Solution Videos to Physics Problems
Mechanics

For video solutions to these problems go to www.foothill.edu/~cascarano/videos.html

KINEMATICS

MECH_01 (the solution video has two parts)
You are in your car, stopped at a red light, waiting to get onto the freeway. When the light turns green you speed up with constant acceleration until you see a highway patrol car. As soon as you see the highway patrol car you brake, slowing your car with constant acceleration, until you reach the speed limit of 55 mph. Being enrolled in physics, you decide to do some calculations. First, you record your observations:

- The distance you traveled between the stop light and spotting the highway patrol car was 200 yards and the time interval was 12 seconds.
- You are driving a white Toyota Corolla (weight of car, you, and all your physics textbooks is 3500 lbs).
- It took 4 seconds to slow down to the speed limit.
- It was a nice day, the sun was shining, and the temperature was 20°C.

Find out everything you can about this situation. Draw graphs of position vs time, velocity vs time, and acceleration vs time. Make sure your numbers make sense, the signs are correct, and assume all the numbers here are good to three significant figures, so you can give your answers to 3 sig figs.

MECH_02 (the solution video has two parts)
You are on the balcony of a high-rise apartment complex eating peanuts and drinking soda. The balcony overlooks the swimming pool, which is directly below. After a few too many sodas you start throwing peanuts down into the pool below. You quickly realize that if you drop a peanut from rest, wait 1 s, and throw a second peanut straight down, they hit the pool at the same time (they make a single splash). Being enrolled in physics, you decide to do some quick calculations. You grab some paper and take a few measurements:

- Vertical distance from balcony to pool: 80 feet
- Mass of the peanuts: 3 g
- Type of soda you were drinking: Diet, extra caffeine, natural, cherry, jalapeño delight
- Temperature: 70°F

Find out everything you can about this situation. Draw graphs of position vs time, velocity vs time, and acceleration vs time for both peanuts on the same set of axis. Make sure your numbers make sense, the signs are correct, and assume all the numbers here are good to three significant figures, so you can give your answers to three sig figs.

MECH_02B (from Young and Freedman 12th edition, 2-46)
An egg is thrown nearly vertically upward from a point near the cornice of a tall building. It just misses the cornice on the way down and passes a point 50 m below its starting point 5 s after it leaves the thrower's hand. Ignore air resistance. Find the initial and final velocity. Although there is no video solution for it, you can also find the highest point and the velocity and acceleration at the highest point.

MECH_03B (from Young and Freedman 12th edition, 2-80)
(the solution video has two parts) A flowerpot falls off a windowsill and falls past a window below. Ignore air resistance. It takes the pot 0.42 s to pass this window, which is 1.9 m high. How far is the top of the window below the windowsill from which the flowerpot fell?

MECH_05B (from Young and Freedman 12th edition, 3-86)
A man is riding on a flat train car traveling at a constant speed of 9.1 m/s. He wishes to throw a ball through a stationary hoop 4.9 m above the height of his hand in such a manner that the ball will move horizontally as it passes through the hoop. He throws the ball with a speed of 10.8 m/s with respect to himself. A) When the ball leaves his hand, what must the velocity of the ball be relative to the flatcar (magnitude and direction)? Relative to the ground? B) How many seconds after releasing the ball does it pass through the hoop? C) At what horizontal distance in front of the hoop must he release the ball?

FORCES & NEWTON'S LAWS

MECH_06 Free Body Diagrams #1
Two boxes are attached together with a rope. You grab hold of the box on the right and pull it to the right. The floor is frictionless (Well, at least the floor where the boxes are sliding is frictionless. You obviously need friction between your feet and the floor to be able to pull on the boxes.) Draw a free body diagram for each of the boxes.

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MECH_07 Free Body Diagram #2
Two boxes are sitting on the floor right next to each other (their sides are touching). You are pushing the boxes to the right by pushing on the left most box. Again, let's start with a frictionless floor under the boxes. Don't worry, we'll add friction soon. Draw a free body diagram for each box.

MECH_08 Free Body Diagram #3
A single box is sitting on an inclined plane (which slants up as you move to the right). You grab onto the box and pull on it. The direction of your force is parallel to the inclined plane and pointing in the uphill direction. Again, let's start with a frictionless surface under the box. In the next example we will add friction. Draw a free body diagram for the box.

MECH_09 Free Body Diagram #4
A single box is sitting on an inclined plane (which slants up as you move to the right). You grab onto the box and pull on it. The direction of your force is parallel to the inclined plane and pointing in the uphill direction. There is friction between the box and the surface (yes, our ability to deal with "real world" problems is improving). Draw a free body diagram for the box. What assumptions did you have to make in order to draw the free body diagram?

