Students will be able to:

1. Define the period of motion
2. Define the frequency for motion
3. Mathmatically relate the period and frequency
4. Convert from RPM's (revolutions per second) to Hertz
5. Use the definitions of period and frequency to solve word problems
6. Discuss the relationship between centrifugal and centripetal forces.
7. Describe why a person slides tothe outsid eof a curve in a car as observed from inside the car.
8. Discuss what supplies the centripetal forces
9. Correctly write the units equations from memory
10. List the S. I. units associates with each quantity
11. Solve word problems utilizing the formulae and conepts in the unit.
12. Calcualte the g's felt by a rider in an amusment park when

    1. he/she is spun in a horizontal circle (carousel)
    2. he/she is spun in a vertial circle (roller coaster loops, playground swings.)

13. Describe why an irregular shaped roller coaster loop is better than a circular loop.
14. Solve problems based on an automobiles ability to supply a lateral acceleration and its "cornering."
15. Solve problems utilizing formulae and ratios.

Answer all questions in standard SI units.

FREQUENCY AND PERIOD PROBLEMS

1. A turntable rotates an album at 33 revolution per minute, RPM. What frequency is this?

2. A car's engine spins at 1500 RPM. What is the frequency of the rotating engine?

3. Little Bobby Bolo noticed his bolo swung around his head 3 times every 1.40 seconds. What is the period and frequency is of the rotating bolo?

4. A baton twirler spins her baton 12 times in a second when it is tossed into the air. What is the period and frequency of the rotating baton?

5. Middle "c" on the musical scale has a frequency of 256 Hz. How many times a seconds is the sound wave vibrating?

6. Little Ms. Watchful noticed that some kids rotated on a carousel with a frequency of 0.66 Hz. How many times a second did the carousel rotate?

DISCUSSION PROBLEMS

DIRECTIONS: Discuss the following situations in terms of ideas related to centripetal force and circular motion:

7. Turns on a race track are banked inward.

8. An earth satellite will stay in orbit at some distance from the earth only if it going at the right speed.

9. If a satellite is going faster than the required speed, it will leave its orbit.

10. If a satellite slows down, it will fall to the earth.

11. It is difficult to make a sharp turn if a car is going very fast.

12. A small sports car can negotiate a winding road easier than a large car.

13. A centrifuge is used as a separator in lab.

14. A spin dry washing machine in operation.

15. A scale attached with a string to a mass shows a greater reading when the mass is swinging than when it is stationary.

16. A small bucket full of water can be swung in a vertical circle without the water spilling out.

17. Astronauts could experience variable g forces in a human centrifuge before manned rocket launches were tried.

18. Riding a bike without a rear fender through a puddle produces a spray of water down the rider's back

GENERAL PROBLEMS

19. A children's carousel rotates 3 times every 2 seconds. The diameter of the carousel is 3.0 meters.
- What is the period of motion?
- What is the tangential velocity of the carousel?
- What is the centripetal acceleration of the rider at the edge of the carousel?

20. When traveling down the road at a constant speed of 55 mph, 26.4 m/s, the tangential velocity of the wheels is also 55 mph. If a car tire is 65.0 cm in diameter, then;
- What is the period and frequency of the spinning car tire?
- What is the centripetal acceleration of a rock stuck in the tire's tread?

21. Given that the Earth is 1.49×10^{11} m from the Sun. And the earth's period of motion is 365.25 days. Calculate how fast it is revolving around the Sun. Put your answer in m/s.

22. Do the same thing for the Moon: Given it is 3.8×10^{8} m from the Earth and revolves around the Earth every 27.31 days. Put your answer in $^{m}/s$.

23. Given the Earth has a mass of 5.98×10^{24} kg and the Moon has a mass of 7.34×10^{22} kg, what centripetal force is necessary to keep each in orbit.

