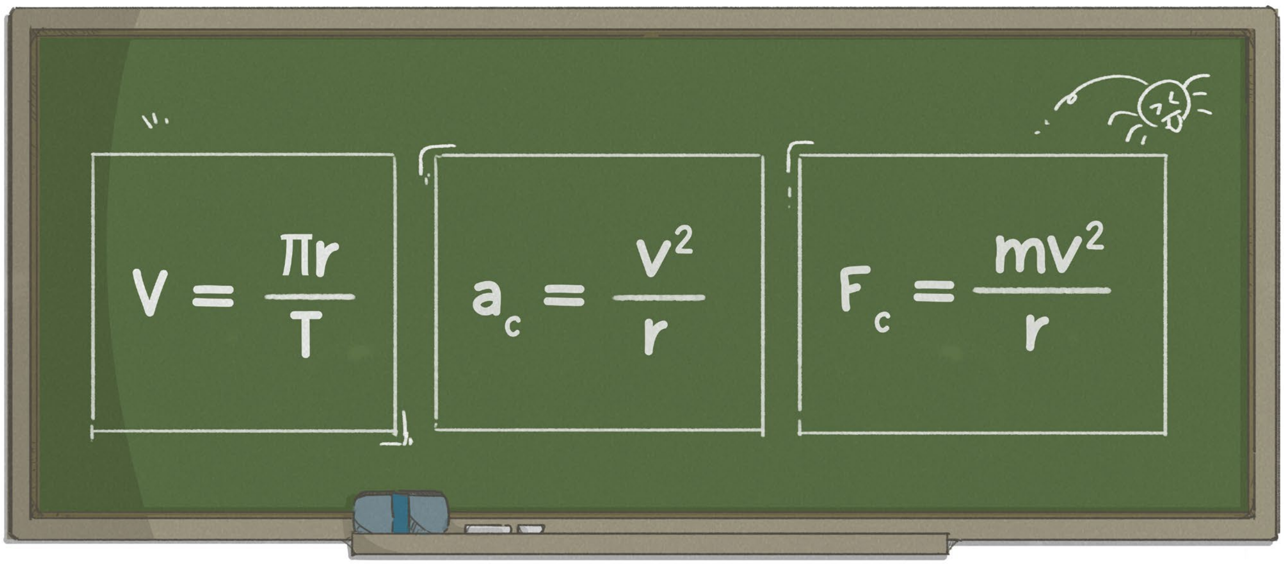
Name: ______________________________

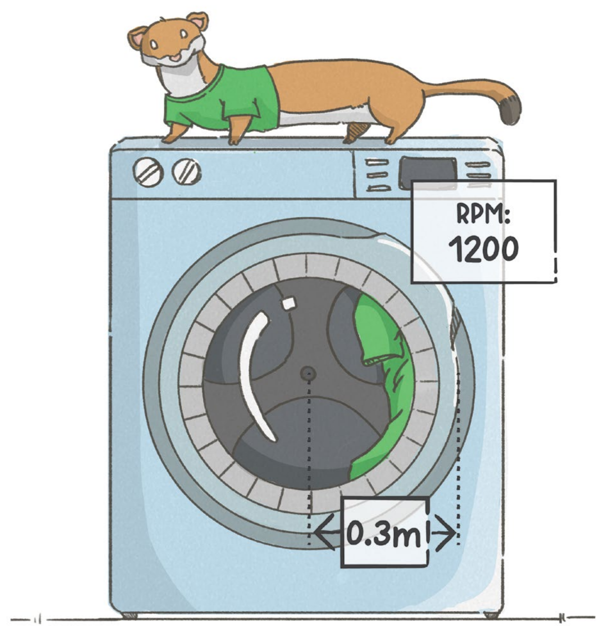
Date: __________ Period: ___________

CIRCULAR MOTION

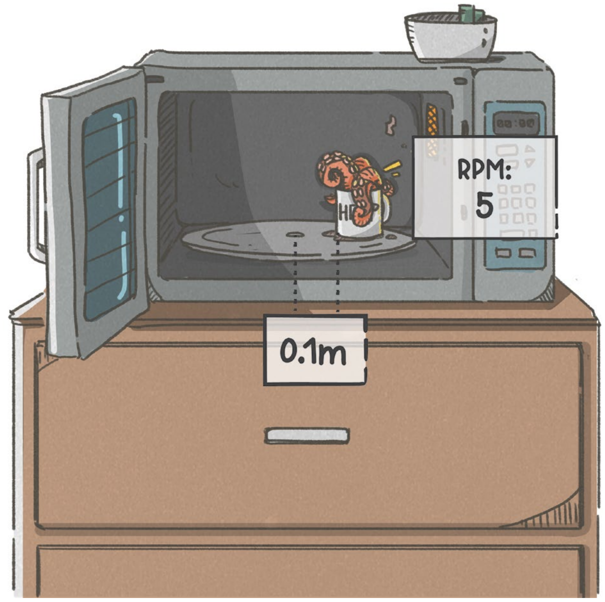
LINEAR VS ROTATIONAL SPEED



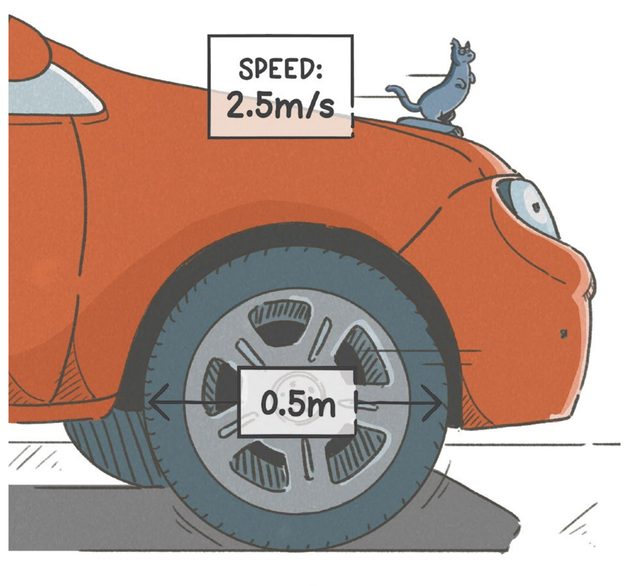
#1 A standard washing machine is set to 1200 rpm. If the radius of the washing machine is 0.3 m, what is the linear speed of a piece of clothing when it is stuck to the side of the machine?