MECH_10B (from Young and Freedman 12th edition, 4-28)
Two blocks are stacked, one on top of the other. You pull horizontally on the lower block, so the two blocks move together as a unit. While it is moving, make a free body diagram for each block if (a) the surface is frictionless and (b) there is friction between the surface and the lower block and your pulling force is equal to this friction force.

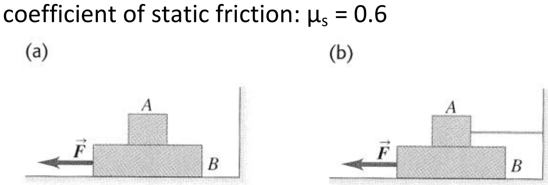
MECH_11 Newton's Laws #1 (the video has two parts)
Same situation as "MECH_06 Free Body Diagram #1":
Two boxes are attached together with a rope. You grab hold of the box on the right and pull it to the right. The floor is frictionless. Find the tension in the rope and the acceleration of the system of boxes given the following information:
Weight of box 1 = 40 N   Pulling force = 20 N
Mass of box 2 = 8 kg

MECH_12 Newton's Laws #2
Same situation as "MECH_07 Free Body Diagram #2":
Two boxes are sitting on the floor right next to each other (their sides are touching). You are pushing the boxes to the right by pushing on the left most box. Again, let's start with a frictionless floor under the boxes. Find the acceleration of the system of boxes given the following:
Weight of box 1 = 40 N   Pushing force = 20 N
Mass of box 2 = 8 kg

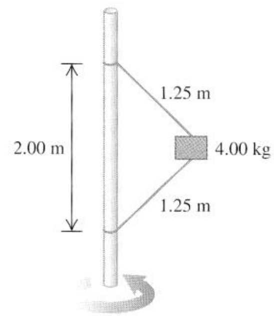
MECH_13 Newton's Laws #3
Same situation as "MECH_08 Free Body Diagram #3":
A single box is sitting on an inclined plane (which slants up as you move to the right). You grab onto the box and pull on it. The direction of your force is parallel to the inclined plane and pointing in the uphill direction. The surface is frictionless. In the next example we will add friction. Find the acceleration of the box given:
Mass of box = 4 kg   Pushing force = 20 N
Angle of incline = 20°

MECH_14 Newton's Laws #4
Same situation as "MECH_09 Free Body Diagram #4":
A single box is sitting on an inclined plane (which slants up as you move to the right). You grab onto the box and pull on it. The direction of your force is parallel to the inclined plane and pointing in the uphill direction. There is friction between the box and the surface. Find the acceleration of the box if:
Mass of box = 4 kg   coefficient of kinetic friction: μ_k = 0.1
Pushing force = 20 N   coefficient of static friction: μ_s = 0.2
Angle of incline = 20°

MECH_15B (from Young and Freedman 12th edition, 5-67)
Block A rests on top of block B. A horizontal force pulls block B (the lower block) to the left. Find the magnitude of this force needed to move block B with constant speed if (a) block A rest on B and moves with it and (b) if block A is held at rest by a horizontal force to the right and block B slides under block A.
Weight of block A = 1.2N   Weight of B = 3.6 N
coefficient of kinetic friction: μ_k = 0.3
coefficient of static friction: μ_s = 0.6



MECH_17C (from Young and Freedman 12^{th} edition, 5-104)
The 4 kg block in the image is attached to the vertical rod by two strings. When the system rotates about the axis of the rod, the strings are extended, as shown, and the tension in the upper string is 80 N. (a) What is the tension in the lower string? (b) How many revolutions per minute does the system make? (c) Find the number of revolutions per minute at which the lower string just goes slack.



WORK & ENERGY

MECH_21 Work
Same situation as FBD #4 and Newton's Laws #4:
A single box is sitting on an inclined plane (which slants up as you move to the right). You grab onto the box and pull on it. The direction of your force is parallel to the inclined plane and pointing in the uphill direction. There is friction between the box and the surface. Find the work done by every force acting on the box as it slides 3 m up the incline plane, if:

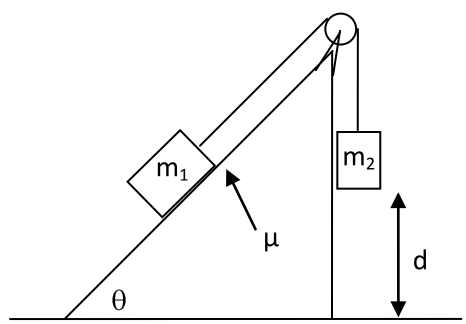
Force, F = 100 N — Coefficient of kinetic friction: $\mu_k = 0.3$
Mass, m = 5 kg — Coefficient of static friction: $\mu_s = 0.4$
Incline angle, $\theta = 30°$

MECH_22C (from Young and Freedman 12^{th} edition, 6-37)
A force F is applied to a 2 kg radio controlled model car parallel to the x-axis as it moves along a straight track. The x-component of the force varies with the x-coordinate of the car as shown. Calculate the work done by the force F on the car when the car moves from (a) x = 0 to x = 3 m; (b) x = 3 m to x = 4 m; (c) x = 4 m to x = 7 m; (d) x = 0 to x = 7 m; (e) x = 7 m to x = 2 m.