24. A bicycle wheel of radius 0.325 m rotates at a speed of 10.0 m/s (22.4 mph).
a. If a person is riding the bike, how fast are they traveling?
b. What is the frequency and period of rotation of the bicycle's wheel?

25. The time shaft ride at King's Dominion has a radius of 5.0 m and spins with a period of 1.3 seconds (only a guess).
a. What is the tangential velocity of the ride?
b. What is the centripetal acceleration of the ride?
c. How many g's is this?

26. An upright clothes washer spins clothes around 50 times in 20 seconds. Its radius is 0.30 m.
a. What is the period and frequency of the clothes dryer?
b. What is the tangential velocity of the clothes in the washer?
c. What is the centripetal acceleration of the clothes in the washer?

27. A car is traveling at 24.6 m/s (55 mph). The radius of the tire is 0.40 m. a rock is stuck in the tire.
a. What is the tangential velocity of the rock?
b. What is the centripetal acceleration of the rock?
c. What is the frequency and period of motion?
d. If the rock flies off the tire, how fast will it be traveling and how will its path of motion be related to the radius vector?
e. If the rock's mass is 0.0010 kg, what force holds the rock in the tread of the tire?

28. While playing with a HOT WHEELS race set, a child puts together 2 pieces of track on the loop-the-loop. Normally the loop-the-loop is made with only one piece of track. So now the circumference of the track is doubled.

a. How is the radius affected?

b. A car that supplies its own velocity runs along the loop-the-loop. If the same car is used on each size loop-the-loops, then;

- How do the periods compare?
- How do the centripetal accelerations compare?
- How do the centripetal forces compare?

29. While playing Bolo-Master of the world, the radius the rock is twirled around with is held constant and the velocity is doubled a moment later.

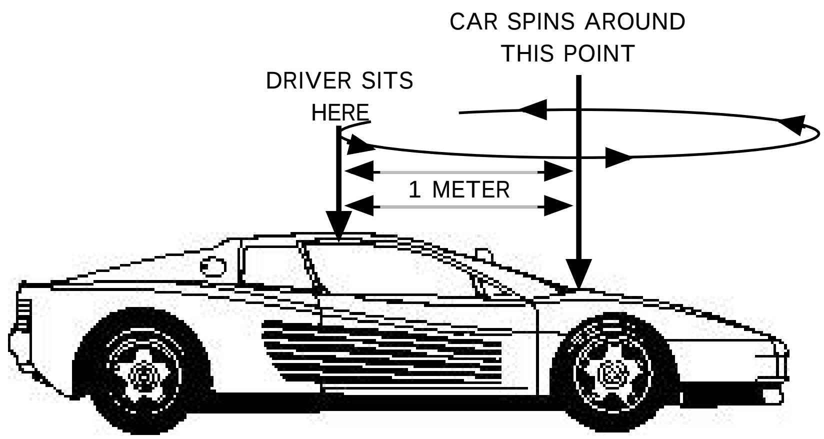
a. How do the centripetal accelerations compare?

b. How do the periods of motion compare?

30. As a car goes around a flat curve, what supplies the centripetal force necessary for the car to go in a curved path?

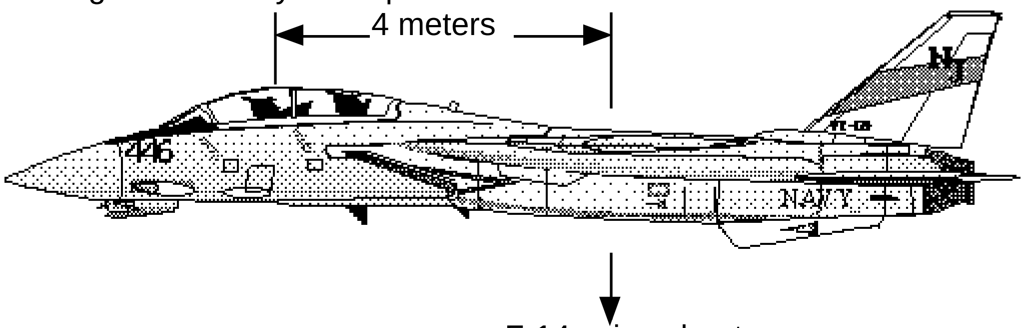
31. A car spins out on an ice covered road. The car's length is 4 meters. The driver is 1 meter from the car's spin center. The car spins 4 times around in 3 seconds.

