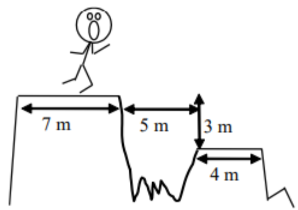
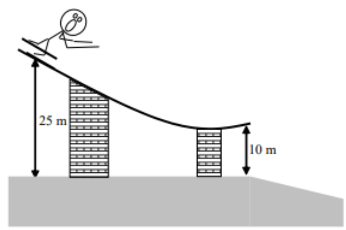
3.4: Summary Problems and Projects

Summary Problems

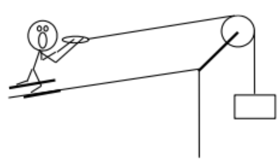
1. A physicist/baseball player hits a ball to very deep centerfield. It's going, going, ... Video analysis shows that the ball leaves his bat at a speed of 35 m/s, an angle of 40° above horizontal, and exactly 1.2 m above the ground. The centerfield fence is 400 feet (120 m) away and 4.0 m high. Starting at the top of the fence is a grassy hillside sloping away from the field at 10° above horizontal. The game is being played in the Vacu-Dome (ignore air resistance). Where on the field or on the hill or on the wall does the ball strike?
2. The strange man at right wants to leap safely down to the plateau below, without landing on the jagged rocks. He can accelerate at 2 m/s^2. At what range of angles, if any, can he jump to land safely? Assume he doesn't slow down as he redirects his velocity on lift-off and he doesn't slide off the plateau on landing.



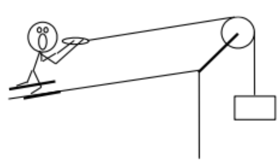
3. In the ski jump, a 55 kg skier (with *really* slippery skis) starts from rest at the top of a 25 m starting ramp declined at 40°. At the end of the ramp is a sharp bend that allows the skier to leave the ramp oriented at 10° above horizontal. At this point, the skier is 10 m directly above the mountainside. The mountainside slopes downward at 10° below horizontal. Where (along the mountainside) does the skier land?



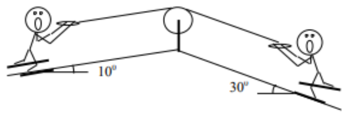
4. If possible, design an uphill skiing device (select the necessary incline angle, ballast mass, and coefficient of friction) such that people with mass less than 50 kg move up the incline while people with mass more than 75 kg move down the incline. Do not use an incline steeper than 15°, or absurd values for the coefficient of friction.



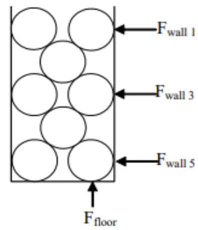
5. In the uphill skiing device at right, the block is released from rest 15 m above the ground. However, the 45 kg skier starts 22 m from the tip of the incline. If possible, select the necessary incline angle, ballast mass, and coefficient of friction such that skier travels all of the way to the tip of the incline before sliding back down. Do not use an incline steeper than 15°, or absurd values for the coefficient of friction.



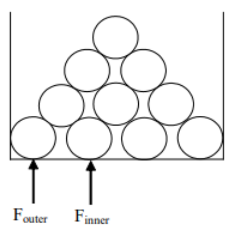
6. The tandem skiing device at right is very rare, and nearly useless. In fact, for the situation pictured neither skier moves. The skier on the left slope has a mass of 65 kg, and the frictional coefficient between her skis and the slope is (0.15, 0.10). The frictional coefficient between the skier on the right slope's skis and the slope is (0.25, 0.20). Find the range of possible values for the mass of the skier on the right slope.



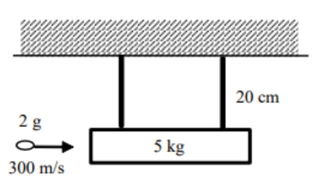
7. In a tall container of water, the largest forces are exerted on the bottom surface of the container. In addition, the force exerted on the wall of the container increases with depth below the surface. These intuitive facts are not necessarily true with a tall container filled with a granular material, such as sand. To see this, examine the hypothetical container at right. Each of the spheres represent a grain of sand, with mass M and radius R. The width of the container is 5 R.



   a. The forces exerted by the sand grains on the walls of the container and on the floor of the container are labeled at right. (The forces in the diagram are the Newton's Third Law partners to these forces. The numbering system refers to the sand level, with the top level labeled 1, the next layer underneath 2, etc. Thus, the sand does not touch the wall at level 2 or 4.) To verify the statement above, show that the largest of these four forces is not F_{floor}, and that the largest wall force is not $F_{wall\ 5}$. Ignore any frictional effects between the sand grains.
   b. Find the minimum width of the container such that F_{floor} is less than or equal to $F_{wall\ 3}$. For narrower containers, the force exerted on the floor is indeed larger than any of the forces exerted on the walls.
8. If you were buried underneath a sandpile (I hope this fate never befalls you), the force pressing down on you would not necessarily be a maximum under the center of the pile. To see this, examine the hypothetical sandpile at right. Each of the spheres represent a grain of sand, with mass M and radius R. The width of the container is 9.5 R.