MECH_23C (from Young and Freedman 12^{th} edition, 6-81)
A 5 kg block is moving at 6 m/s along a frictionless, horizontal surface toward a spring with force constant 500 N/m that is attached to a wall. The spring has negligible mass. (a) Find the maximum distance the spring will be compressed. (b) If the spring is to be compressed by no more than 0.15 m, what should be the maximum value of the initial velocity of the block?

MECH_26 Energy (the solution video has three parts)
The following system of two masses is released from rest. Find the speed of box 2 just before it hits the ground. (See if you can verify that the boxes actually start moving when they are released – look at the static friction force. Also, verify that M1 will go up the incline when the system is released and not slide down the incline.)

$m_1 = 20$ kg — coefficient of kinetic friction: $\mu_k = 0.2$
$m_2 = 50$ kg — coefficient of static friction: $\mu_s = 0.4$
d = 5 m — $\theta = 30°$



MECH_28 Energy (the solution video has two parts)
A mass M is sitting on an incline plane and attached to a spring. The spring is attached to the box on the "up hill" side of the box and is attached to the incline plane at some point higher up from the box (and it is parallel to the incline plane). The mass is initially at rest and the spring is unstretched. Find how far the box slides down the incline plane before coming to rest for the first time. Also, determine if the box will stay at rest at that point or go back up the incline due to the spring.

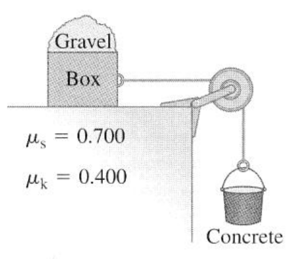
Mass of box, m = 100 kg — Coefficient of kinetic friction: $\mu_k = 0.3$
Spring constant, k = 30N/m — Coefficient of static friction: $\mu_s = 0.4$
Pushing force, F = 20 N — Angle of incline, $\theta = 20°$ (with respect to horizontal)

MECH_29 Energy
You have a friend who is a crime scene investigation technician and she calls you for help with a problem. A motorcyclist was driving uphill on a paved road when he was thrown from his motorcycle, hit the pavement, and slid up the hill to a stop. Being enrolled in physics, you decide to do

some quick calculations. You grab some paper and record some information:

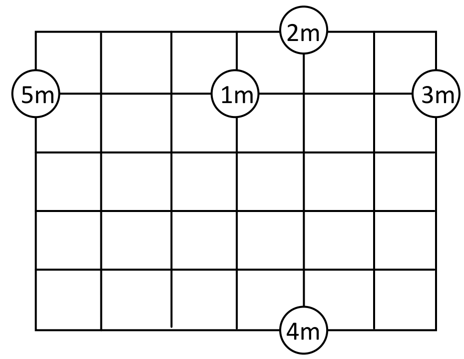
- The motorcyclist was wearing a black leather protective suit.
- You wrap a 10 kg mass in similar leather, attach a spring scale, set it on a horizontal section of pavement, and start pulling (your force is directed parallel to the pavement). The spring scale reading increases to a maximum value of 78.5 N before the mass breaks free and begins sliding on the pavement.
- You wrap a 10 kg mass in similar leather, attach a spring scale, set it on a horizontal section of pavement, and start pulling (your force is directed parallel to the pavement). The spring scale reading is 39.2 N when the mass is sliding across the pavement with constant speed.
- The motorcycle was red in color.
- Marks on the pavement indicate the motorcyclist slid 35 feet before coming to rest.
- The road is inclined at 20° to the horizontal.
- The sky is blue, the sun is shining, and it is 25°C.

MECH_30C (from Young and Freedman 12th edition, 7-39)
At a construction site, a 65 kg bucket of concrete hangs from a light (but strong) cable that passes over a light friction free pulley and is connected to an 80 kg box on a horizontal roof. The cable pulls horizontally on the box, and a 50 kg bag of gravel rests on top of the box. The coefficients of friction between the box and the roof are shown. (a) Find the friction force on the bag of gravel and on the box. (b) Suddenly, a worker picks up the bag of gravel. Find the speed of the bucket after it has dropped 2 m from rest.