• What is the period and frequency of the spinning car?
• What is the period and frequency of the driver in the car?
• What is the tangential velocity of the driver?
• What is the centripetal acceleration of the driver?
• What is the centripetal acceleration in g's?



32. In the movie Top Gun, an F-14 fighter jet gets stuck in a flat spin. The jet rotates such that the pilot, 4 meters from the planes spin center, feels a centripetal force of 6 g's. There the pilots hand weighs 6 times as much as normal.

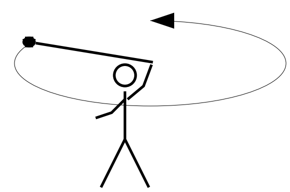
- What is the centripetal acceleration of the pilot in m/s^2.
- What is the period of motion of the pilot?
- What is the tangential velocity of the pilot?



33. For every problem that describes a person's motion, calculate the centripetal force felt on each rider if their mass is 60 kg.

34.

While playing "Bolo Master of the World" little Lisa was spinning a rock around her head on a string 1.32 m long. The rock travels around once every 1.43 seconds.
(A) What is the speed of the rock?
(B) What is the centripetal acceleration of the rock?
(C) If the rock has a mass of 0.15 kg then, what is the centripetal force acting on the rock?



35. A race car is traveling around a race at an average speed of 65.625 m/s (147 mph). The race car takes 2 minutes and 44 seconds to go around the track once.
(A) What is the centripetal acceleration of the car?
(B) Is the car WEIGHS 7840 N, then what is the centripetal force acting on the car?
(C) What do you think supplies the centripetal force to turn the car?

36. An ice skater spins with her hands stretched out from her body. Her hand is 1.12 meters from the axis the is spinning along. Her hands are spinning at 5.74 m/s.
(A) What is the centripetal acceleration of her hand?
(B) How many g's is your answer in (A)?
(C) If her hand has a mass of 0.2 kg then what is the centripetal force acting on her hand?
(D) How long does it take for her to spin around once?

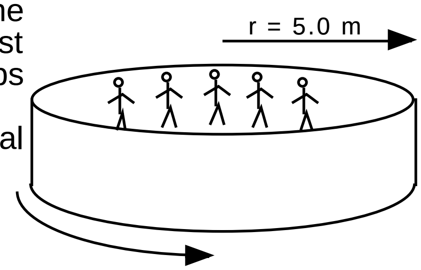
37.A dog is chasing his tail. The radius of the circle that dog makes is 0.62 meters. The dog runs in a circle 10 times in 7.2 seconds.
a) What is the period of motion of the dog?
b) What is the speed of the dog?
c) What us the centripetal acceleration of the dog?
d) If the dog has a bandanna tied to his neck, mass is 0.024 kg, then what is the centripetal force acting on the bandanna?

38 A merry-go-round travels with a tangential speed of 3.5 m/s. Its diameter is 34 m across?
a) What is the centripetal acceleration of the merry-go-round?
b) How long does the merry-go-round take to go around once?
c) What is the centripetal force acting on a 45 kg rider 15 meters from the center of merry-go-round?