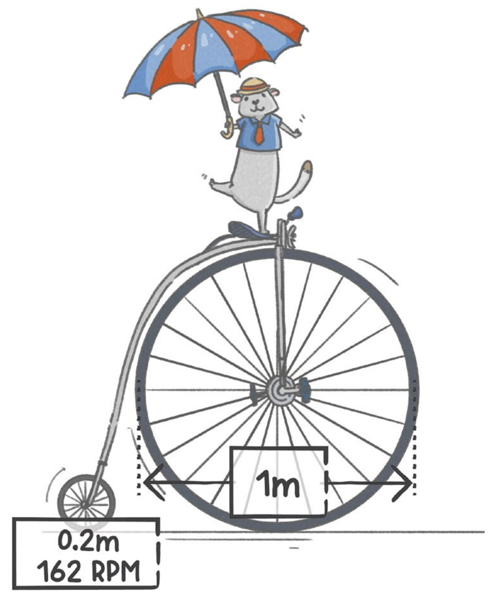
#2 A microwave turntable rotates at about 5 rpm. If you put a cup on the turntable 0.1 m from the center, what will its tangential (linear) velocity be?



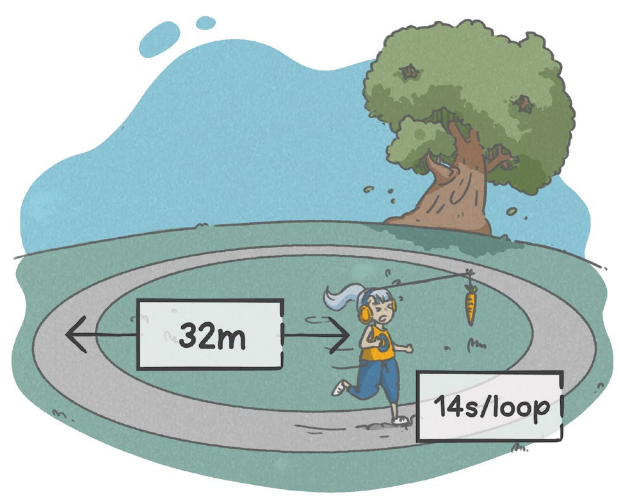
#3 A car tire has a diameter of 0.5 m. If the car is driving at 25 m/s (meaning the edge of the tire is also travelling at 25 m/s), what is the tire's rotational speed in rpm?



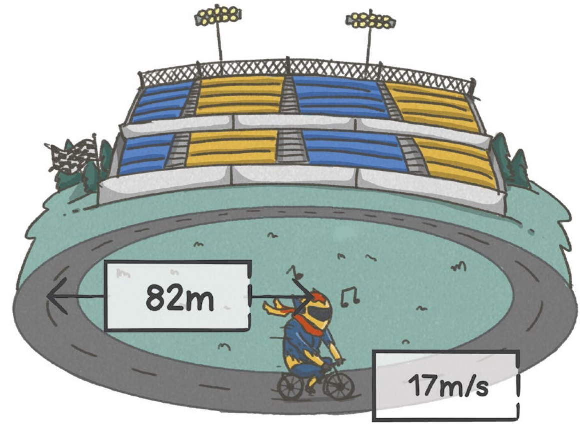
#4 A penny farthing bike has two differently sized tires. The small one has a diameter of 0.2 m, and the larger one has a diameter of 1 m. If someone is riding the bike so that the small tire is rotating at 162 rpm, how fast is the bike travelling and what is the rotational speed of the large tire?



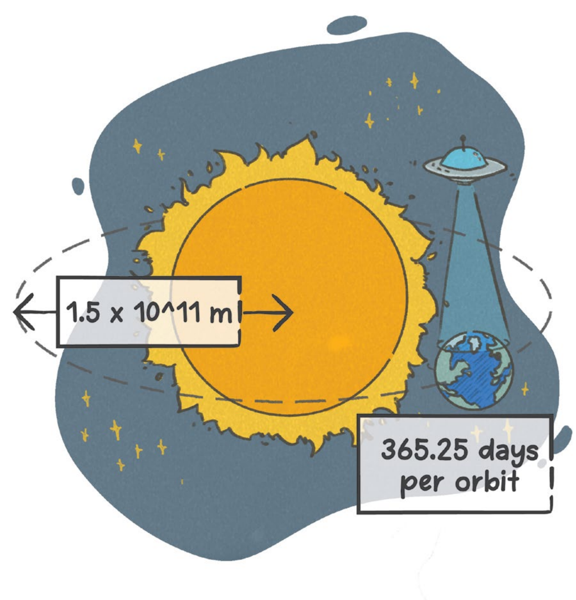
#5 If you are jogging around a circular track of radius 32 m, and it takes you 14 s to complete one loop, what is your linear velocity?



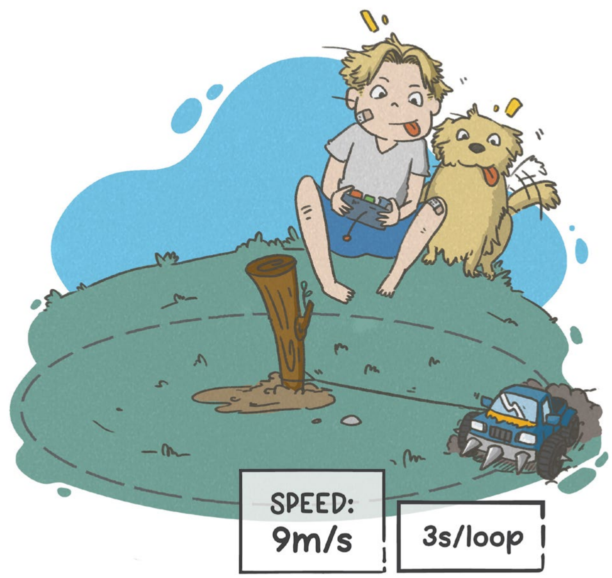
#6 If you are driving at 17 m/s, how long would it take you to drive around a loop of radius 82 m?



#7 If we make a simplification and pretend the Earth's orbit is roughly circular, what is its tangential (linear) velocity in m/s? (Assume the radius of the Earth's orbit is approximately 1.5 x 10^11 m, and that it takes the Earth 365.25 days to travel once around.)

