# AP Physics C 1718 Final Project Prospectus

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***1 Introduction***

To learn the theory behind how the intricate inner workings of many modern day machines is important, but to develop the skills, and experience to design one and put it into practice is true engineering, and also the reason a project of such caliber was undertaken. This project highlights and necessitates many of the critical proficiencies that go into engineering design.

The materials are all precisely chosen after many considerations of alternatives, and design functionalities are catered towards listed requirements. The methodology to completing the many tasks given is intertwined with the abilities of the designers and made to be as optimal as possible, while conforming to the laws of physics. Proper diagrams and designs are made to a degree of precision to be followed, but also allow leeway for tested variables and nuances.

*1.1 Prospectus Overview*

This paper is written to allow a glance into the thoughts and ideas that are going into this project. From the design of the body, to the mounted devices and planned functionalities, to the circuitry and measurement design, everything is studied against alternatives and prepared to utmost detail to ensure precision and efficiency during the undertaking of the project. Within the paper are the body designs, measurements, mounted mechanisms, pondered alternatives, scheduling, budgeting, blueprints, and circuitry.

***2 Design Overview***

The following section introduces the body of the vehicle and design considerations that went into its planned overlook. The body is the most important for working within constraints.

*2.1 Dimensions*

The body of the vehicle is built with many parts and protrusions, thus requiring precise measurements to be taken into account. This is all too important when it comes to the vehicle's movement, as operating turns and corners are hugely dependent on design proportions.

*2.1.1 Primary Body*

The main body of the vehicle is composed of a board of balsa wood that measures 35cm by 20.5cm. This specific type of wood is chosen because it is lightweight and easy to carve. This board is modified to have a curved front, so that corners do not collide into walls as the vehicle turns. This curve is based on a circle of radius 17.5cm, centered at the middle of the wooden board. This circular shape allows the vehicle to turn on the spot without collision when it is that distance from the wall. The dimensions of this board were chosen to allow for sufficient space to mount all the required circuitry, along with the mine collecting mechanism. The dimensions ensure that, in a run through the length of the testing space, an adequate area can be covered, while not compromising the vehicle's ability to turn.

### *2.1.2 Alternative Body Considerations*

An alternative to this setup would be to use a model car for a base. However, a wooden board was determined to be superior, since with a wooden board, circuitry can be easily mounted and secured on the top. The bases of model cars can tend to have an uneven surface, which can cause difficulty when these materials are mounted. Wooden boards also tend to have a stronger structure than the typical plastics in model cars, so with the usage of wood, a heavier load can be supported. Additionally, with a wooden base, the shape of the vehicle can be easily modified for optimal movement, something that is not possible with a pre-built car.

### *2.1.3 Mounted Design Summary*

At the very front of the board, an ultrasonic sensor is mounted, which allows the vehicle to detect obstacles ahead of it and turn accordingly. 2 pairs of wheels are located along the sides of the vehicle, in the front and the back. These wheels have a radius of 5cm, and are fabricated using the same wood. In order to increase the frictional force between the wheels and the ground, rubber bands will be tied around the circumferences of the wheels, acting as grips. The wheels were chosen to be fabricated so that they would be compatible with the already fabricated base. Again, this allows flexibility in design that a pre built wheel would not offer. The back wheels are powered by motors attached to their axles using a strong adhesive. The front wheels are left unpowered, and serve to maintain the stability of the vehicle while moving and turning.

A wooden bar of length 35.5cm, width 1 cm, and height 1cm is secured along the width of the board, so that it hangs 2.5cm off the ground. This bar is located 14cm from the front wheels, and has 5 individual magnets mounted under it, for the purpose of picking up the mines. Each magnet is a cube with side length 1 cm. The bar's location 2.5cm from the ground ensures the collection of mines, and the spacing from the front wheels ensures that the mines will not be picked up until they pass over the front wheels, so that the upwards force applied to the mines during collection does not affect the vehicle's motion. Due to the dimensions of the bar, it protrudes out of the width of the board, which is to ensure that a larger area can be covered when searching for mines. Its length is double the radius of the circle used to design the curve of the front of the board. This ensures that, when turning, it does not collide with the walls.

*2.2 Mine Collection*

Since the primary objective of the project is to retrieve the "mines" from the arena, it is of utmost importance to determine optimal methods to doing so. This means heavy consideration of all possible mechanisms to achieve such goal.

*2.2.1 Alternative 1: Claws*

Claws are not ideal because they require precision. The claw must be able to get under the mine when the mine is flat on the floor. Even after picking up the mine, the claw must move the mine to the storage. This will require multiple motors, increasing the cost. Throughout these movements, there is the chance that the mine is not in the perfect position and may get caught on a part of the robot, or may slip out of the claws. This method has too many moving parts, creating too many scenarios in which it will fail.

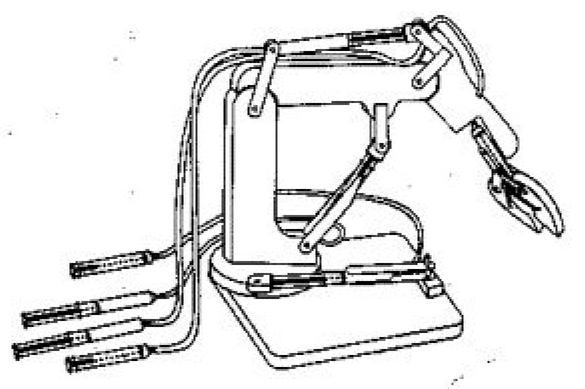


**Fig 2.0 - This depicts a sample hydraulic claw system used commonly to pick up items.** The front shows the claws which would in theory, snatch up the lids. This can be mounted on to the body, but would be heavy and unbalanced.