AMUSEMENT PARK APPLICATIONS

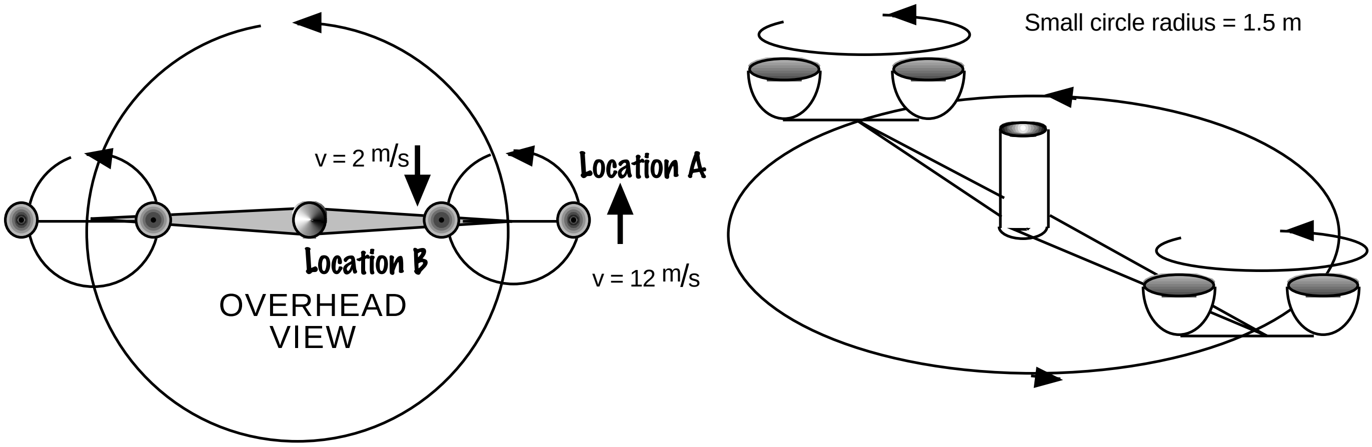
39.

In an amusement park, there is a ride called the “Mexican Hat.” The ride is basically a big barrel that spins very rapidly. The rides rest standing up against the barrel’s wall. While spinning, the floor drops down while inertia holds the passengers in place.

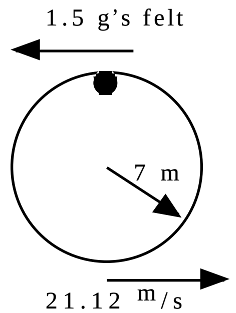


a A rider feels a force associated with 2 g’s of centripetal acceleration when riding this ride. How fast is the ride spinning?
b How long does it take to complete one cycle of motion?
c How many times does the ride go around in 1 minute?

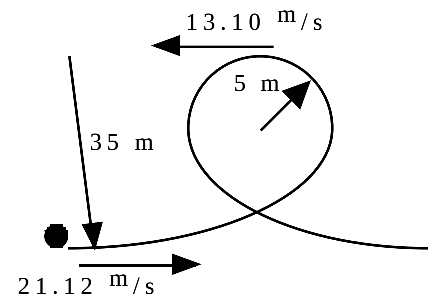
40. In an amusement park, there is a ride called the “Mad Hatter’s Teas Party.” The ride is basically a pair of tea cups that spin very rapidly. The pair itself spin on a larger circle.



a How many g’s of centripetal acceleration does the rider feel at the outer most edge of the circle? (The radius at this point is the large radius plus the small circle’s radius.)
b How many g’s of centripetal acceleration does the rider feel at the inner most edge of the circle? (The radius at this point is the large radius minus the small circle’s radius.)
c Use an average velocity between the inner and outer most point to determine the time it takes for the passenger to spin around once in the smaller circle of motion.