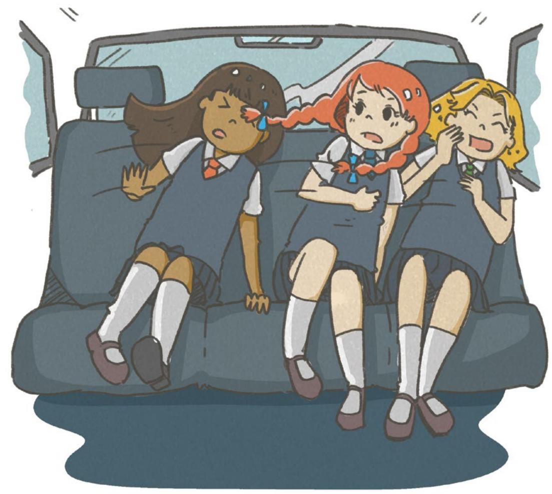


#8 You have a remote-controlled car that has a top speed of 9 m/s. You tie a string to it, attaching the other end of the string to a stake in the ground. You start the car and, because of the string, the car drives in loops around the stake instead of straight. If you want the car to take exactly 3 s to make each loop, how long should you make the string?



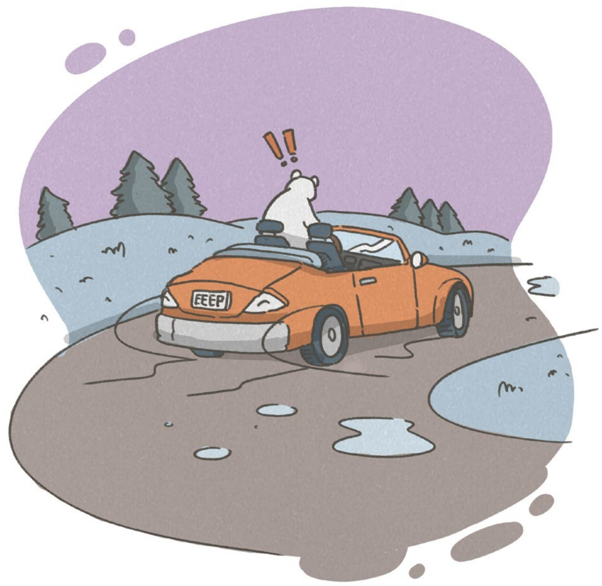
CONCEPTUAL QUESTIONS

#9 You and your friends are riding in the back seat of a car. The car makes a sharp turn and everybody gets smooshed to the right side. Which way did the car turn? Why were you all pushed towards the outside? (Hint: you weren't really pushed at all...)

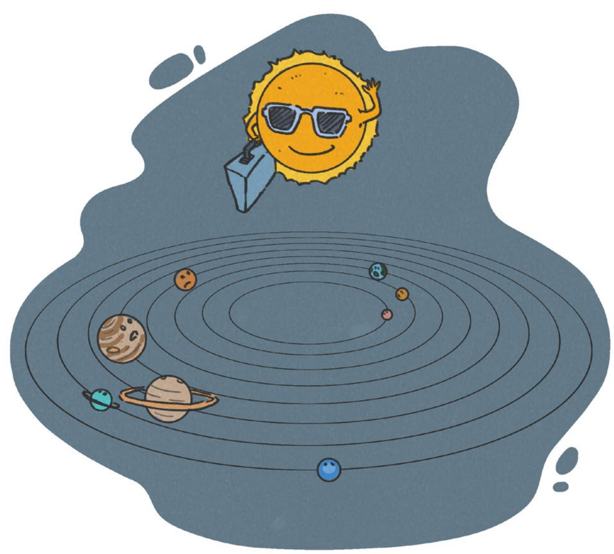


#10 You tie a ring to a piece of twine and whirl it over your head like a lasso. If the piece of twine breaks, what will the path of the ring look like when it flies off?

#11 You are driving a car on a wet road. You take a turn too fast and start sliding. If you continue sliding (meaning your wheels have no control over the direction you go), what will your trajectory look like?



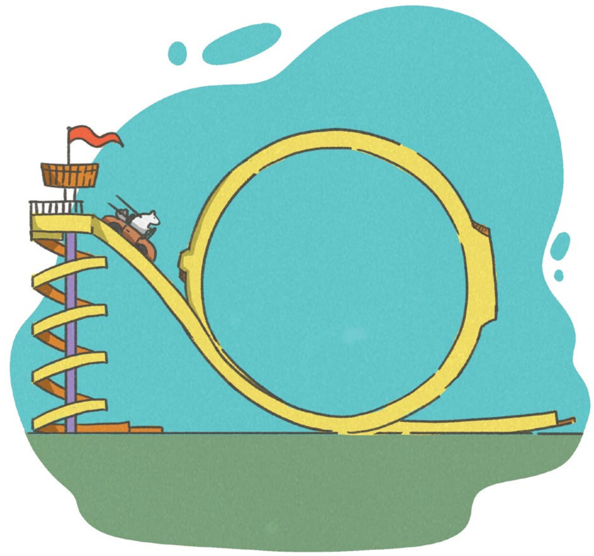
#12 If the sun suddenly disappeared, what would the paths of the planets look like? (Meaning, they were travelling in elliptical orbits one moment, then the sun and all its gravity disappeared. What would happen?)



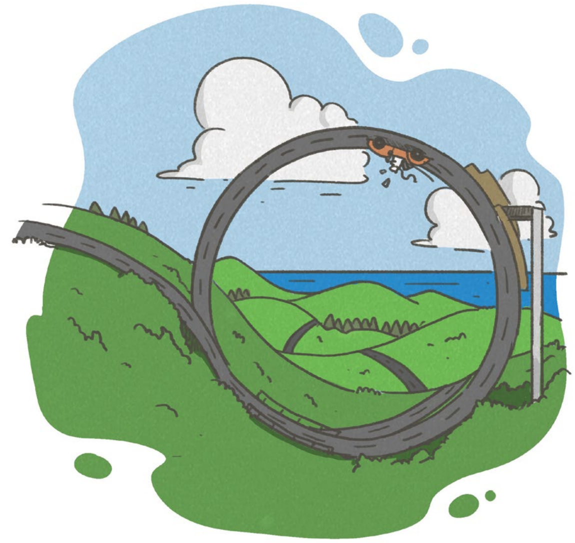
#13 You tie a rope to the handle of a bucket and swing it in a vertical circle. As it moves through the loop, from the bottom where you're pulling up on it to the top where you're pulling down on it, is the force you pull on it with constant? If not, at what moments are you pulling the hardest and at what moments are you pulling the least?