MOMENTUM & CENTER of MASS

MECH_40 Center of Mass (point objects)
Find the center of mass of the following system of five particles:

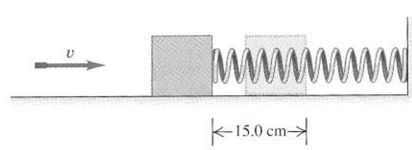


MECH_41 C of M (calculus required, the video has two parts)
Find the center of mass of the following two solid objects:

a) A long, thin rod of length L and mass M and uniform density
b) A long, thin rod of length L and mass M and density given by
(where a is a positive constant and x is the distance, in meters, from one end of the rod)

MECH_44 Momentum
Let's start with a simple problem, two train cars move toward each other, collide, and move separately (independently from each other) after the collision. Find the final velocity of car #2
velocity of car #1 before collision = 10 m/s to the right
velocity of car #2 before the collision = 20 m/s to the left
velocity of car #1 after the collision = 7.143 m/s to the left
mass of car #1 = 100 kg   mass of car #2 = 40 kg

MECH_45C (from Young and Freedman 12th edition, 8-75)
A rifle bullet with mass 8 g strikes and embeds itself in a block with mass 0.992 kg that rests on a frictionless, horizontal surface and is attached to a spring. The impact compresses the spring 15 cm. Calibration of the spring shows that a force of 0.75 N is required to compress the spring 0.25 cm. What is the initial speed of the bullet?



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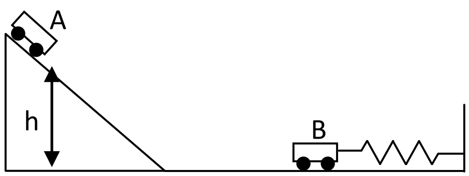
MECH_46C (from Young and Freedman 12th edition, 8-84)
A 5 g bullet is shot *through* a 1 kg wood block suspended on a string 2 m long. The center of mass of the block rises a distance of 0.45 cm. Find the speed of the bullet as it emerges from the block if its initial speed is 450 m/s.

MECH_47 Momentum
Two identical, frictionless carts are positioned as shown. Cart A is released from rest on an incline. Cart B is attached to a spring and is initially at rest at the equilibrium position of the spring. Cart A collides with cart B and the two carts stick together. They come to rest when the spring has been compressed by 0.52 m. Find the starting height of cart A.

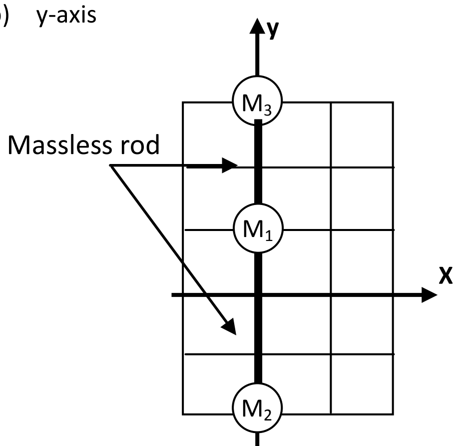


Given:
mass of cart A = 10 kg   Spring constant, k = 300 N/m
mass of cart B = 10 kg   Maximum spring compression=0.52m

ROTATIONAL MOTION

MECH_50 Rotational Inertia (point objects)
Find the rotational inertia of the following system of particles attached to a massless rod about the:

a) x-axis
b) y-axis



mass of particle 1, m_1 = 1 kg   mass of particle 3, m_3 = 3 kg
mass of particle 2, m_2 = 2 kg   Grid spacing = 1 m

MECH_51 Rotational Inertia (solid objects, calculus required)
Find the rotational inertia of a thin, uniform rod of length L located along the x-axis and rotating about the y-axis when the rod is located:

a) Between x = 0 and x = L
b) Between x = -L/2 and x = +L/2
c) Between x = a and x = a+L (a is a positive constant)

mass of rod = M   Rod is of uniform density
Length of rod = L

MECH_52 Rotational Inertia (parallel axis theorem)
Given the rotational inertia for case b in MECH_51, use the parallel axis theorem to find the rotational inertia for cases a and c.

MECH_55C (from Young and Freedman 12th edition, 9-92)
The pulley and the cylinder turn without friction through stationary, horizontal axles that pass through their centers, as shown. A light rope is wrapped around the cylinder, passes over the pulley, and has a 3 kg box suspended from its free end. There is no slipping between the rope and the pulley surface. The uniform cylinder has a mass 5 kg and a radius 40 cm. The pulley is a uniform disk with a mass 2 kg and a radius 20 cm. The box is released from rest and descends as the rope unwraps from the cylinder. Find the speed of the box when it has fallen 1.5 m.