*2.2.2 Alternative 2: Suction*

Suctions cups, unlike claws, do not require as much precision. The idea would be to push the flexible suction cup into the mine, creating a low pressure region in between the cup and the mine, making the mine stick to the cup. Then, the cup can move the mine into storage. However, like the claws, there are too many ways this method can fail. Suction cups are never perfect.

There will always be some amount of air that is able to leak into the region between the cup and the mine, reducing suction and eventually allowing the mine to break free of the cup. They are also very susceptible to damage. Any imperfections that appear in the cup will greatly increase the rate of failure as it becomes easier for air to move into the cavity. Additionally, both actions of pushing the cup into the mine and moving the mine into storage require expensive and power-hungry motors. The mechanism requires a lot of energy from the battery.

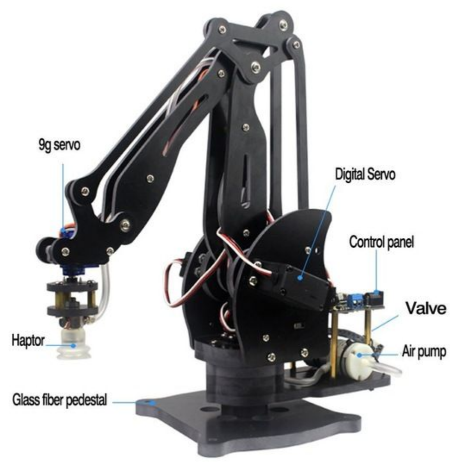



**Fig 2.1 - This is an example of a robot arm fashioned with a pump suction cup at its end.** From this, it can be seen that this can be mounted on the body of the vehicle, but would present the same problem of weight and balance as well as energy requirements.

*2.2.3 Alternative 3: Adhesive Appendage*

A sticky arm that can pick up the mine through adhesives is another alternative. This would involve an appendage that has adhesive on the end meant to stick to the mine allowing for easy pick up. Since each arm can only pick up one mine at a time, there are two options for how to proceed. 1: have multiple arms that each pick up a mine. First, to do this you need multiple arms. That means a different motor to control each arm and also a way to manipulate each arm into position to pick up the mine. This can be maneuvering of the vehicle itself or movement of the arm. The turns the vehicle must perform take a long time to execute and moving the arm requires yet even more motors. Either way is inefficient in terms of money and time. 2: remove the mine from the arm so that the arm can be used again. This requires a separate mechanism that would remove the mine. It also requires some form of storage in order to keep the mine where it needs to be. All of these complicated, expensive methods pale in comparison to using magnetism.

*2.2.4 Magnetic Sweep*

First of all, with magnets, there is no need to detect the mines before collecting them. The magnets will pick up any ferromagnetic material at any given time. Claws, suction cups, and sticky arms all need motors in order to move to the mine and pick it up. This is not so with magnets. They can be left in place. Their resting position and active position are one and the same, removing any need for motor control. This saves money, power, and also makes the design simpler and less likely to fail. Additionally, with magnets, if the strength of the magnet is not great enough, one can just add more magnets. It is easy to adjust and adapt the design to any unforeseen issues. Also, this design doesn't need storage. A magnet can pick up multiple mines without dropping any due to the way magnetism is able to operate through solid objects.

**Fig 2.2 - This is a magnetic sweeper, similar to dust sweepers but for small magnetic parts, commonly found in workshops.** Our original idea was further supported with this discovery and is somewhat similar.

Lastly, permanent magnets were chosen over electromagnets. Since there is no con to leaving the magnets on all the time, it would be more efficient to use permanent magnets since they do not require electric current.

*2.2.5 Magnetic Design*

Using the logic described above, it was decided that a set of permanent magnets, with individual dimensions of 1x1x1 cm, be placed on the underside of the vehicle. The mines are known to be ferromagnetic, so the magnets will be able to attract them. The magnets will be placed between the front and back wheels, at a distance such that the front wheels can roll past the mines and will not be on the mines when the magnets begin to attract them. Given that mines will be 5 inches or less in diameter, this distance is set to 14 cm (5.5 inches). The magnets will be mounted on a long wooden rod that hangs below the main body of the vehicle. The rod will extend beyond the width of the vehicle itself. This allows for the vehicle to sweep a large swathe of area, even if it does not drive directly over it. The magnets would be about 2.5 cm above the ground. This was decided because the magnet's range of influence is able to achieve a distance of 2.5 cm and this distance allows a single magnet to pick up multiple mines, as the mines won't drag on the ground even if multiple mines are stacked together on one magnet.

*2.3 Mobility*

For the movement of the vehicle, the designs that went into consideration were front-wheel drive, rear-wheel drive, 4-wheel drive, and all-wheel drive. As the names suggest, these design ideas were modeled off real world cars and their capabilities.