Circular Loop



Spiral of Archimedes Loop

41. For the circular loop, how many g's are felt by the rider at the bottom of the loop as they enter the loop? (7.5 g's)

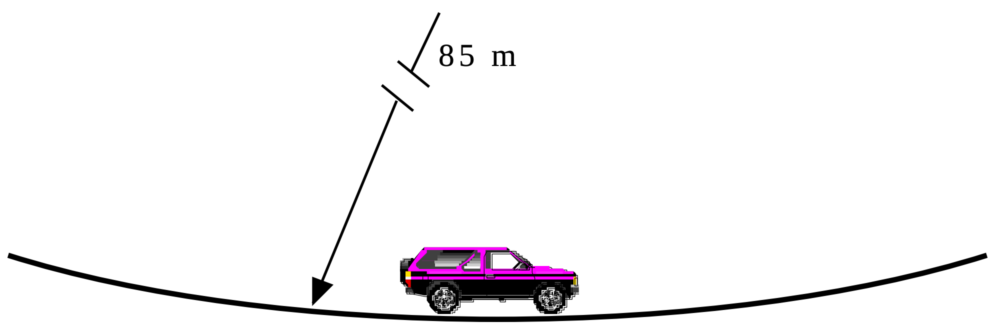
43. For the circular loop, how fast is the roller coaster car traveling at the top of the loop? (12.10 m/s)

44. For the Spiral of Archimedes loop, how many g's are felt by the rider at the top of the loop as they enter the loop? (2.5 g's)

45. For the Spiral of Archimedes loop, how many g's are felt by the rider at the bottom of the loop as they enter the loop? (2.3 g's

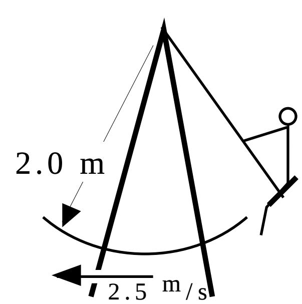
46.

How fast is the car traveling if the passenger's feel 1.5 g's at the bottom of the road's dip. (20.41 m/s)

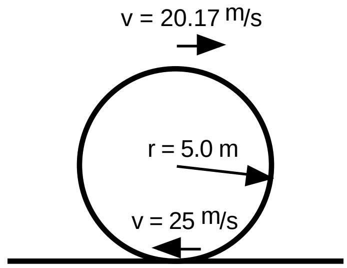


47.

How many g's does the child on the swing feel if they are traveling as shown at the right. (1.32 g's)



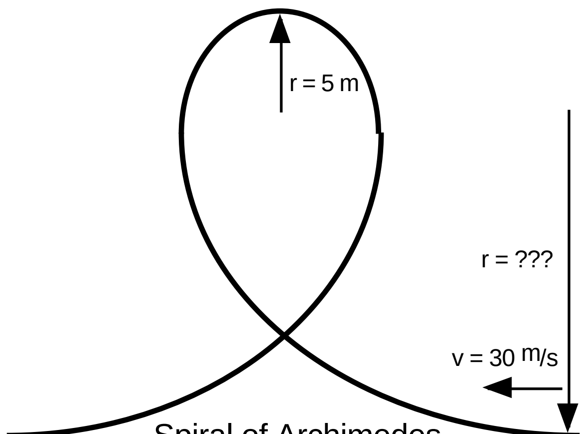
48. A roller coaster travels in a circular loop of radius 5.0 m. At the bottom of the loop the roller coaster car is traveling 25.00 m/s. At the top of the loop the roller coaster car is traveling 20.17 m/s.



a What is the centripetal acceleration exerted by the track at the top and the bottom of the loop in g's.

b How many g's are **felt** by the rider at the top and the bottom of the loop?

49. A roller coaster travels in a loop whose shape is irregular. The shape is called the spiral of Archimedes or Clothoid. The spiral of Archimedes is a circular shape whose radius changes as its height increases. This spiral has a radius of 5 m at the top.



Spiral of Archimedes

a What is the centripetal acceleration exerted on the rider by the track at the top of the loop if the rider is traveling 20 m/s at the top in m/s^2.

b How many g's are FELT by the rider at the top of the loop?