#14 You are driving over a series of hills and valleys. These hills and valleys are curved in such a way that they look like parts of circles. If you drive as quickly as you can, where do you feel the lightest and where do you feel the heaviest?

#15 If you send a toy car down a ramp and through a vertical loop (so that it's upside-down at the top of the loop), what happens to the car's speed as it climbs up to the top of the loop? What happens to the car's speed as it descends the other side of the loop?

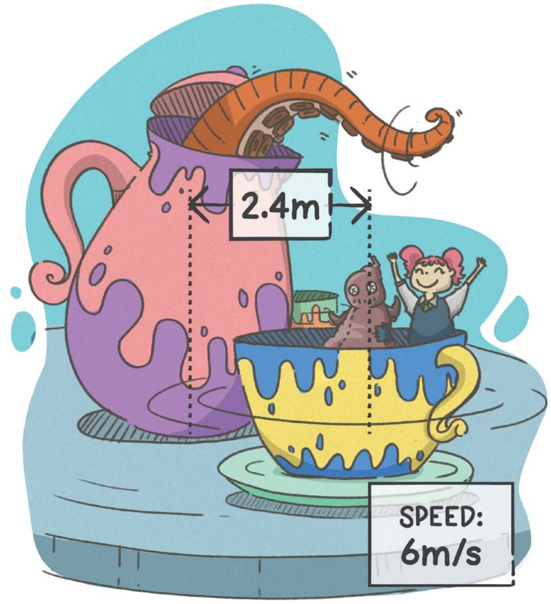


#16 If you drive a car through a vertical loop at a constant speed, how does the normal force on the car from the road at the bottom of the loop compare to that at the top of the loop?



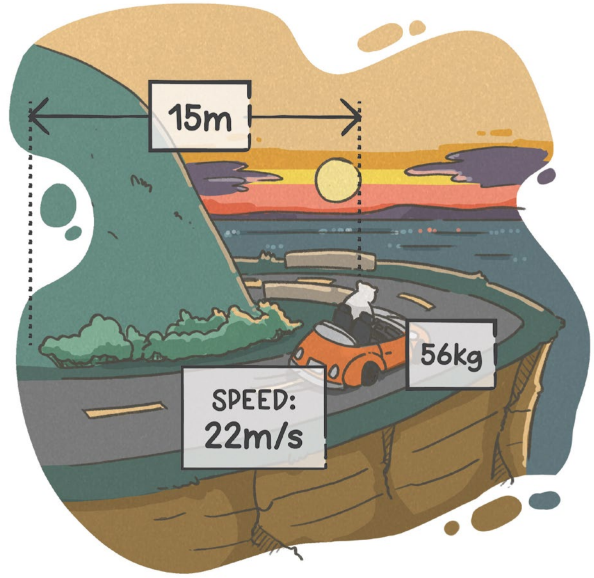
CENTRIPETAL FORCE AND ACCELERATION

#17 You are riding the teacup ride at a fair, and your teacup is 2.4 m from the axis it's rotating around. If you are travelling at 6 m/s, what centripetal acceleration do you experience?

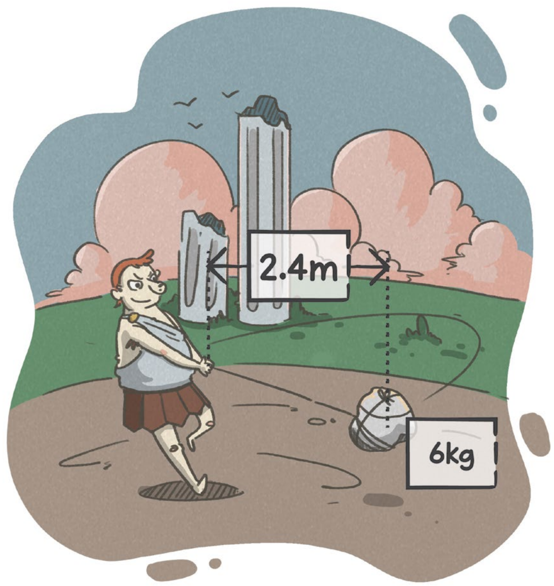


#18 You are designing a merry-go-round for kids. The motor you have rotates at 6 rpm. If you want the kids to experience no more than 0.5 g of acceleration, what is the closest you can place the horses to the center?

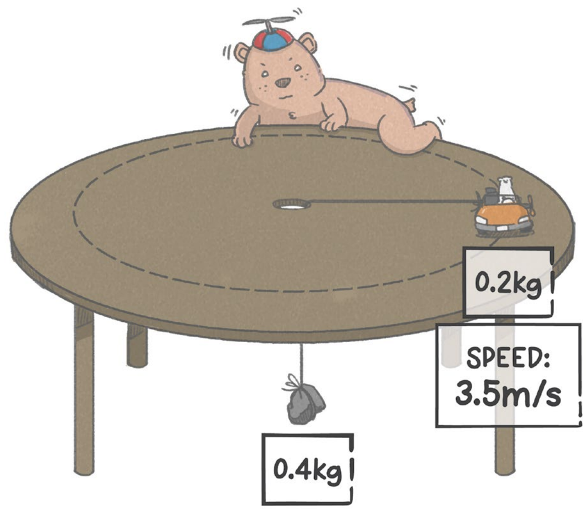
#19 If you have a mass of 56 kg and you are driving at 22 m/s around a curve of radius 15 m, how much centripetal force do you feel?