*2.3.1 Front-Wheel Drive Review*

Front wheel drive is the arrangement in which the engine and transmission are solely connected to the front wheels.

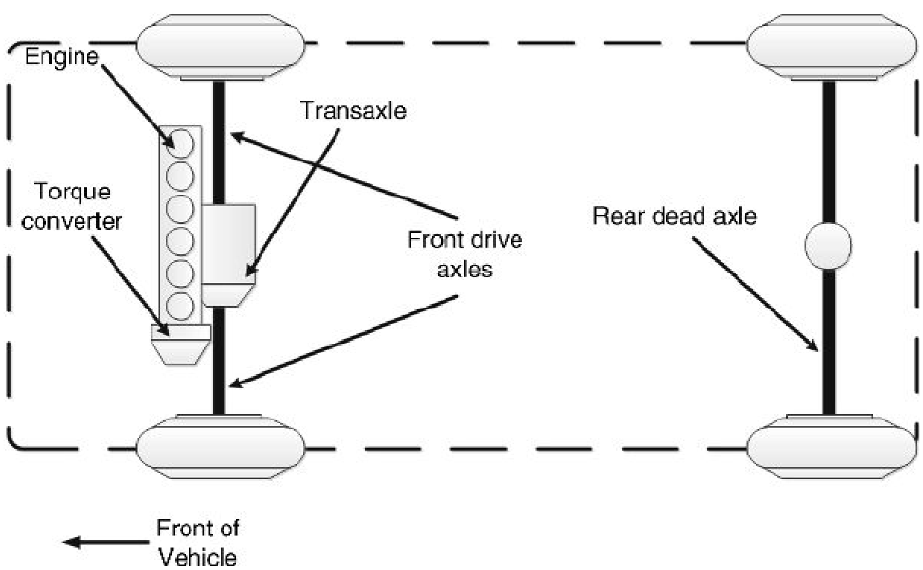



**Fig 5.0 - A simple diagram depicting the engine-axle system of a front-wheel drive car.** It can be seen that the back wheels operate about a dead axle disjointed from the engine. The placement of the engine is at the front shifting the weight.

The back wheels are left to rotate freely and simply follow the front wheels and offer support at the back end of the vehicle. This setup in everyday cars is most common. It also provides better traction compared to rear-wheel drives because most cars contain a large portion of the weight, mostly the engine, in the front. This pushes the center of mass forward compared to the rear-wheel drive. The working wheels are acting on the largest normal force, which increases friction when driving. Front-wheel drives are usually chosen because it reduces manufacturing costs of the car due to requiring less components and a simpler complexity overall. Front-wheel drives also generally reduces weight of the car overall. This means higher fuel economy. The problem with front-wheel drives, is that handling may not be as optimal, as the weight distribution isn't balanced and the turn point of a car is always the front. This means every turn is pushing its major load first, which causes a high momentum at every turn. If a turn must be stopped, and the traction of the wheels aren't sufficient, the car may find itself sliding due to the increased momentum.

In a configuration where the rear end of a vehicle is light, front-wheel drive makes driving the car nearly impossible. That's why most pickup trucks operate using rear-wheel drive. The rear wheels would have little to no normal force and are in danger of straight up losing contact and floating off the ground on anything mildly bumpy. Thus, if there isn't an adequate weight distribution, or at the very least enough load on the rear end of the car, front-wheel drives can only operate on the smoothest of roads. Of course, for most family cars, this isn't a problem. Another problem with front-wheel drives is if one of its 2 powered wheels gets raised off the ground. While on normal everyday roads, this isn't a problem, offroading or unexpected obstacles may cause an imbalance. This raises the other problem that only 2 wheels are being powered. If one wheel becomes unable to apply force to the car, the car basically becomes stuck, as the other remaining wheel usually isn't enough to haul it out. This makes front-wheel drive cars perform very poorly in nonsmooth paths.

### *2.3.2 Front-Wheel Drive Applications*

For the mine detector, a front-wheel drive configuration would place the servo motors near the front of the vehicle and its front wheels would do all the work. The rear wheels would simply follow along. This design has its upside in that placing traction at the front allows for better forward motion since the primary weight will be clashing with any obstacles. One such obstacle would be the ground outlet covers. These cause protrusions in the ground which the vehicle will have to overcome, and having the primary power in the front allows for the momentum of the front to force the vehicle over. Since turns will be made slowly, the problem with imprecise turning shouldn't be a large factor. The ground is smooth, but the material of the wheels should allow adequate traction.

The main problem with front-wheel drive is in its wide turn. Since the vehicle operates without a steering wheel, the turn must be made either with one wheel rotating forward while the other rotates backward for an on-the-spot turn, or the inside wheel rotating slower for a wide turn. The wide turn leads to areas in the corners of the stadium which aren't covered and if mines were distributed to these corners. That's why one-the-spot turns were chosen as the method of turning, but this leads to another problem. As the wheels are in the front, hugging the wall on the first forward path leaves no leeway for the long back to turn.

