terms of G, m, and a?

2. A satellite of small mass, m, orbits a planet of large mass M in an elliptical orbit with closest point R and farthest point $2R$ away. At the farthest point away in the orbit, the satellite is moving with velocity v_o. Then, the satellite is instructed to begin orbiting in a circle of radius $2R$. What is the new speed of the rocket in terms of v_o?