Kennywood Park's Annual Educational Day

Physics and Statistical Test Questions

Test Created By:
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Statistics

EXTERMINATOR
Length.....1400 feet
Height.....50 feet
Top Speed.....29 mph

JACK RABBIT
Length.....2,200 feet of track
Top of Incline.....48 feet
Top Speed.....40 mph
Train Weight.....4,200 lbs.(3 cars @ 1400 lbs. ea)
Train Length.....30' 6"

PHANTOM'S REVENGE
Length.....3,500 feet of track
Biggest Drop.....232 feet
Highest Point Above Ground.....160 feet (lift hill)
Top Speed.....85 mph
Train Weight.....approximately 1,100 lbs.
Train Length.....60' 6"

PIRATE
Height.....66 feet
Mass.....28 tons
Boat Length.....45 feet
Ride Length.....86 feet
Capacity.....54 passengers

RACER
Length.....5,300 feet of track (2,650 each train)
Highest Point Above Ground....70 feet
Top Speed.....45 mph
Train Weight.....6,800 lbs.(4 cars @ 1700 lbs. ea)
Train Length.....39' 6"

SKY ROCKET
Length.....2,100 feet of track
Maximum Height.....95 feet
Max Speed.....50 mph, 22.2 m/sec
Acceleration Time.....3 seconds.
Empty Train Weight.....6200 lbs.
2 cars in the Sky Rocket Train, 6 people ride each car

STEEL CURTAIN
Length.....4,009 feet of track
Maximum Height.....220 feet
Top Speed.....74 mph
Empty Train Weight.....16,800 lbs.
Ride Weight.....2,800,000 lbs.

THUNDERBOLT
Length.....3,100 feet of track
Highest Point Above Ground.....60 feet
Top Speed.....48 mph
Train Weight.....7,200 lbs. (4 cars @ 1800 lbs ea)
Train Length.....38 feet

Average weight of one passenger.....154 lbs

Helpful Equations

$T = 2\pi\sqrt{(L/g)}$	$C = 2\pi r$	$U_g = mgh$	$K = ½mv^2$
$v = \triangle x / t$	$v_f = v_i + at$	$a = \triangle v / t$	$P = mv$

Remember that these formulas use METRIC units

1 lb = 0.453592 kg	1 ft = 0.3048 m	1 mph = 0.44704 m/s

Aero 360

Built in 2000, this 20 Meter swing ride takes riders for a loop attached to the Kennywood Arrow! Weighing close to 5000 Kilograms, each arm swings its riders higher and higher until it completes a full loop.

A. Draw a free-body diagram of the Aero 360 at both the top and bottom of the loop, labeling the forces. Use relative lengths of all force vectors in order to reflect the size of all the forces.

B. Assuming that all 5000 Kilograms are placed at the end of each arm, calculate the minimum speed it would take in order to complete one loop.

C. Calculate the apparent weight of the arm(Tension) at the bottom of the loop (Assume constant operational velocity using Part B).

D. On the Aero 360, there is actually a counterweight positioned on the opposite side of the riders. Would it require more or less torque from the axel in order to rotate the arm up to operational velocity? Justify your answer with either calculations or reasoning.

Sky Rocket

One of Kennywood's most famous coasters, the Sky Rocket features a magnetic start that accelerates the 2800 kg cart from 0-50 mph (22.5 m/s) in 1.8 seconds! This 30 meter tall coaster also includes three different inversions in order to make for one exciting ride.

A. What is the average acceleration of the cart?

B. Calculate the force required during the launch to uniformly accelerate the cart (Assume negligible friction.)

C. Coasters like the Sky Rocket utilize banks whenever making a sharp turn. Using forces, explain why these banks help to ensure the safety of riders while also allowing for faster turning speed.

Phantom's Revenge

A 2001 remake of the original Steel Phantom, this thrilling roller coaster takes its riders on an exhilarating 2 minute adventure. With a maximum height of 50 meters and a maximum speed of 85 miles per hour (38 m/s), this roller coaster gives its riders a scarily good time!

A. The ride starts with a slow ascent from the ground to the rides maximum height. This 45 second climb slowly lurches the 500 Kg cart up 50 meters. Calculate the work done on the cart during this climb as well as the average power output.

B. Immediately following this ascent, the cart stops and then experiences a vertical displacement of 47 meters. Calculate the final velocity after the first drop.

C. The second and largest 70 meter drop takes the riders underneath the Thunderbolt at the ride's maximum speed. Calculate the velocity at the top of the drop.

D. Using impulse, what is the net force experienced by the cart from the 3 second climb from the bottom of the first hill to the top of the second hill (Use velocity calculations from parts B and C)?

Pirate

Built in 1982, the Pirate swings back and forth, giving riders a sense of weightlessness. Weighing 28 tons (28,000 kg) and holding up to 54 passengers, this ride operates similarly to a pendulum.

A. Calculate the period of one oscillation of the Pirate without passengers.

B. Would the period change if the ride was full?

C. The current height of the swing is 66 feet (20.12 m). If the swing height was increased or decreased, would the period change?

Miscellaneous FRQs

1) A Kennywood rider is nervous about riding fast roller coasters and decides to pick between two of the highest speed roller coasters, so as to not overwhelm himself. He decides to use the total kinetic energy to decide which will be the tamest option. Between Phantom's Revenge (Top speed: 85 mph) and Steel Curtain (Top speed: 74 mph) which has the lowest kinetic energy?