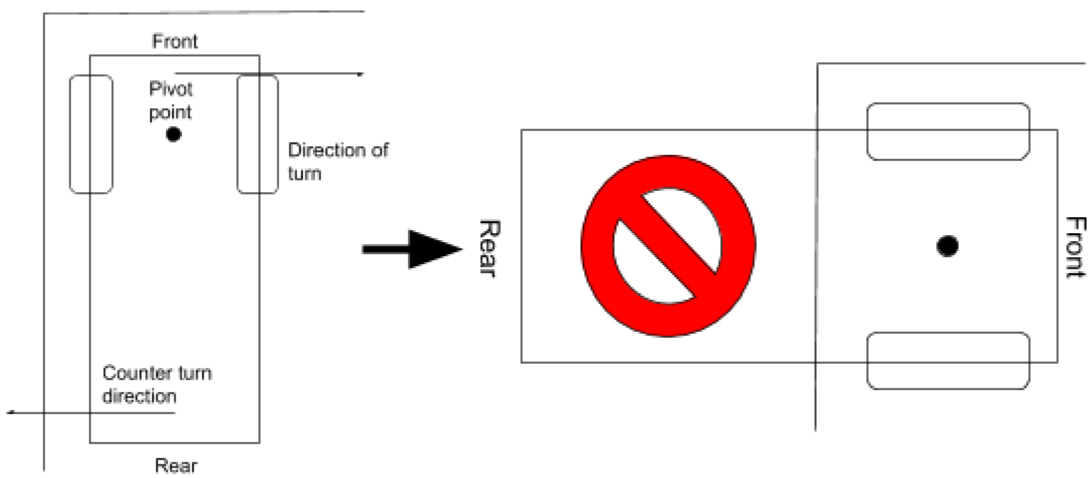



**Fig 5.2 - This shows how a front-wheeled on-the-spot turn would lead to the rear end of the vehicle hitting the wall.**

To combat this, the vehicle would have to start about 2/3rds its body length away from the wall and end the same length before the wall to allow a full 180° turn. This would again leave areas that can't be covered by its path, which is why front-wheel drive isn't optimal.

*2.3.3 Rear-Wheel Drive Review*

The rear-wheel drive arrangement is similar to that of the front wheel but in this case, the rear wheels are the ones being powered and the front are left to rotate freely.

Rear-wheel drive is often found in high-performance sports cars and trucks. Like in the front-wheel drive configuration, traction is high when the weight is on the driving wheel. For normal family cars, the engine is in the front so generally the weight will also be shifted to the front, but for sports cars, the engine is designed to be in the back. This rear-weighted traction allows for a faster acceleration and higher performance overall, which is why it's preferred in sports cars. Trucks generally have a load at the rear end, which delivers the same effect as the the rear engine. Having rear driving wheels helps accelerate the load. Removing the need for the engine and other components to be at the front also allows the rear-wheel drive cars to have a smaller steering radius increasing the precision of turns. The layout of parts of the rear-wheel drive means operating one is much simpler and the car itself can take much more abuse.

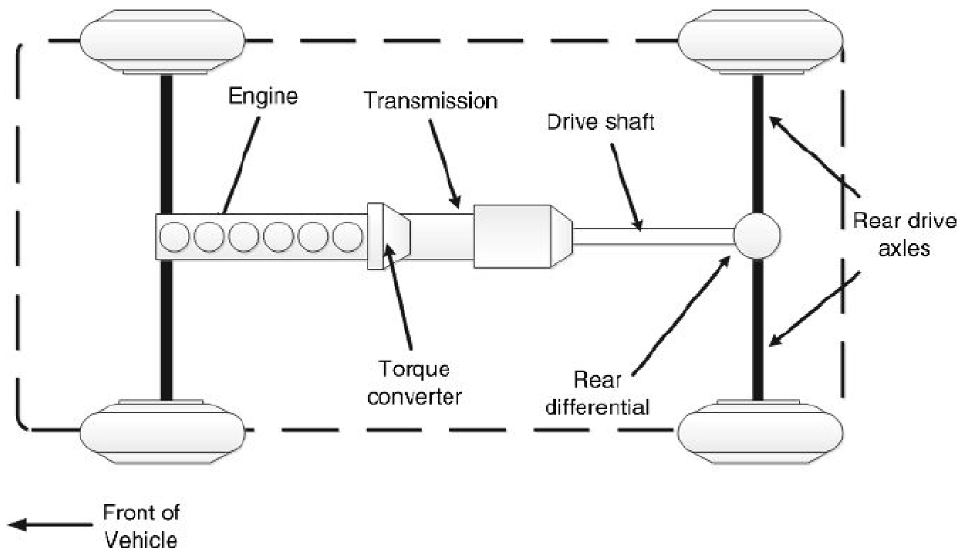



**Fig 5.3 - A simple diagram depicting the engine-axle system of a front-wheel drive car.** It can be seen that the front wheels operate free of the engine. The placement of the engine is near the middle with the rest of the system stretching down to the rear, evenly distributing the weight.

Due to a lack of central weight, rear-wheel drive cars are lighter on all 4 wheels which make them exceptionally poor at driving on slippery roads. Rear wheel drives also tend to be heavier overall, due to its increased amount of parts. This also causes an increase in the car's creation complexity. Both cause rear-wheel drive cars to be pricey compared to front-wheel drive.

