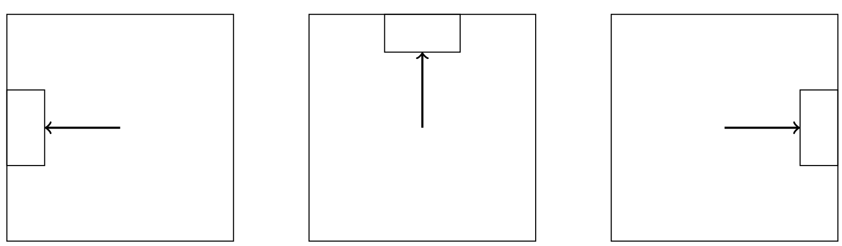
Force Problems (Stewart Edition)

Easy

1. Mr. Stewart wanted to be an astronaut when he was little, but he ended up only as a theoretical physicist. However, there is an opportunity for everyday people to experience outer-space! The G-FORCE ONE is a modified Boeing 727-200 airplane that is able to fly in a parabolic patterns to simulate zero-gravity, or gravity on other planets. A ticket costs $4,500, with 15 parabolic maneuvers.
   (a) The plane moves both in the vertical direction and the horizontal direction. How should the pilots drive the plane such that the only force participants feel is in the vertical direction? (Hint: Think back to kinematics.)
   (b) What acceleration does the plane need to travel to simulate zero-gravity?
   (c) What acceleration does the plane need to travel to simulate gravity on the Moon? A 60kg person weighs 96.6N on the moon.
   (d) What acceleration does the plane need to travel to simulate gravity on Jupiter? A 60kg person weighs 1487.4N on Jupiter.
   (e) The maximum height of the plane is over 7,000 meters. Will the gravitational field caused by Earth be slightly higher or slightly lower than $9.8m/s^2$?
   (f) Therefore, will the actual acceleration the plane needs to travel at be slightly higher or lower than the calculated values for parts (B), (C), (D)?
   (g) Mr. Stewart wasn't able to afford to buy a ticket so he instead decides to set up his own rival company where he uses a zero-gravity elevator. The elevator speeds up when descending to simulate micro-gravity and halfway down, starts to slow down (he doesn't want to kill his clients!). The elevator is 200 meters high. For how long can the elevator simulate lunar gravity?

2. The coefficient of static friction between a book and an elevator is 0.5. Mr. Stewart applies a force on the block perpendicular to the surface it's on. The elevator is accelerating at $2m/s^2$. For each of the three situations below, what is the minimum force does Mr. Stewart needs to apply such that the book is stationary if:

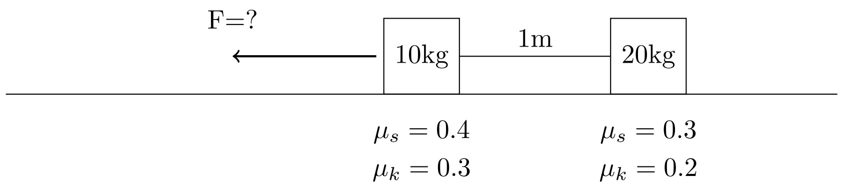


   (a) The acceleration is down?
   (b) The acceleration is up?
   (c) The acceleration is to the right?
   (d) Bonus (grade 12): the acceleration is $2m/s^2$[right 45° up]?

3. The next few questions relate to Newton's Third Law of Motion.
   (a) The Earth's 23.5° tilt is responsible for the seasons. However, this number is slowly changing as Earth actually "wobbles". This is known as "precession" and causes ice ages. Using Newton's third law, explain why this happens.
   (b) One of Mr. Stewart's students agrees that every force has an opposite reaction. He states that when you fire a gun, the recoil knocks you back. However, the bullet is much faster than the recoil. Therefore, he claims that the force and the reaction force isn't always equal.
   (c) Mr. Stewart dislikes the term "reaction" when talking about Newton's third law. Why is he so annoyed about that?
4. Due to air resistance, all falling objects will eventually reach a constant velocity called the terminal velocity.
   (a) What must be true about the force of air resistance when an object reaches this terminal velocity?
   (b) The force of air resistance is given by $F_{drag} = kv$ where k is a constant and is dependent on the object. What are the units for k?
   (c) For a regular human, $k = 10.7kg/s$. What is the terminal velocity of a 58kg human?
   (d) (difficult) Mr. Stewart is using Interactive Physics to demonstrate 2D Kinematics to his grade 11 students. He shoots a red ball horizontally at a blue ball and drops the blue ball at the same time. Since they should both experience the same vertical acceleration, they will collide with each other. However, Mr. Stewart forgot to turn air resistance off. Will the balls still collide or will he embarrass himself in front of his students?
5. The next few questions relate to the concept of friction
   (a) Mr. Stewart wants to move his heavy fridge. He can't get it moving by himself, but with the help of his friend he gets it moving. After the fridge starts moving, Mr. Stewart tells his friend he doesn't need to help anymore. Why would he say that?
   (b) Why is it easier when walking on a low-friction surface such as ice?
   (c) In real life, can the coefficient of static friction be zero? negative? over one?
   (d) A bucket is attached to a pulley via a rope. Will it be easier or harder to lower the bucket into a well if the coefficient of friction between the rope and the pulley increases?
   (e) If the rope is wrapped multiple times around the pulley, will it be easier or harder to lower the bucket into the well?

