C34: Cumberland Valley HS X
Aditya Kendre

Gravity Powered Vehicle

Evaluation of the problem (ii)

We are trying to create a vehicle that is capable of harvesting energy from gravity, by placing the vehicle on a ramp above the surface; thus, storing gravitational potential energy. Letting the vehicle travel down the ramp will turn the gravitational energy into kinetic energy. The vehicle would then proceed to stop at a specified distance (target point) without any additional energy.

All propulsive energy must come from the gravitational potential energy of the mass of the Vehicle. The entire Vehicle must start from an elevated, non-horizontal position on the ramp. A release mechanism must be included as part of the Ramp to hold the Vehicle in the ready-to-run configuration until triggered by the participants. The Vehicle's total mass must not exceed 2.000 kg. Electronic components and electric devices are not permitted. An approximately ¼" round wooden dowel must be attached to the front of the Vehicle. The dowel's front bottom edge will be the Vehicle's Measurement Point for distance measurements. The Vehicle and the Ramp, together, in the ready-to-run configuration, must fit within a rectangular box with a 50.0 cm x 50.0 cm base and a height of 100.0 cm. Also, the Practice Log must include four or more parameters (which include Target Distance, Vehicle Distance from Target, and Run-Time) for ten or more practice runs.

The score, which is how the performance of the vehicle is evaluated, is calculated mainly using the vehicle distance from the target point and the time the vehicle took to reach the target point unless penalties were awarded. This suggests the objective is to optimize the accuracy and precision of the vehicle relative to the target point, over the time taken for the vehicle to reach the target point. The equation below illustrates how the score is calculated:

$$vehicle\ distance\ (cm)\ \times\ 2 + run\ time + penalties = score$$

Background Research (iii)

Gravitational potential energy is a type of potential energy, which is the energy that is held by an object because of its relative position to other objects, this energy is stored in the object due to the gravitational field of Earth. the gravitational potential energy is defined below [1]:

$$U = mgh$$

Where m is the object's mass, in this case, the vehicle, G is the Earth's gravity, and H is the distance from the surface to the object's center of mass. Hence having the vehicle's center of gravity as high as possible on the ramp allows the vehicle to start with more gravitational potential energy [1]. This gravitational potential energy can be converted into kinetic energy [2], the energy that is used to create motion [1]. Thus, starting with more gravitational energy Allows the vehicles to have more kinetic energy to use to create motion. the equation for kinetic energy is Defined below [2]:

$$KE = 0.5mv^2$$

Where m is the mass of the object, in this case, the vehicle, and V is the velocity of the object [2]. solving these two equations yields the equation below [6]:

$$gh = 0.5v^2$$

The equation suggests that the height of the vehicle's center of mass is directly correlated to the velocity of the vehicle when exiting the ramp [1].

Friction is the force that resists the relative motion of objects starting against each other. He plays a major role not only in the accuracy aspect but also in the speed of the car. Friction is defined by the product of the coefficient of friction and the normal force. The equation is defined below [3]:

$$f = \mu N$$

Where μ is the coefficient of friction, and N is the normal force. The normal force is a component of a force that is often perpendicular to the surface [4]. We need to optimize both the coefficient of friction and the normal force. This is extremely important not only when braking but also when the vehicle is rolling down the ramp [5]. We want the vehicle to roll in a straight path down the ramp, so the vehicle can be precise in where the vehicle stops relative to the Target point [3]. having extreme variation in the path down the ramp creates unnecessary deviation from the desired path to the Target; it not only increases time but also severely decreases the precision of the vehicle [4].

Friction is also very important in the selection of the wheel, many believe that the more surface area the wheel has the more fiction it will create, this is not true because the equation States that only the normal force and the coefficient of friction affect the friction [3], and both the normal force and the coefficient of friction are unaffected by the surface area of the wheel. however, increasing the surface area of the wheel increases the stability of the car, meaning that the vehicle is less likely to veer to the left or right [1]. This is important because if the vehicle where to where its position would severely decrease and as a result the distance from the target point would increase, thus, higher the vehicle's score [4].