   a. The forces exerted by the sand grains on the floor of the container are labeled F_{outer} (for the outer grains) and F_{inner} for the inner grains. (The forces in the diagram are the Newton's third law partners to these forces.) To verify the statement above, show that F_{inner} is no larger than F_{outer}.
   b. The configuration shown requires a frictional force to act between the bottom surface of the container and the sand grains. Determine this frictional force on each grain of the bottom level.
9. Two identical 750 kg automobiles, one moving east and the other moving north, collide. After the collision they remain joined together and move with a common velocity. The wreckage skids 43 m at 300 north of east. The coefficient of friction is (0.6, 0.5). How fast were the automobiles traveling before the collision?
10. A bullet is fired at a suspended, stationary, slab of wood. The bullet remains embedded in the wood after the collision, and the slab swings out to the right. To what maximum angle from vertical does the slab swing?



Projects

Hawking Goes Zero-g

Note

Based on: “Hawking goes zero-G,” www.msnbc.msn.com/id/18334489/

World-famous physicist Stephen Hawking experienced eight rounds of weightlessness on Thursday during a better-than-expected airplane flight that he saw as the first step toward a trip in space.

"It was amazing," Hawking told reporters afterward, using his well-known computerized voice. "The zeroG part was wonderful, and the high-G part was no problem. I could have gone on and on.

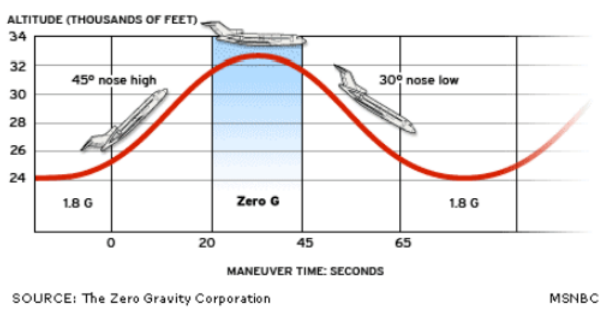
Hawking's host, Zero Gravity Corp. co-founder and chief executive officer Peter Diamandis, said before the flight that he'd claim success if Hawking had just a single half-minute float in weightlessness aboard the company's specially modified Boeing 727 jet. It turned out that Hawking took eight turns with ease

"He would have flown more if we let him," said Noah McMahon, one of Hawking's coaches as well as Zero Gravity's chief marketing officer. "He was all smiles all the time."

Zero Gravity had originally planned to bring Hawking back to NASA's Shuttle Landing Facility here after six ups-and-downs. "We negotiated and agreed to do two more," Diamandis told reporters jokingly. After the landing, Hawking's fellow fliers gave him a round of applause.

Hawking is one of the globe's best-known scientists — not only because of his best-selling works on the mysteries of black holes and the origins of the universe, but also because of his increasing disability due to a degenerative nerve disease known as amyotrophic lateral sclerosis. He is almost completely paralyzed and can communicate only via facial gestures and a gesture-controlled computer system.

The zero-G airplane flights conducted by Zero Gravity, as well as government space programs, duplicate the sense of weightlessness that astronauts feel in orbit for about a half-minute at a time. The plane follows a parabolic, roller-coaster course through the sky. During the top half of each parabola, airplane passengers feel as if they're in free-fall — but when the plane pulls out of its descent, they feel more than the normal pull of gravity.



The graphic above illustrates the idealized flight plan for a zero-g flight. Assuming the jet enters the shaded “zero-g” portion of the flight at the illustrated 45° nose high position, exits at 30° nose low, and the passengers experience “zero-g” for the entire shaded region, complete a kinematic description of the plane’s motion. Based on your analysis, is the illustrated change in altitude consistent with the above assumptions?

Steep Streets[3]

Note

Based on: “Here in Beechview,” postgazette.com, January 30, 2005

Despite the twin "Do Not Enter" signs at its midpoint, Canton Avenue isn't a one-way street. It's a no-way street. No way you're going to drive up it. Not this time of year, when it's covered with ice and snow. This Beechview byway is way too steep–even to plow.

It's the steepest street in this hilly town and, probably, the region, with a grade of 37 percent -- that is, rising 37 feet per 100 feet of run. So confirm records from the city Department of Engineering and Construction. Canton could be the steepest street anywhere. Figures can be fuzzy, but the best San Francisco can do are grades of 31.5 percent. The world's steepest claim is made by Baldwin Street in Dunedin, New Zealand, but its steepest part, according to the town's own Web site, is only 35 percent. Could Pittsburgh have a world record hidden in the trees high above Banksville Road?