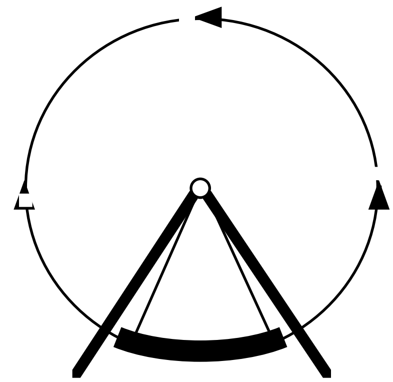
c If the track is to be designed so that the same number of g's are to be FELT by the rider at the bottom of the track, what must the radius be?

d If the rider's mass is 70 kg, What centripetal force is exerted on the rider at the bottom?

50

THE BERSERKER

The Berserker is a ride where the passengers are fastened into a "boat." The boat swings back and forth like a swing. Finally, it swings with so much speed that it makes a complete revolution. This ride is not a true example of the type of circular motion that we are studying because its tangential velocity decreases and increases as the ride swings up and down. However, we can still analyze parts of its motion if we ignore the period of motion and remember that it does travel in a circle. (Assume a Dr. Suess world)



The diameter of the Berserker is 25.1 m. When the Berserker reaches the bottom of the ride it is traveling with a speed of 22.2 m/s.

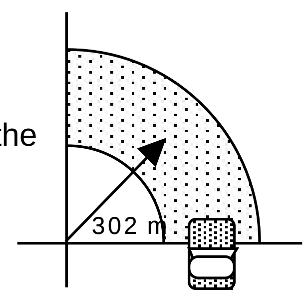
(a) What is the centripetal acceleration of the ride?
(b) How many g's is this ride?

VEHICULAR APPLICATIONS

51.

A 1000 kg car travels around a turn whose radius is 302 m at 20 m/s.

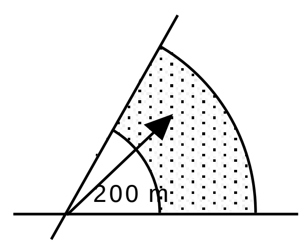
a What is the centripetal acceleration of the car?
b What is the centripetal force applied to the car?
c How much time does it take for the car to travel around the curve if the curve is 90°?



52.

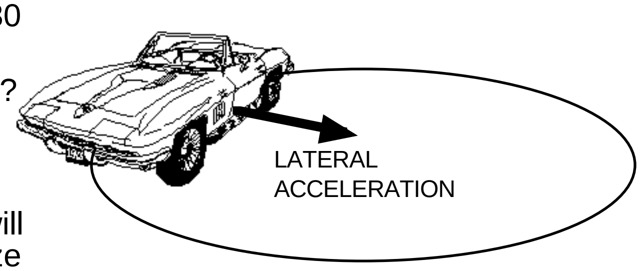
A 500 kg car travels around a curve with a centripetal force of 2500 N. The curve’s radius is 200 m.

a What is the velocity of the car?
b What is the centripetal acceleration of the car?
c How much time does it take to complete the curve if the curve travels around 60°?



53.

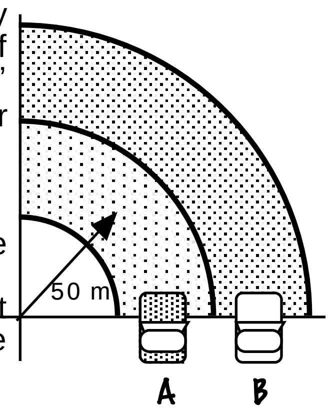
A 1500 kg car can travel around in a circle of radius 30 m at a maximum speed of 12.124 m/s.



a What is the car's centripetal acceleration in m/s^2? (This is the maximum centripetal acceleration.)
b What is the car's lateral acceleration in m/s^2?
c What is the car's centripetal acceleration in g's?
d The maximum centripetal acceleration for a car will remain the same for the car no matter what size circle it travels in. What is the maximum velocity this car could travel around a curve of radius 300 m?
e What is the quickest time this car could travel around a curve with a radius of 200 m and 45°?

54.