Furthermore, the moment of inertia is a quantity that determines the truck needed for angular acceleration, whether it is in the negative or positive direction. the moment of inertia is defined below [4]:

$$I = 0.5MR^2$$

Where is the mass of the object in this case the wheel, and R is the radius of the object? the moment of inertia Determines how fast the wheels will start to spin and how much energy end time the wheels were taken to brake to a complete stop. as the car brakes near the target point, the brakes need to full stop [3]. the moment of inertia calculates How difficult it is for the wheel to come to a complete stop. we want the wheel to come to a complete stop as fast as possible this would increase precision [4].

The shape of the ramp is also very important, do you want the vehicle to experience the least amount of friction on the ramp while maintaining a straight path and create a smooth transition between the ramp and the surface of the track. The brachistochrone, for instance, states the fasted path between two points, considering gravity. However, we are not looking for the fastest path, because the amount of time it takes the car to travel down the ramp is not included in the vehicle's time, rather the time starts half a meter after the starting line. hence, we want the ramp to take away the least amount of energy possible from the vehicle. this will ensure the vehicle has enough energy to travel to the Target point, as well as reach the point in a short amount of time.

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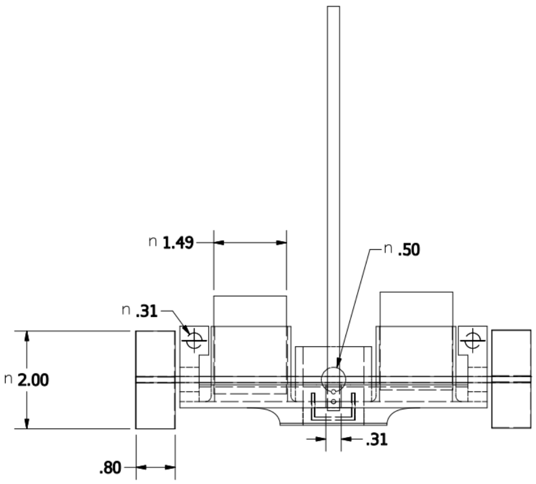
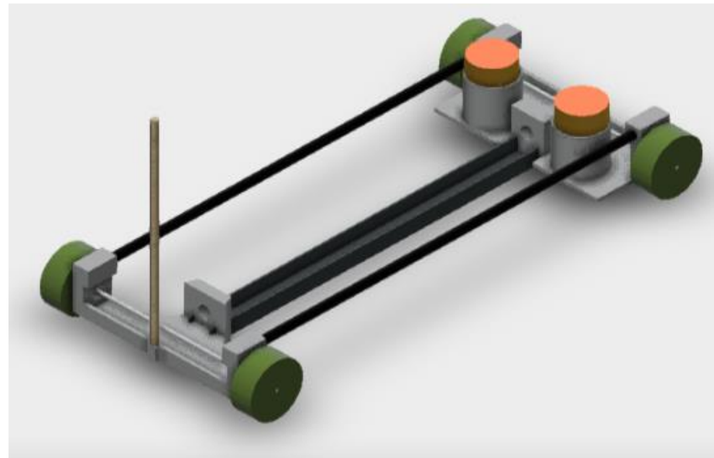
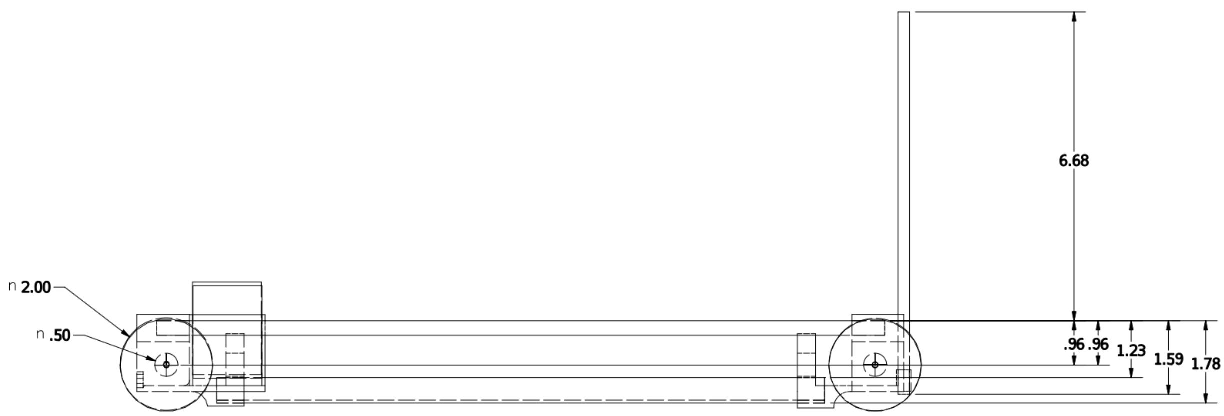
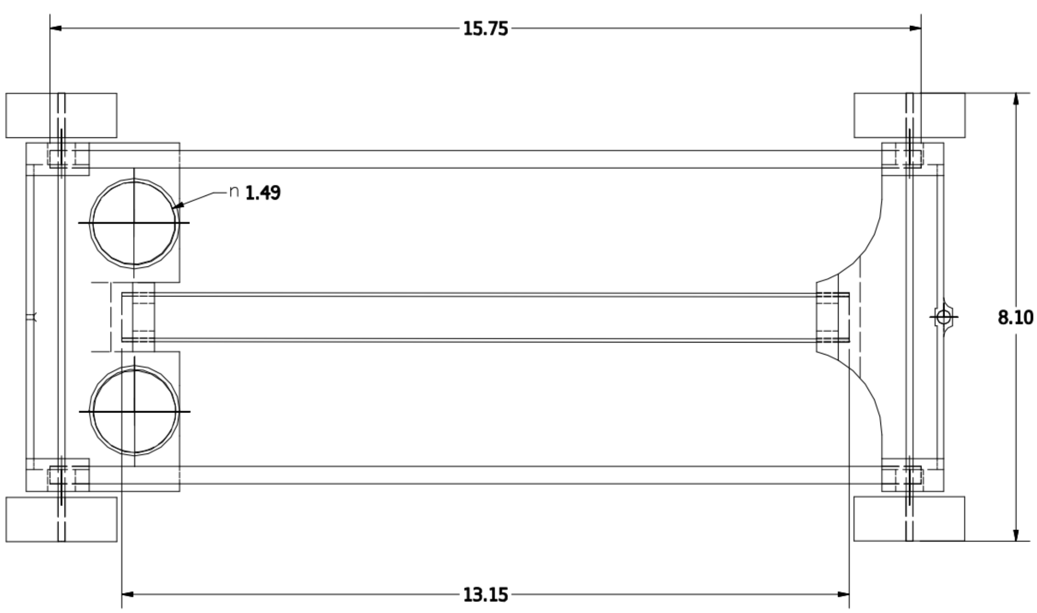
Design Specification (iv)









Design Rationale (v)

our decisions were many based upon the physics and mechanical principles that were discussed in the background research. we decided to make the car as heavy as possible which is 2 kilograms because this would allow the most amount of gravitational potential energy. we tried to make the car as light as possible in the beginning, then added wait to the rearmost part of the vehicle until it weighed 2 kilograms. this in turn caused the center of mass to be as far back as possible and as far back as possible on the rap, maximizing the distance between the surface and the center of mass of the vehicle.

the design of the car was designed from topographical optimization, which suggests the best structure of the car. the vehicle also used a c channel in the middle and two carbon fiber rods to make sure that when the car breaks, the vehicle has no flex because of the access mass in the rear of the car.

from the front, you can see that there is a hole in the C Chanel holder on the rear and front of the car. this whole is used to set the car on the ramp, without this the vehicle word very drastically in the path.