Whatever the case, over a distance that would be about two blocks in a normal city, Canton goes from almost flat to free-fall. However, that doesn't stop people from trying to drive up it. Not many make it. So says Dolores Love, who lives at the very base of Canton, on the other side of Coast Avenue (also in the Top 20, with a grade of nearly 18 percent). The view from her living room is straight up Canton, and she and her husband, Ed, are in the process of improving that vista while improving their house.

"Part of the reason we put these big windows in is so we can watch the goofballs try to drive up the hill," she says. "I'm serious. ... I live for it."

Sure enough, the first big snow this month brought the first fools attempting to conquer Canton. She watched the car climb about a third of the way up, then slide back and over a curb, where it teetered like something out of a cartoon. Last Sunday, the Loves were heading out to watch the Steelers game when they witnessed the spectacle of three guys in a four-wheel-drive pickup trying to muscle up the street -- because, you know, it's there. The truck slid all the way back and into a tiny guardrail next door.

The handful of households up top are supposed to drive out on Hampshire Avenue (a mere 23 percent grade). The two families who live on the sheer stretch know to park down on Coast when it snows and walk up the steps that are Canton's sidewalk. This adds a new dimension to unloading groceries and other tasks.

The five steepest streets in Pittsburgh

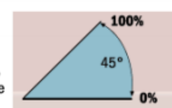
Street	Neighborhood	Grade
Canton Avenue	Beechview	37%
Dornbush Street	Homewood	32%
Boustead Street	Beechview	29%
East Woodford Avenue	Carrick	27%
Rialto Street	Troy Hill	25%

Some of the other steep streets

- Cutler Street on North Side
- Tesla Street in Hazelwood
- Hampshire Avenue in Beechview
- Capital Avenue in Brookline
- Potomac Avenue in Banksville

Making the grade

The percentage expresses the steepness of the hill as the rise over run expressed as a percentage. A 0% grade is perfectly flat and a 100% grade is 45 degrees from the horizontal.



> **Note**
>
> [3] The street was recently featured in an Audi commercial available at: https://www.youtube.com/watch?v=DH7h...layer_embedded

a. What is the minimum coefficient of friction necessary to safely park your car on Canton Avenue? Is this a static or kinetic coefficient?

b. What is the minimum coefficient of friction necessary to drive your car up Canton Avenue? Is this a static or kinetic coefficient?

c. The steep part of Canton Avenue is 64 m long. Assume you begin from rest at the top of Canton Avenue and allow your car to roll halfway down (without applying the brakes). What minimum coefficient of friction would be necessary to safely stop your car at the base of the hill?

Selected Answers

[1] t2 = 1.86 s

[2] v1 = 11.2 m/s

[3] δrx = 8.3 m

[4] v1 = 3.28 m/s

[5] v1 = 31.4 m/s

[6] The ball hits people in the stands behind home plate. (It sails 10.7 m above home plate.)

[7] $\theta = 44°$

[8] $\theta = 20.1°, 68.8°$

[9] $\theta = 18.6°, 77.2°$

[10] No.

[11] Yes, as long as the cannon is set to 16.4°.

[12] t2 = 0.56 s

[13] t2 = 3.22 s

[14] t2 = 3.22 s

[15] 335 m from home

[16] t2 = 40 s a = 0.15 m/s^2

[17] 52.6 m from ship

[18] 25.7 m from ship

[19] t2 = 33.5 s $\theta = 188°$ from line initially between ship and man

[20] μs ≥ 0.256

[21] a = 0 m/s^2

[22] a = 0.94 m/s^2

[23] m = 65.2 kg

[24] Fsf = 56 N

[25] Fsf = 186 N up

[26] a = 1.39 m/s^2 down

[27] a = 0.84 m/s^2

[28] m = 51.4 kg

[29] t2 = 7.4 s

[30] r2x = 14 m

[31] μk = 0.085

[32] F = 270 N

[33] F = 55.9 N

[34] a = 0.73 m/s^2

[35] a = 0.66 m/s^2

[36] a = 0 m/s^2

[37] Fmax = 980 N

[38] Fmax = 359 N

[39] Fmax = 947 N

[40] Fmin = 210 N

[41] a. r2 = 2.23 m b. t2 = 1.49 s

[42] a. v2 = 2.52 m/s b. r2 = 3.78 m

[43] m = 51.4 kg

[44] a. r2 = 14 m b. t2 = 1.75 s

[45] v2 = 27 m/s

[46] μ = 0.14

[47] v2 = 14.9 m/s

[48] v2 = 8.89 m/s

[49] v2 = 14.3 m/s

[50] θ = 56°

[51] v2 = 5.8 m/s

[52] v2audi = 12.8 m/s

[53] v2audi = 4.86 m/s