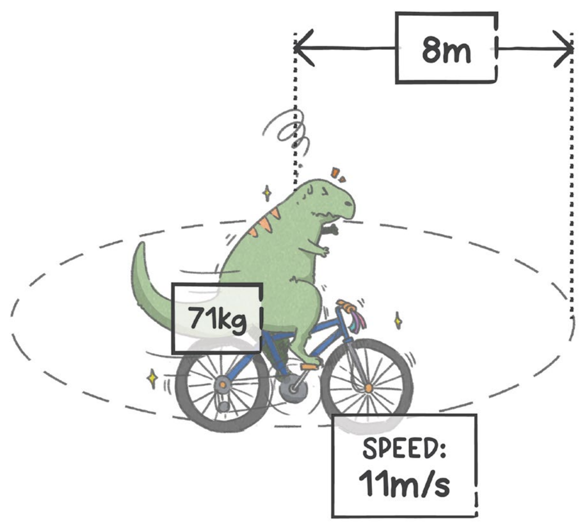
#20 You tie a 6 kg rock to a rope and swing it in a horizontal circle of radius 2.4 m around yourself. If the rope can handle a maximum of 100 N of tension without breaking, what is the fastest you can make the rock go without breaking the rope?



#21 You have a table with a hole in the middle, and you thread a string through the hole. On the underside, you tie a 0.4 kg weight, and on the top side, you tie a 0.2 kg wind-up car that will drive at 3.5 m/s. Once you start the car moving, what will be the radius of the circle that it drives in?

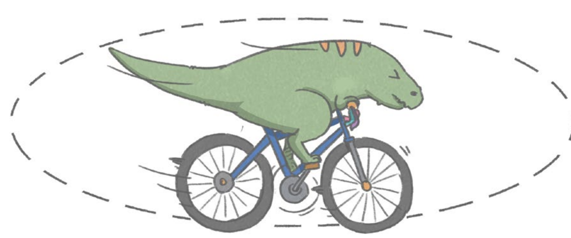


#22 If you ride your bike at 11 m/s in a circle of radius 8 m, and you and your bike together have a mass of 71 kg, what will the force of friction be between your tires and the ground?

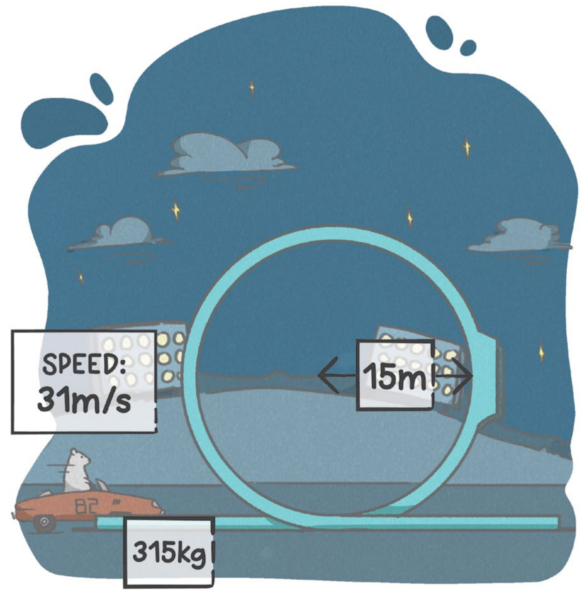


#23 If you are riding your bike in a circle and your tires are experiencing a friction force of 'F' newtons, what will the friction force be (in terms of F) if you double the radius of your circle?

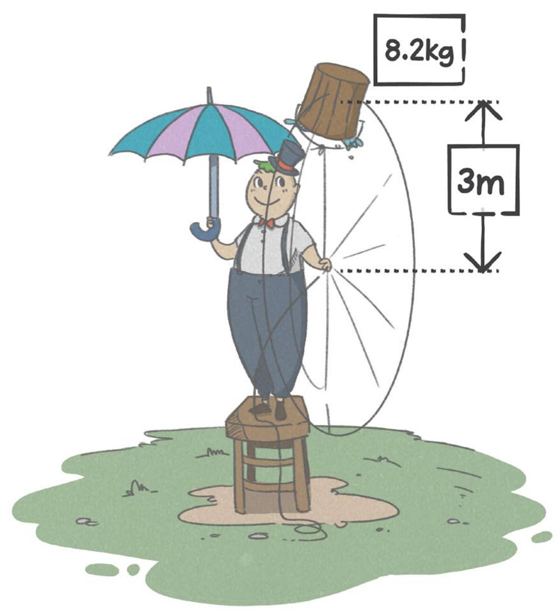
#24 If you are riding your bike in a circle and your tires are experiencing a friction force of 'F' newtons, what will the friction force be (in terms of F) if you double your speed?



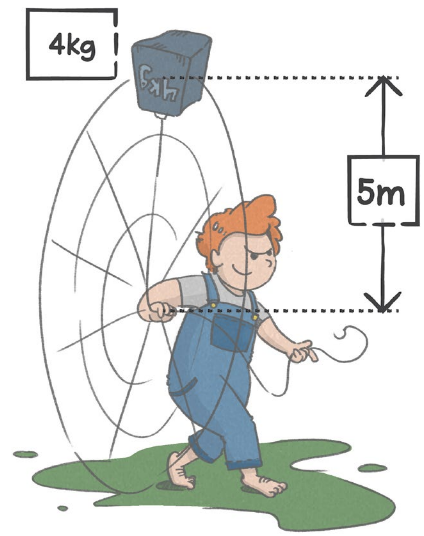
#25 A stunt driver drives their car at 31 m/s in a vertical loop of radius 15 m. The total mass of the car and driver is 315 kg. What is the normal force on the car at the bottom of the loop? At the top?



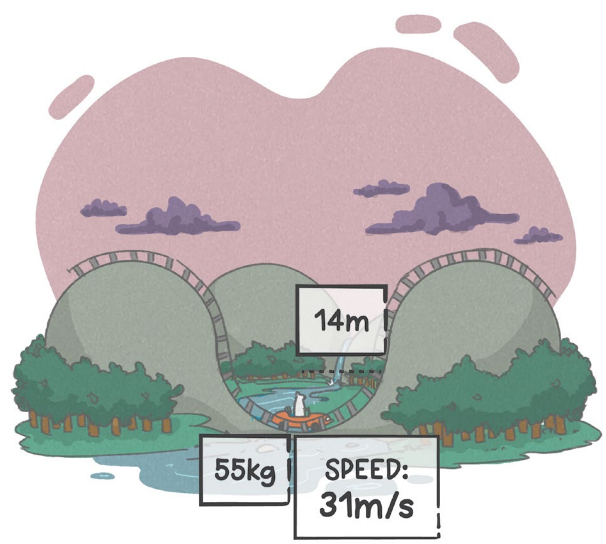
#26 You swing a bucket filled with water (mass = 8.2 kg) in a vertical circle of radius 3 m. What is the minimum speed you can swing it where the water won't spill out of the bucket onto your head?