The braking system of the is a threaded rod with a wing nut, the one that travels across the threaded Rod as it is restricted when the axle moves with the wheel. after a countable amount of rotations of the wheels/axle, the Wingnut collides with an old which stops the wheels from moving by locking up the axle.

we decided to have wheels that were as wide as possible to increase stability but not to increase friction. to increase friction, we used the softest wheels from BaneBot. This increased the friction coefficient Theoretically stopping the car faster because of a greater amount of friction. to decrease the moment of inertia of the wheel we haul it out the center of the wheel, this would allow the Wheels to come to a stop faster.

the shape of the ramp was chosen because it has decreased the amount of friction. in the beginning, the ramp's incline is almost perpendicular to the ground this is to decrease the normal force acting on the wheels which decreases the friction so the car travels faster. as the car travels down the ramp the curve begins to flatten out early and becomes parallel to the ground, this ensures that the vehicle will have a smooth transition between the ramp and the floor. not having a smooth transition introduces variability in the Precision of the vehicle.

The car will be released from the ramp via an archery device, the Archer device is very trigger sensitive. this makes it easy to lease a car as the archery device is on top of the ramp holding the car from the back from falling down the ramp.

Testing and Calibration Plan (vi)

The tests were first done on many different floors, such as hardwood, titled, and even carpet. the point of this experiment was to analyze the magnitude after effect of different floorings would have on the friction and braking system of the vehicle. during testing measurements about the speed, the number of rotations of the wheels in the back and front, the amount of drift in the car, the amount of flex in the car, and the distance away from the target point in both the X and Y plane. this would ensure that we would be able to further analyze the data in more depth later if that analyzation required more feature sets. First, the data will be taken at 6 meters and then 13. to get the measurements for 8 meters and 11 m the data will be interpolated. these data points will then be tested and then the next day two points will be interpolated. repeating this process tell the measurements to converge at 9 1/2 meters. using all the data, points will be interpolated for every tenth of a meter, from there 5th of a meter will be checked. as a reminder, this will be done for each floor. after each floor is finished the coefficient of friction will measure and compare. at this point, we have three data sets one for each floor.

A deep learning model of that is developed which would take in all the parameters recorded during data for each run as well as the corresponding floor coefficient of friction. the last layer of the model output the corresponding number of rotations the wheel indoors during the run. the training set for this model will consist of all the parameters recorded doing all the tests, and the labels would be the rotations of the wheel.

	Time (s)	Rotation of rear wheels (rad)	Rotation of front wheels (rad)	the cm of drift (cm)	flex in the car (cm)	Y distance from target point (cm)	X distance from target point (cm)
Run 1							

Budget (vii)

Building Components:

2x4x96in x 4	Ramp base	16.14
¾-INX49 Particleboard	Ramp surface	30.48
¾ in screws	Holding ramp together	13.99
L brackets	Created right angles for a ramp	12.23
Archery release	Releases car	16.13
Carbon fiber rods	Holds car together	12.73
500g mass x 2	Shifts the center of gravity back	30.24
T81 2” BaneBot x 4	Wheels for the car	10.62
PLA plastic	3d printer	15.45
¼” Threaded rods	Brake for car	5.99
¼" Wingnuts	Braking mechanism	5.02
¼” nuts	Braking mechanism	5.24
¼” Lock colors	Breaking mechanism	3.54
¼” wooden dowel	Wooden dowel	1.62
Al C channel	Center of car	20.24

Tools:

Screw Drivers	Bolting car together	na
Band saw	cutting 4x2s	na
Table saw	cutting ramp surface (particle board)	na
Drill & Bits	assembling ramp	na
Epoxy	gluing carbon fiber	na
Wrench	tightening bolts	na
Hammer	4x2s into position on-ramp	na
3D printer	printing car	na
Acid bath and support dissolvent	dissolving support material	na
Allen Keys	tightening lock nuts	na
CA	gluing wooden dowel	na

Testing Equipment:

tape measure	measuring distance from a target point	na
Portable Friction Testers - Handheld	measuring friction coefficient of floor	na
laser gate	tracking the speed of the car and time have taken	na
Ruler	precise measurement	na
Computer	the calculation for interpolation, and training deep learning model	na

References (viii)

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