*2.3.4 Rear-Wheel Drive Application*

For rear-wheel driving, the servo motors will be placed at the back. This means wide arcing turns for the front of the vehicle. Because the vehicle doesn't follow the configuration of an actual car, being the engine, torque converter, transmission, or drive shaft, the usual distributed weight of a rear-wheel drive car is nullified. Instead, the vehicle is be primarily back heavy. For any protrusions in the road, having a lighter front may actually help, since it can easily rise over such obstacles. While unlike the front-wheel drive, a rear-wheel drive is able to make the corner turns while covering a majority of the area leaving only spots to be checked afterwards. Due to the turning capabilities of the rear-wheel drive, it was selected as the mobility configuration of the vehicle.

*2.3.5 All-Wheel Drive and Four-Wheel Drive Review*

Four-wheel drives and all-wheel drives were ruled out due to the requirement of excess motors. The design is optimal in terms of cost with only the addition of the 2 back motors, so front motors were deemed to only increase the cost with marginal gains in performance based on the reasons above.

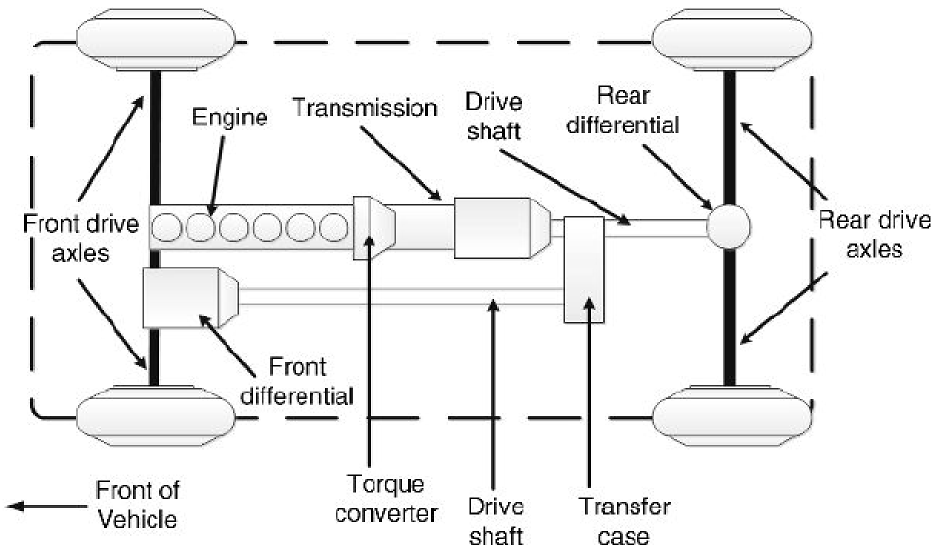



**Fig 5.4 - This is a diagram of an all wheel drive vehicle, with the engine schematics connected to all 4 wheels allowing each to be powered simultaneously.** It can be seem to contain many parts and have a much higher complexity deemed superfluous for our design philosophy.

*2.3.6 Vehicle Mobility Design*

The vehicle moves by turning its two motor-powered back wheels. The motors chosen are servo motors. This was decided based on the reputation of servo motors to deliver a high torque with a high degree of precision. The servo motors are controlled by the microcontroller. To turn on the spot, the microcontroller turns one motor forward and one motor backwards simultaneously. This allows for easy movement near walls, since the turn won't take the vehicle into the wall. In order to avoid collision of the corners of the vehicle and the walls, spacing will be determined during testing and programmed in. Additionally, the rounded shape of the front of the vehicle will help to circumvent this.

Additionally, rather than having a front wheel steering mechanism and making the aforementioned wider turns, the detector will utilize caster wheels. Caster wheels swivel and allow for a full range of motion without requiring any power. This was the largest concern with a steering mechanism as it would also need to be powered by the Arduino. The main issue with caster wheels is that when suddenly needing to make a right angled turn, the wheels will get stuck as the forces that would cause it to rotate clockwise and counterclockwise are closer enough to equal that they can not overcome the friction of the floor and bearing. To combat this, a method will coded so that the detector will move forwards or backwards to initiate the turn and then make the turn.

## *3 Mounted Mechanisms*

To accomplish the tasks given, such as keeping count of the mines picked up, keeping a live video feed of the vehicle in motion, and other useful mechanisms, the body must be mounted with many operations. This will inherently increase the weight as well as size of the vehicle which would reduce its performance, so optimization of the mechanisms mounted is a must. Careful considerations must be made in the decisions and design of the functionalities of the vehicle here.

### *3.1 Mine Detection*

The first and most important aspect of the mine detector, is its detection of mines. The design of detection is paramount in the programming of the vehicle and thus must be done with extensive precision and optimization. Detection of the mines before collection methods considered include using a metal detector, albedo sensor, or proximity sensors.

#### *3.1.1 Metal Detection*

Metal detectors are fairly expensive and are hard to integrate with a microcontroller. Most on the market are handheld devices that make sounds upon detecting metal that are not suited for analog input. Models that allow for integration with an Arduino do not appear to be available for purchase. It is possible to create a metal detector using the Arduino, but there are other problems that make the metal detector impractical. For instance, it can detect metals other than the desired targets. If there was metal beneath the floor, or if it detected another part of the mine-detector-robot, it would create situations which it may not be built for. The reliability of the metal detector is also in question. It depends on the magnetic fields that interfere with its own. The mine might be so small that the size of the magnetic field it creates might not be too different from the size of the fluctuations in Earth’s own magnetic field. If the metal detector is unable to differentiate the two, then it will be incapable of reliably detecting mines.