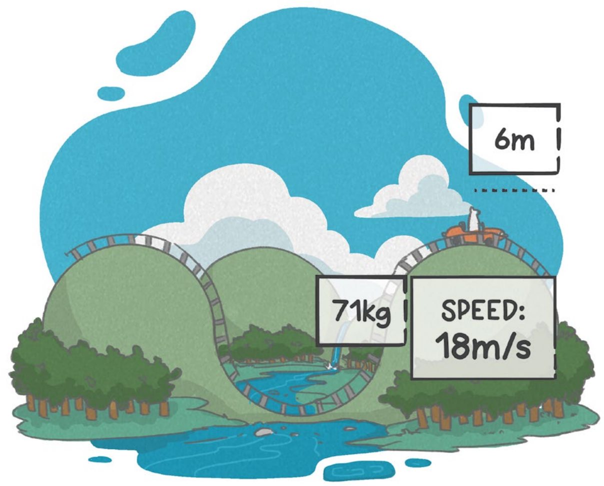
#27 You tie a weight of 4 kg to the end of a rope 5 m long. The rope is capable of supplying a tension force of 60 N before it breaks. What is the fastest you can whirl the rope in a vertical circle without breaking the rope? Is the rope in more danger of breaking at the top or the bottom of the circle?



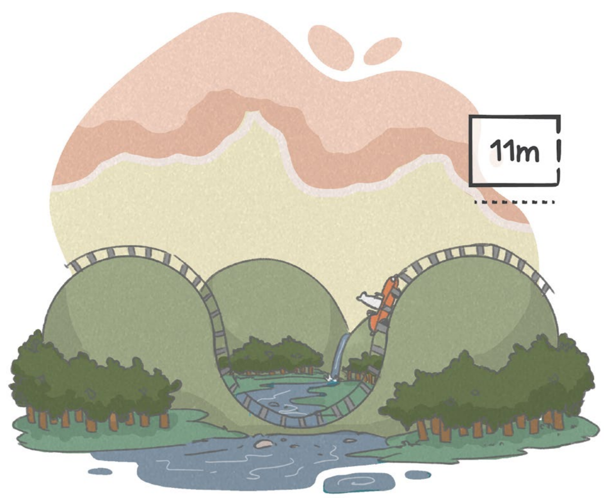
#28 You are driving at 31 m/s down through a valley that is roughly circular, with a radius of 14 m. How much normal force do you experience at the bottom of the valley? (You have a mass of 55 kg.)



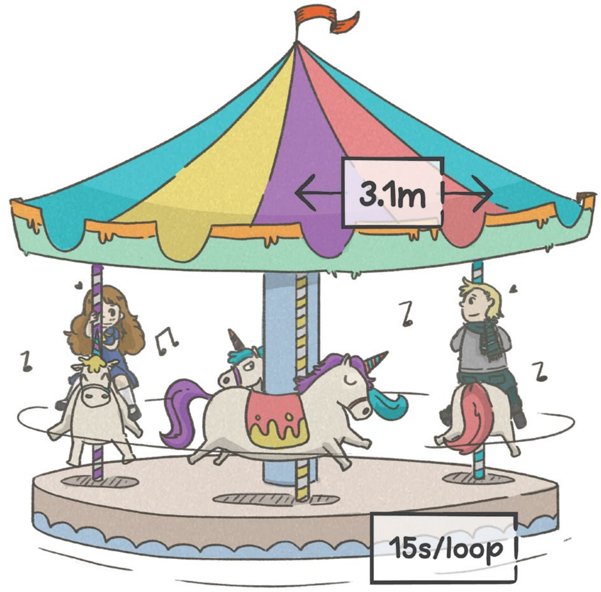
#29 You are driving at 18 m/s over the top of a roughly circular hill of radius 6 m. If you have a mass of 71 kg, how much normal force do you experience at the top of the hill?



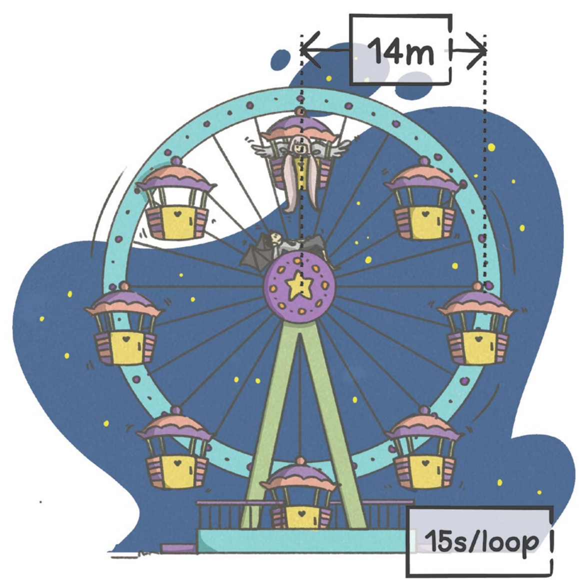
#30 What is the fastest you can drive over a hill of radius 11 m without starting to slightly lift off it as you go over it?



#31 If you are riding a horse on a merry-go-round that is 3.1 m from the central axis, and it takes you 15 seconds to go all the way around, what is your centripetal acceleration?

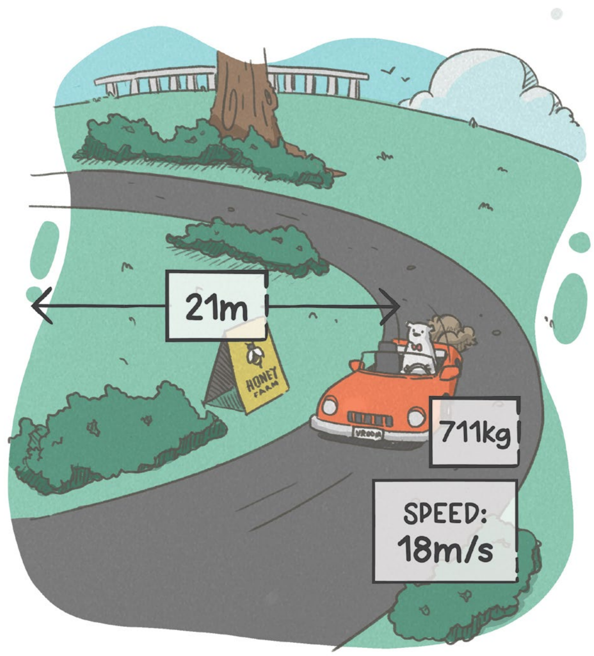


#32 You are riding a Ferris wheel, and you measure that it takes 15 seconds to go all the way around once. If the radius of the Ferris wheel is 14 m, what is your centripetal acceleration?