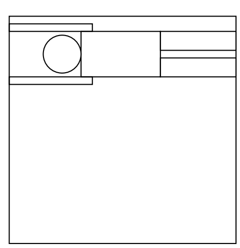
Difficult

1. Mr. Stewart has broken into a bank and stole a block of silver and a block of gold. He attaches the two blocks together with a 2m long string and begins pulling the silver block with a force F to make it start moving. Notice that the coefficients of friction are different for each block.



   (a) Draw a free body diagram for each block.
   (b) What is the minimum force F required?
   (c) After the blocks start moving. What is the acceleration?
   (d) What is the tension in the rope between the two blocks?
   (e) Suddenly after 15 seconds, the police come and Mr. Stewart stops dead in his tracks. Although the silver block stops with him, the gold block continues forward. Using Newton's Laws, explain why this occurs.
   (f) Will the gold block collide with the silver block? If so, what will its speed be when it collides?
   (g) The bored 60kg police officer asks Mr. Stewart to drag the blocks back to the bank. However, he decides to sits on the gold block. Mr. Stewart agrees and starts dragging the blocks back. There is enough friction between the officer and the gold block such that he does not slide off. Draw a free body diagram for the silver block, the gold block, and the police officer when the system is moving.
   (h) When Mr. Stewart is moving at 1m/s, the police officer tells him to move at a constant velocity. What force does Mr. Stewart need to pull with to maintain a constant velocity of 1m/s?
   (i) However, after doing what he is told, Mr. Stewart is getting rebellious. He decides to increase his velocity just enough so the police officer starts sliding off. If the coefficient of static friction between him and the gold block is $\mu_s = 0.5$, how much does he need to increase the force he's currently applying?

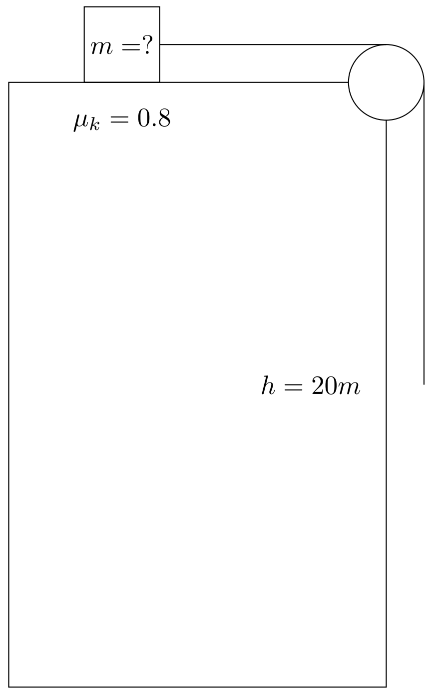
2. Mr. Stewart is taken into custody. However, when no one was looking he ran into a small closet. He thought he was safe, but when he heard approaching footsteps he was forced to hide. Using his superhuman strength, he hid at the top of the closet wedged between two opposing walls. His hands and feet exert a force of $80N$ each on the walls, which is just enough to keep him still.



   (a) Draw a free body diagram for his hands (as one object) and his feet (as one object).
   (b) What is the coefficient of static friction between the room and Mr. Stewart?
   (c) Suddenly, a police officer walks in. Luckily, he does not see Mr. Stewart hiding. However, the room starts accelerating at $1m/s^2$ vertically. Mr. Stewart finds that he needs to exert more force to stay stationary relative to the elevator. Is the elevator moving up or down?

(d) What is the minimum force his hands and feet need to exert now?

3. After the officer leaves and escaping the elevator, Mr. Stewart finds himself on the roof of the police station. He spots a heavy block attached to a pulley with a long rope. Mr. Stewart decides to grab the end of the rope and descend, using the block to slow his descent. The building is 20 meters high and Mr. Stewart can survive the fall if he contacts the ground at $15m/s$. The coefficient of kinetic friction between the block and the roof is 0.8.



(a) What is the minimum weight needed for the block in order for Mr. Stewart to live?

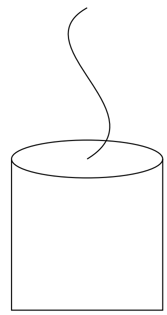
(b) 5 meters down the building, the 60kg police officer from earlier comes and stands on the ramp. What is Mr. Stewart's acceleration?

(c) To try to slow down Mr. Stewart's descent even more, the police officer while still on the block, pushes down on the block with his hands with a force of $10N$. How much has Mr. Stewart's acceleration changed from part (b)?

(d) Will Mr. Stewart still be able to make it down safely? (Remember, Mr. Stewart can let go of the rope any time and live so long as the impact speed is less than $15m/s$)

(e) Caught up in the heat of the motion, Mr. Stewart attempts to speed up his descent by pulling downwards on the rope he's attached to. Will this help? Use Newton's Laws to explain.

4. As if it was a miracle, Mr. Stewart somehow survived and escaped the police station. He stumbles into an arid region, thirsty. Luckily, he finds a well. The well is 40m deep and he at the bottom there is a metal bucket of water. Luckily, there is a rope with one end attached to the bucket and another end at the surface. However, the rope seems in mad condition and can only withstand a maximum of 30N of force before it'll break. The bucket and water is approximately 2kg.



   (a) What is the shortest time possible for Mr. Stewart to get the water he wants without breaking the string?

   (b) Mr. Stewart wants to lower the bucket and get some more water when he finds another identical rope. He attaches that rope to the bucket as well such that he will be pulling on the ends of two ropes simultaneously. How long will it take for him to get the water from the bottom to the top now?

   (c) What if Mr. Stewart adds another rope? What about 4 ropes? 5? Can you find a generalized expression for the shortest possible time if n ropes are attached to the bucket?