*3.1.2 Albedo Sensors*

Albedo sensors are able to detect light levels. The idea with these would be to aim them at a position below the vehicle to detect the different light levels when it is aimed at a mine. This depends on the level of light reflected by the mine to be sufficiently different than the light reflected by the floor. This may not be true, since the floor is not uniform and is composed of several shades. The albedo sensor may be unable to find exactly what is and isn't a mine. Also, each sensor can only monitor one point at a time. This makes it difficult to cover ground. If it is desired to cover more ground faster, then more albedo sensors are required, eating up budget and also needing an additional way of collecting mines from the different positions, whether through a movable collector or through multiple collectors.

*3.1.3 Proximity Sensors*

Proximity sensors use electromagnetic fields or radiation to detect nearby objects. It looks for a change in the field or for a reflection of the radiation it emitted. The electromagnetic field variant suffers much the same issues as the metal detector. It might detect other objects and could be affected by ambient noise. The electromagnetic radiation variant fares the same shortcomings as the albedo sensor. While it is able to use infrared rather than visible light, it might not be able to effectively differentiate the amount of light reflecting off the mine and the light from the floor. It is also a point-monitor and cannot cover ground quickly.

*3.1.4 Collection Timing*

It seems that detecting the mine prior to collection is cumbersome and expensive. Luckily, using permanent magnets, it is unnecessary to detect the mines before collecting them. What is then required is detection after collection. This method of detection must be able to sense that a mine has become attracted to one of the magnets.

Again, the previous methods come to mind, but the field-sensing variants may be ineffective in the presence of a strong magnetic field such as that of the permanent magnet and the radiation-sensing variants may miss the mines because the magnets may pick them up in inconsistent positions or they may still be unable to differentiate the mine from the floor.

*3.1.5 Load Cell Detection*

Instead, what was decided on is the load cell. It is able to detect a difference in weight reliably and accurately because it is based on the strain experienced by the cell. This is impervious to fluctuations in the surrounding magnetic fields and does not depend on light to function. Weight is an intrinsic property of mines and will be consistently applied to the load cell when a mine becomes attracted to a magnet. It is also easily integrable with an Arduino since it essentially functions as a variable resistor. They are fairly cheap (around $8 a piece) and multiple can be used in conjunction to increase accuracy. It is planned that two load cells will be used to measure the change in weight on the rod carrying the magnets.

### *3.2 Wall Detection*

To remain within the arena and maintain operations, the vehicle must not run into the walls of the arena. While rotational speed of the motors and an internal timer can be used to predetermine distances, it was decided a wall detection device is safest when it comes to dealing with error and the unknown.

#### *3.2.1 Ultrasonic Sensors*

An ultrasonic sensor is mounted at the front of the vehicle to detect when it nears a wall. This detection will trigger the turn. Once the vehicle has made a 90° turn, it will move forward 3/4ths its width if able and make another 90° turn. If it is unable to, it will simply turn when too close to the wall. The direction that the vehicle turns is based on a counter that alternates between left and right every two turns. The ultrasonic sensor allows for easy programming and adjustments during testing. This makes them optimal for a project like this, while retaining precise measurements to remove worries during any performance.

### *3.3 Microcontroller*

In the world of electronics, Arduinos seem to be the go-to microcontroller for versatility and ease-of-use. With all the functions needed to be managed onboard the vehicle, microcontrollers allow the vehicle to operate itself in fully automated functions.

#### *3.3.1 Arduino Usage*

Arduinos are easily integrable with many different types of sensors, displays, etc. and can be programmed using C++ to do virtually anything with its connected components. However, there are several models of Arduinos all with similar functionalities.

#### *3.3.2 Arduino Selection*

The Arduino Nano is compact and functional. However, the compactness comes at a cost of a small number of pins. When the seven-segment display can take up 8 or 9 pins by itself, a small number of pins is unworkable. The same problem comes up for boards such as the Uno or the Leonardo.

The Arduino Mega solves this issue. It has a total of 54 digital I/O pins and 16 analog input pins. This allows for all the modules to be connected and working with the Arduino. As such, this is the microcontroller that was decided upon for the project.

### *3.4 Display*

Real world rovers all have displays, as it is extremely helpful to the operator to be able to see what's going on. This allows for the assessment of the vehicles paths as well as potential problems it may encounter to adjust for the future.

#### *3.4.1 Seven-Segment Display*

A seven-segment display will be used to display the number of mines collected. It is easy to integrate with the Arduino and very well designed for this task. The only function of the seven-segment display is to show a single number, which is exactly what is needed. It's incredibly simple and costs less than $2. Since it is able to perform its task reliably, the only field in which another mechanism could upstage the seven-segment display in is cost. However, it is hard to see how something else could do this, seeing as the seven-segment display costs nearly nothing. Even if anything were cheaper, $2 is no big loss. With this in mind, it is difficult to see how anything could be better suited to the task than a seven-segment display.

### *3.5 Wireless Data Relay*

In present day electronics, wireless is king. Wireless connections allow for long distance operations, including such mine detection functions. Whether it is the phone, or the keyboard, wireless connections allows users much more freedom in their tasks, as well as opening new avenues to automation.