2) The height requirement for the Steel Curtain is 52 inches or taller. The distribution of height of nine-year-old children is approximately normal with mean 52.5 inches and standard deviation 1.75 inches. Which of the following is closest to the probability that a randomly selected nine-year-old child will <u>not</u> meet the height requirement for the ride?

3) Kennywood is interested in finding out if there is an association between the time of day and people's willingness to ride the roller coasters. They took a random sample of 500 people from the park and recorded their answers. The table summarizes the results.

		Time of Day					
Are they willing to ride?		**11 am**	**1pm**	**3pm**	**6pm**	**9pm**	**<u>Total</u>**
	Yes	38	76	85	81	59	339
	No	62	24	15	19	41	161
	<u>Total</u>	100	100	100	100	100	500

Use the information above to answer the following questions:

A. State the name of the test needed to determine whether or not there is an association between the time of day and people's willingness to ride the roller coasters.

B. State the null and alternative hypotheses:

C. Are all the conditions met in order to complete the test? (Random, large counts, 10%)

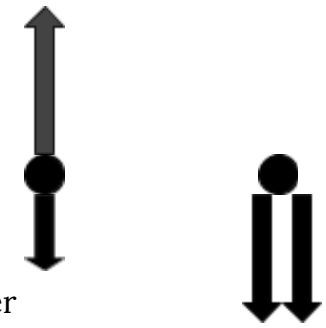
D. Is there convincing evidence that the alternative hypothesis is true?

Field Study

1) Pick one roller coaster in the park. Calculate the gravitational potential energy of the coaster at the top of its lift hill (assume the ride is full). If friction is considered negligible during the descent, what would the coster's kinetic energy be at the bottom of the hill?

2) Observe one wooden coaster and one steel coaster. Are there any similarities or differences? Are there certain features (ex: loops) seen in steel coasters but not wooden coasters, or vice versa? Provide an explanation that supports your answer.

Answer Key:



Aero 360:

A. One point for each correct FBD

(Tension is bigger than weight and pointing up on bottom)
(Weight and Tension point down on the top)

B. One point for equation and one point for correct answer (mg=(mv^2)/r) (10m/s for significant figures; 9.899 m/s exact)
C. One point for equation and one point for answer (Carry over minimum speed if it varies) (T=mg+(mv^2)/r) (99,000 N)
D. It would require less torque from the motor because the counterweight would provide additional torque in order to help counterbalance the torque caused by the arm's weight.

Sky Rocket:

A. One point for correct answer. (28m/s^2 rounded for sig figs; 27.778 m/s^2 exact)
B. One point for formula; One point for correct answer (carry over incorrect answers from part A)
(f=ma) (78400 N)
C. During a flat sharp turn, the force of static friction alone accounts for the centripetal acceleration. However, a banked track also incorporates the cart's normal force by angling the track towards the center of rotation. In this way, there are more forces able to account for the centripetal acceleration, so there is a higher possible speed at turns.

Phantom's Revenge:

A. One point for the work equation;one point for the power equation; two points for correct power and work.(W=fd)(P=W/t)(245000 J and 5444 Watts)
B. One point for the equation; one point for correct answer (mgh=(½)mv^2)(30 m/s for sig figs.;30.351 exact)
C. One point for the equation; one point for correct answer (-mgh+½ m(vfinal^2)=½ m(vinitial^2))(23m/s for sig figs.;22.865m/s exact)
D. One point for equation; one point for correct answer(Carry incorrect answers from B and C) (f=m(vfinal)-m(vinitial)/t)(1200N for sig figs.;1166.667 N exact)

*One additional Brownie Point (doesn't count)if the student drew a picture of something Kennywood related, two if it was funny.

Pirate:

A. T = 9 seconds (Formula T = = $2\pi\sqrt{(L/g)}$ should be seen in supporting work).
B. Mass is not needed when calculating T, so the period will not change.
C. When the height is increased, the period is longer, and when the height is decreased, the period is shorter.

Misc. FRQs:

1) Phantom's Revenge: ½ * 449(kg) *85 ^2 = 1622012.5 J Sky Rocket: ½ * 2812.27 (kg) *50^2 = 3515341.25 J Phantom's Revenge although having a higher top speed has less overall jules of kinetic energy, therefore the nervous rider determines Phantom's Revenge to be the more manageable of the two coasters.
2) 0.38755 - On calc.: NormalCdf (lower:-99999, upper: 52, mean: 52.5, SD: 1.75)

3A) Chi squared test for independence

3B) H_o: there is no association between the time of day and people's willingness to ride the roller coasters
H_a: there is an association between the time of day and people's willingness to ride the roller coasters.

3C) Random: yes-they took a random sample of 500 people from the park.
10%: yes- It's safe to assume there are more than 5,000 people in Kennywood.
Large counts: yes- all expected values are greater than 5

3D) Yes, the p value of .00000000000003 is less than the alpha value of .05.

Field Study:

1) Answers may vary - Formulas $U_g = mgh$ and $K = ½mv^2$ should be used to calculate gravitational potential energy and kinetic energy of the desired coaster - Conservation of Energy should be stated when discussing kinetic vs gravitational potential energy.
2) Answers may vary - Several similarities, differences, and features should be listed, as well as valid reasons that support the answers. These reasons could include when the coaster was made, materials used, etc.