Two cars are traveling around a two lane curve as shown. the cars stay side by side around the turn. Therefore the take the same amount of time to finish the 90° curve. The radius of curve "A" is 50 m. Curve "B" is 3.5 m longer. Car "A" is traveling at a constant velocity of 10 m/s. Car "A" has a mass of 1200 kg.



a How much time does it take for car "A" to finish the curve?
b How fast must car "B" travel to keep up with car "A?"
c What centripetal force must car "A" exert to make it around the curve without slipping?
d If car "B" is to exert the same centripetal force as car "A," then what must car "B's" mass be to make it around the curve in the same amount of time as car "A?"

CAR'S AND CORNERING PROBLEMS

Use your car's acceleration chart to solve the following.

55. What is the maximum velocity that a Lamborghini Diablo can go around a curve if it the curve has a radius of 50 m?

56. What is the maximum velocity that a Range Rover can go around a curve if it the curve has a radius of 50 m?

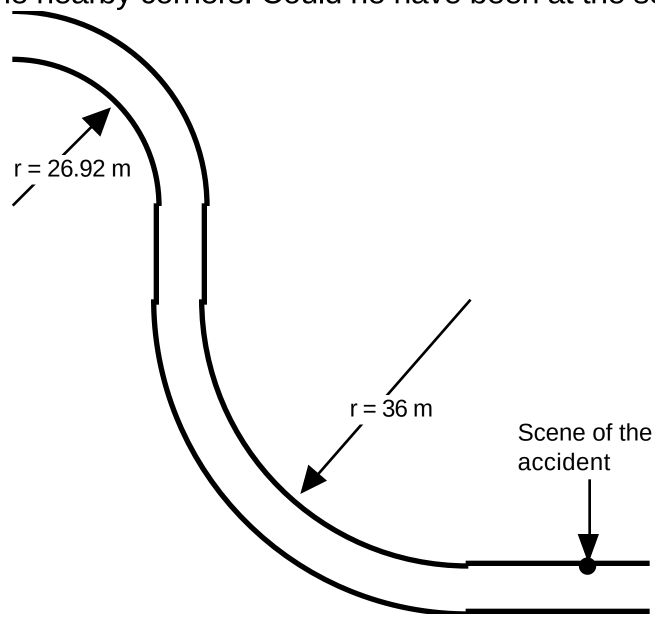
57. a How much centripetal acceleration is needed so a car can go around a curve at 21 m/s if the curve's radius is 50 m? (Answer in g's and m/s^2)
b Which cars can navigate the curve without slipping?

58. What is the smallest radius curve that a "Nissan 300ZX" can travel around at 25 m/s.

59. How fast could a "Geo Metro Lsi" take the same curve as the Nissan in #4?

60. Detective Columbo was looking at an accident when he noticed something. He saw that the car traveled around a curve of radius 30 m at 15.43 m/s, 34.6 mph, before the car began to slip to the outside. Columbo sends this information to you in the crime lab. It is up to you to send him a list of possible cars that the perpetrator may have been driving. Using physics, which possible cars could the suspect have been driving?

61. In a court trial a suspect is accused of fleeing the scene of an accident. The suspect's car is a dark green "Toyota 4Runner 4WD" . A witness testified that they saw a dark green vehicle traveling about 30 mph around the nearby corners. Could he have been at the scene of the crime?



62. A 1000 kg car can travel around in a circle with a centripetal acceleration of 0.7 g's without slipping. When the car loses traction on a road, it exerts a centripetal acceleration of 0.3 g's.

a What is the car's centripetal acceleration in $^m/_{s^2}$ when it <u>is not</u> slipping?
b What is the car's centripetal acceleration in $^m/_{s^2}$ when it <u>is</u> slipping?
c How big of a turn could the car turn at a constant velocity of 20 $^m/_s$ without slipping?
d How big of a turn could the car turn at a constant velocity of 20 $^m/_s$ when it begins to slip on a road?
e Here is the scenario. A car is going around a turn without slipping. Suddenly the tires begin to slip thereby reducing the centripetal acceleration. Assuming the curve has a radius equal to that in problem "c," what velocity does the car need to travel at in order to safely navigate the same curve.
f In each problem (c,d) how much time does it take to complete a turn of 180°?