#### *3.5.1 WiFi Connection Review*

For wireless data transfers, WiFi seems to be the obvious choice. It's available at the test site and is used daily, proving itself to be functional and reliable. However, one must consider that the WiFi provided has firewalls and blocks not known at the moment. If one of these blocks were to prohibit the connection between vehicle and computer, then the data transfer will never go through and the wireless relay will have failed. Relying on outside assistance is possibly catastrophic and just gives one more possible source of failure.

### *3.5.2 Bluetooth Connection Review*

Instead, if the connection comes purely from the vehicle and the computer, then failure is much less likely. Using a Bluetooth module that facilitates the master/slave model, the vehicle will be able to set up a solid connection with the computer and relay data in that manner. While Bluetooth is a short-range connection, the vehicle will only be operating in a short range anyways, so it isn't a problem. Another con of Bluetooth is its low baud rate. However, since the video feed will be handled independently, this is not an issue either. This is also a very cheap method of creating a connection. The bluetooth module that connects to the microcontroller only costs $8.

### *3.6 Mounted Camera*

As said previously, the ability to watch the vehicle move and monitor its performance is paramount to the improvement of such projects in the future. This leads to the inevitable device of a camera mounted onto the vehicle. Sending live video back to the user assists the user in determining programming quirks and nuances when placed in real world situations.

A camera module is both convenient and versatile. Having WiFi capabilities allows it to be remotely accessed and controlled from a PC. It also allows for the mine count and position display to be shown in a separate window so that the live feed may also be observed at the same time. Once recorded on the computer, the footage can also be edited easily. Other cameras without wireless capabilities may suffer from mobility issues due to wiring, or may need to have their footage physically removed if it is to be viewed on a PC. This sort of setup can also be fitted into positions that are not usually observable by the human eye, allowing for greater range of vision and a more versatile viewpoint.

## ***4 Testing***

One of the unconcrete things about such a project, is the variability when it comes to performance in real world scenarios. This is due to environmental factors that cannot be accounted for in the initial paper design. To deal with such problems, the physical vehicle must be allowed to test through various controlled variables to determine optimal settings for performance.

*4.1 Magnetic Sweep Height*

To determine the height of the magnet from the ground, similar soup can lids found at home and at common supermarkets which all can be used to test the strength of the magnet. This can be done many times over, with controlled diameters and thicknesses of the lids. This can further be tested with a moving vehicle to adjust the height of the magnetic sweep further. If the vehicle drives over the lids without the magnetic picking up the lid, it's obvious the magnetic strength isn't strong enough. This leads the 2 options. Either the amount of magnets is increased to increase the magnetic field strength, or the height of the magnets is lowered to be closer to the location of the mind. These changes can be done numerous times, either independently or together, to optimize all possible configurations of how we achieve the goal of picking up the can lids.

*4.2 Wheel Rotational Speeds*

Wheel rotational speeds during forward movements can be determined using trial runs along makeshift tape tracts depicting a theoretical path. These tape tracts can be made with turns, and straight paths which the vehicle will be programmed to follow. With the programmed rotational speeds, it can be measured with video and instruments to determine how close or far off the vehicle's movement is to the intended path. With this data, it is then possible to optimize the rotational speeds down to many significant digits to gain the intended precision that comes with turns and coasts. These minute adjustments can also be documented for future approaches to similar projects, and the data can then be used for further optimization, if the situation calls for more than just turning.

*4.3 Sensor Range*

The range of the ultrasonic sensor can also be tested during the turn trial runs to optimize area coverage while preventing contact between the vehicle and the wall. Using precise measurement instruments, the exact time the sensor detects a wall can be found and thus altered to the desired distance. This should of utmost important for spacing of the vehicle's wide body turn and will allow for the easy programming of such turn in the sensor. It must also be tested for detection while the vehicle is moving, as many effects of physics such as friction and momentum must be accounted for. The range can thus be adjusted further depending on the determined speed of the vehicle from the rotational speeds above.

## *5 Timeline*

The timeline of the project is given by the following set of Gantt charts which indicate approximate timelines for individual aspects of the project.

### *5.1 Programming Schedule Gantt Chart*

This Gantt chart describes the schedule for the programming aspect of the assignment.

| Dates | Dec 4 | Dec 9 | Dec 16 | Dec 17 | Dec 23 | Dec 27 | Jan 2 | Jan 5 | Jan 6 | Jan 7 | Jan 10 | Jan 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Main | | | | | | | | | | | | |
| Basic motor control | | | | | | | | | | | | |
| Ultrasonic Sensor | | | | | | | | | | | | |
| Load cell | | | | | | | | | | | | |
| Mine Count | | | | | | | | | | | | |
| Turning method | | | | | | | | | | | | |
| Position | | | | | | | | | | | | |
| Bluetooth | | | | | | | | | | | | |
| Testing | | | | | | | | | | | | |

### *5.2 Assembly Schedule Gantt Chart*

This Gantt chart describes the schedule for the assembly of the vehicle.

| Date | Dec 4 | Dec 9 | Dec 16 | Dec 17 | Dec 23 | Dec 27 | Jan 2 | Jan 5 | Jan 6 | Jan 7 | Jan 10 | Jan 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gathering Parts | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chassis | | | | | | | | | | | | |
| Wheels | | | | | | | | | | | | |
| Magnet Beam | | | | | | | | | | | | |
| Testing | | | | | | | | | | | | |
| Assembly | | | | | | | | | | | | |

*5.3 Auxiliary*

All progress will be documented in an online log using Google Sheets in order to keep all group members updated. This will be produced upon request of a progress report.