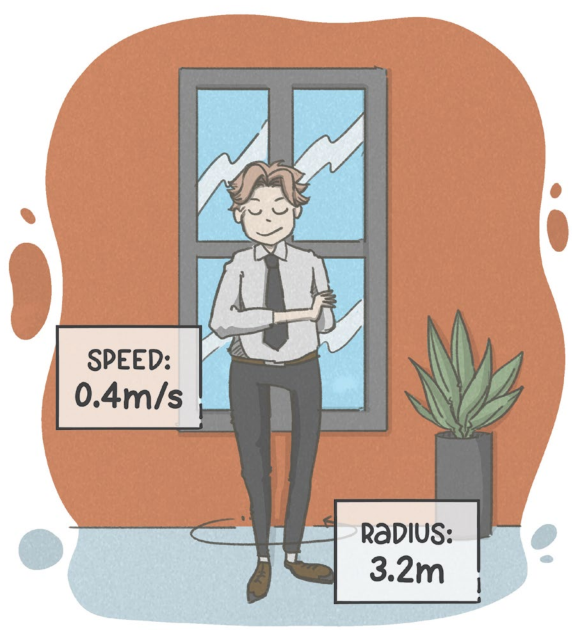


QUESTIONS INVOLVING FRICTION

#33 You are driving at 18 m/s when you take a turn of radius 21 m. What is the force of friction between your tires and the road, if you are driving at a constant speed? (You and your car together have a mass of 711 kg.)

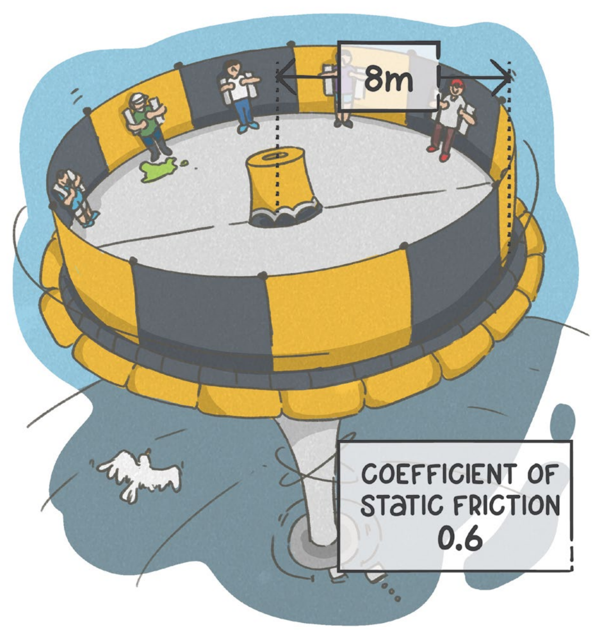


#34 Your dress shoes are somewhat slippery on the bottom. You notice that when you walk at 0.4 m/s, the tightest turn you can take has a radius of 3.2 m. What is the coefficient of static friction between your dress shoes and the ground?



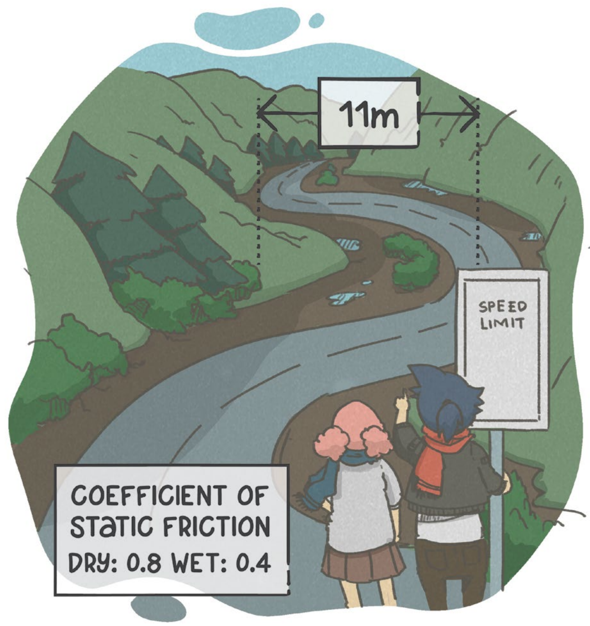
#35 If your tennis shoes have twice the grip (twice the coefficient of static friction as the shoes in the previous problem) How tight of a turn could you take at 7 m/s? (Meaning, what is the smallest radius turn you could make?)

#36 There is a ride at an amusement park that looks like a cylindrical tube of radius 8 m. To ride the ride, you and a group of people get into the cylinder and stand with your backs against the wall. The cylinder starts to spin and lift into the air, then the bottom drops out. You don't fall because the friction between your back and the wall holds you up. If the coefficient of static friction is 0.6, what must the rotational speed of the ride (in rpm) be in order to keep you from falling?

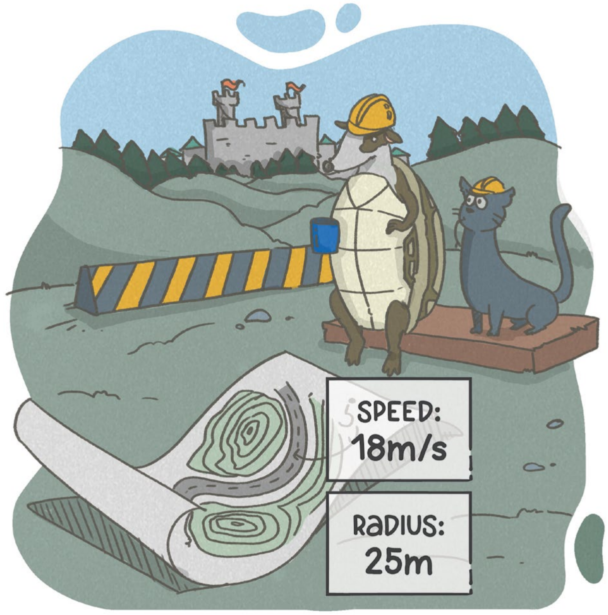


#37 You are driving your car at night in the rain. The coefficient of static friction between your tires and the road is 0.45. You drive around a turn of radius 23 m. What is the fastest you can take that turn without skidding out?