RATIO'S

Note: What ever changes occur to the force, also occur to the acceleration.

Describe the how the first variable is affected assuming the changes mentioned in the other variables.

63. a_c: The velocity is constant while the radius is tripled
64. T: The velocity is constant while the radius is tripled
65. v_t: The acceleration is constant, the radius is halved
66. T: The acceleration is constant, the radius is halved
67. F_c: The velocity doubles and the period remains constant
68. v_t: The radius is doubled and the period is tripled
69. R: The force is changed by a factor of 5/8 and the period is changed by a factor of 3/2
70. T: The force changes by 3/7 and the velocity changes by 3.
71. R: The force changes by 3/7 and the velocity changes by 3.

72. F_c: The radius is tripled and the period changes a factor of 2/3

73. a_c: The velocity changes by a factor of 7/8 and the radius changes by 6

74. T: The radius is quadrupled and the force is tripled

75. v_t: The radius is quadrupled and the force is tripled

76. r: The acceleration changes by 1/4 and the period changes by 5/6

77. r: a_c triples, v remains constant

78. T: v changes by a factor of $^3/8$, R changes by a factor of $^5/2$

79. F_c: r triples, v remains constant

80. v: a_c remains constant, T triples

81. a_c: v changes by a factor of $^4/6$, R is halved

82. T: v changes by a factor of $^2/3$, a_c changes by a factor of $^5/4$

83. r: Fc doubles, velocity triples

84. v: a_c changes by a factor of $^1/3$, period changes by a factor of $^4/3$

1		0.55 Hz
2		25 Hz
3		T=0.47 s f = 2.14 Hz
4		T = 1/12 f = 12 Hz
5		???
6		???
22		1011.88 m/s
31	a	3/4 s, 4/3 Hz
	b	3/4 s, 4/3 Hz
	c	8.38 m/s
	d	70.18 m/s^2
	e	7.16 g's
34	a	5.8 m/s
	b	25.48 m/s2
	c	3.82 N
35	a	2.51 g's
	b	2011 N
36	a	29.42 m/s
	b	3.00 g's
	c	5.88 N
	d	1.23 s
37	a	0.72
	b	5.41 m/s
	c	76.15 N
	d	1.83 N
39	a	9.9 m/s
	b	3.17 s
	c	18.93 Times
40	a	TOP; 8.30 g's BOTTOM; 12.76 g's
	b	TOP; 7.3 g's BOTTOM; 13.76 g's
48	a	20 m/s
	b	1.04 g's
	c	88.31 m
	d	713.44 N
49	a	39.27 m/s2
	b	4.01 g's
50	a	1.32 m/s2
	b	1324.5 N
	c	23.72 s
51	a	31.62 m/s
	b	5 m/s
	c	6.62 s
52	a	4.90 m/s2
	b	4.90 m/s2
	c	0.50 g's
	d	38.34 m/s
	e	40.14 s (For a complete circle)
53	a	7.85 s
	b	10.7 m/s
	c	2400 N
	d	1121.5 kg; [a=2.14 m/s2]
54		21.58 m/s
55		19.3 m/s for the 1996 car, 17.57 m/s for the 1990 car
56		Cars>= 0.90 g's
57		75.03 m
58		23.16 m/s
59		cars >= 0.87 g's
63		1/3
64		3
65		$\frac{\sqrt{2}}{2}$
66		1/2
67		2
68		4/3
69		45/40 = 9/8
73		$\sqrt{7}$
74		$\frac{2\sqrt{3}}{3}$
75		$2\sqrt{3}$