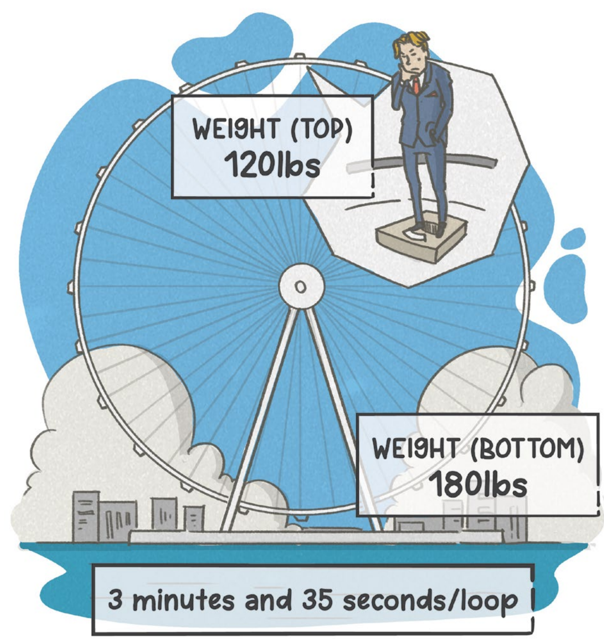
#38 A local town is wanting to put up a speed warning sign on a winding road and they've asked you to figure out what the maximum safe speed is. You take some measurements, and you know that when the road is dry the coefficient of static friction is 0.8, when the road is wet the coefficient of static friction is 0.4. If the tightest turn has a radius of 11 m, and you want to keep people at a speed of 15% below the level where they would start to skid in the worst conditions, what speed should you recommend the town put on the sign?



#39 Another local town decides that rather than posting a speed limit on their own dangerous turn (because they know people often ignore those signs), they will instead bank the turn, pitching the road at an angle so that not as much friction will be required. They then take speed measurements, and find that most drivers take the turn at about 18 m/s. If the radius of the turn is 25 m, at what angle should they bank the turn so that no friction will be required?



#40 You bring a scale with you onto a Ferris wheel. You measure your weight when it's stopped to be 150 lbs. When it starts to move, you find you weigh 120 lbs at the top and 180 lbs at the bottom. You also use the timer on your phone and see that it takes 3 minutes and 35 seconds to go all the way around once. What is the radius of the Ferris wheel?



ANSWER KEY

Circular Motion

Round all answers to the nearest tenth.

1. 37.7 m/s
2. 0.1 m/s
3. 954.9 rpm
4. 1.7 m/s 32.4 rpm
5. 14.4 m/s (you're clearly a giant or a superhero)
6. 30.3 s
7. 29,865.3 m/s
8. 4.3 m
9. The car turned left. Even though it feels like a force pushed you all to the right side of the car, in reality, it was that the car was turning left out from under you. Because of Newton's First Law, you all had the tendency to keep going straight, and the friction between you and the car seat was trying to pull you to the left along with the car, but it wasn't quite enough. So, really, it was the car sliding out from under you as it turned left and you continued straight.
10. In order for things to move in a circle, they require a force to be pulling them towards the center at every moment (we call this the centripetal force). If the string breaks, that centripetal force is gone, so the ring will go flying off in a straight line, tangentially to its previous circular path. (It often feels intuitively like the object should curve somehow, or maybe fly outwards, but in reality it just goes back to doing what Newton's First Law says it should do: fly straight in the direction it was initially travelling.)
11. Similarly to problem 10, you will slide in a straight line, in the direction you were travelling when your tires lost traction.
12. If the sun suddenly disappeared, besides the many other terrible effects, there would no longer be a gravitational pull towards the sun to keep the planets in their orbits. It would take some time for the last of the sun's light to reach the planets, and also for the information that the gravitational pull is gone to reach the planets, too. But once it did, the planets would continue off in straight lines (barring their gravitational interactions with each other, of course).
13. If you swing a bucket in a vertical circle, you will be pulling harder on it at the bottom, because you're pulling against gravity to lift the bucket upwards. At the top, you don't have to pull as hard (or maybe at all) because gravity is helping you pull the bucket downwards.
14. You would feel the lightest at the top of each hill, and the heaviest at the bottom of each hill. Again, this is because at the bottom you're fighting against gravity to pull yourself back upwards (or rather, the seat of your car has to push harder on you to push you back up). At the top, gravity is pulling you down, and you're accelerating downwards, so the normal force between you and the seat of your car (or between the road and the tires of your car) doesn't have to be as big.
15. As the car climbs the loop, gravity is pulling down on it, so the car slows down. It reaches its slowest speed at the top of the loop, then starts

speeding up as it goes back down, reaching its fastest speed at the bottom of the loop.

16. Similarly to the bucket problem above, the normal force on the car is greatest at the bottom of the loop because the normal force has to overcome gravity in order to push you upwards in your circular path. When you are at the top of a loop, gravity is helping supply the centripetal force needed to pull you back down, and the normal force doesn't have to do as much, if anything.
17. 15 m/s^2
18. 12.4 m
19. 1,806.9 N
20. 6.3 m/s
21. 0.6 m
22. 1,073.9 N
23. F/2
24. 4F
25. 23,268 N at the bottom, 17,094 N at the top
26. 5.4 m/s
27. 5.1 m/s
28. 4,314.4 N
29. 3,138.2 N
30. 10.4 m/s
31. 0.5 m/s^2
32. 2.5 m/s^2
33. 10,969.7 N
34. 0.49
35. 5.1 m
36. 13.6 rpm
37. 10.1 m/s
38. 5.6 m/s
39. 52.9 degrees
40. 2,294.9 m