### *6 Budget*

This is a table describing the parts used and the cost of each part.

| Item | Price (CAD) all values rounded up to nearest quarter |
|---|---|
| Arduino Mega | 52.50 |
| 9V Batteries | 8.00 |
| Ultrasonic Sensor Module | 4.50 |
| Servo Motors | 12.00 |
| Camera module | 30.00 |
| Bluetooth Module | 8.00 |
| Neodymium Magnets | 5.00 |
| Strain Gauges | 17.50 |
| Seven Segment Display | 2.00 |
| Wooden dowels | 3.00 |
| Hot Glue | 2.00 |
| Solder (iron already owned) | 3.50 |
| Operational Amplifiers | 7.00 |
| Electrical Components | 3.00 |
| Styrofoam/Cardboard | 0.00 |
| Miscellaneous | 17.00 |
| Total | 175.00 |

| Vehicle parts (not included under budget) | |
|---|---|
| Wood (primarily balsa) | 10.00 |
| Caster wheels | 4.00 |
| Rubber Bands | 1.00 |
| Nails | 1.00 |

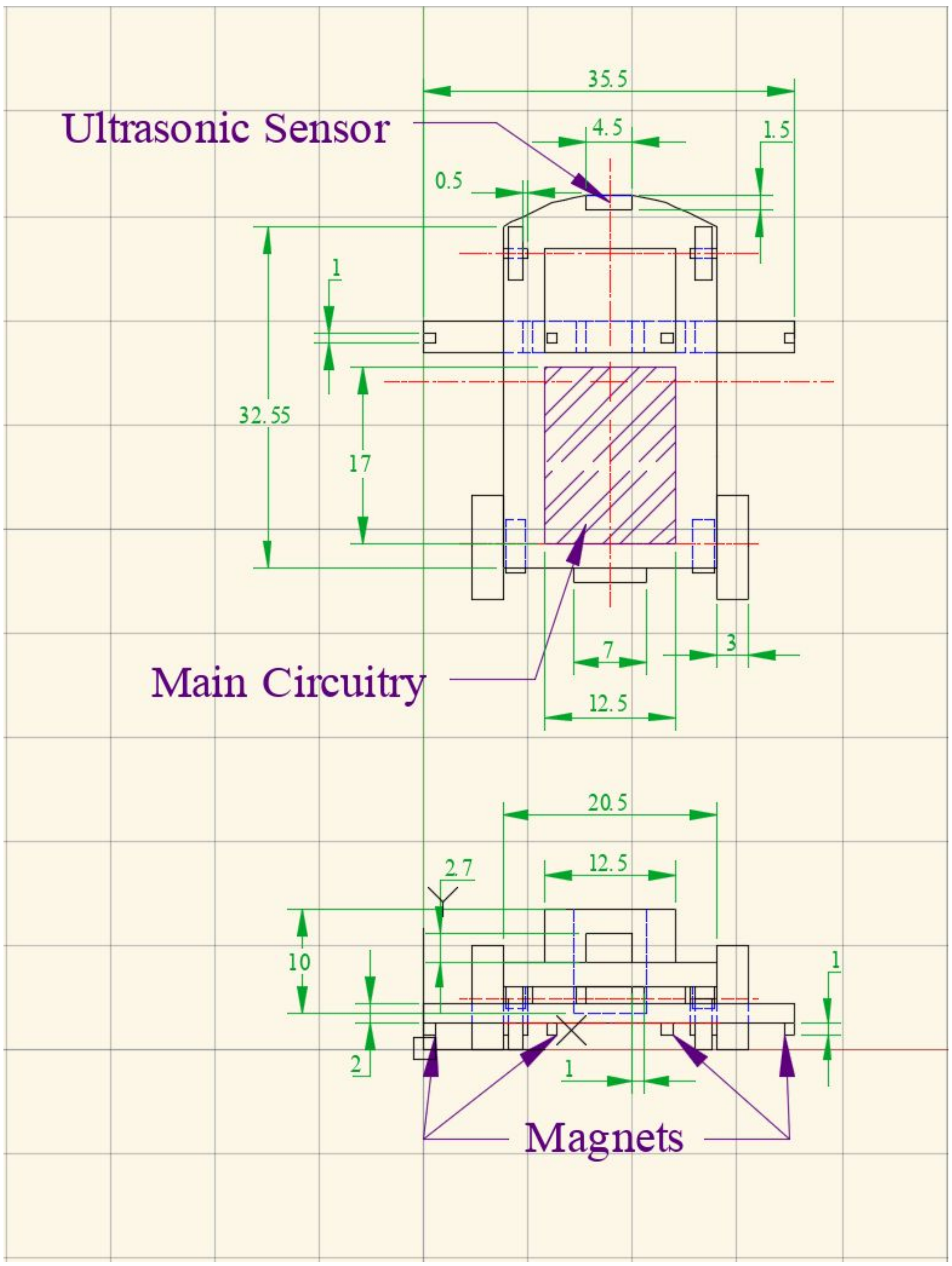
***7 Schematics***

The following are schematics for the vehicle and the circuitry involved.

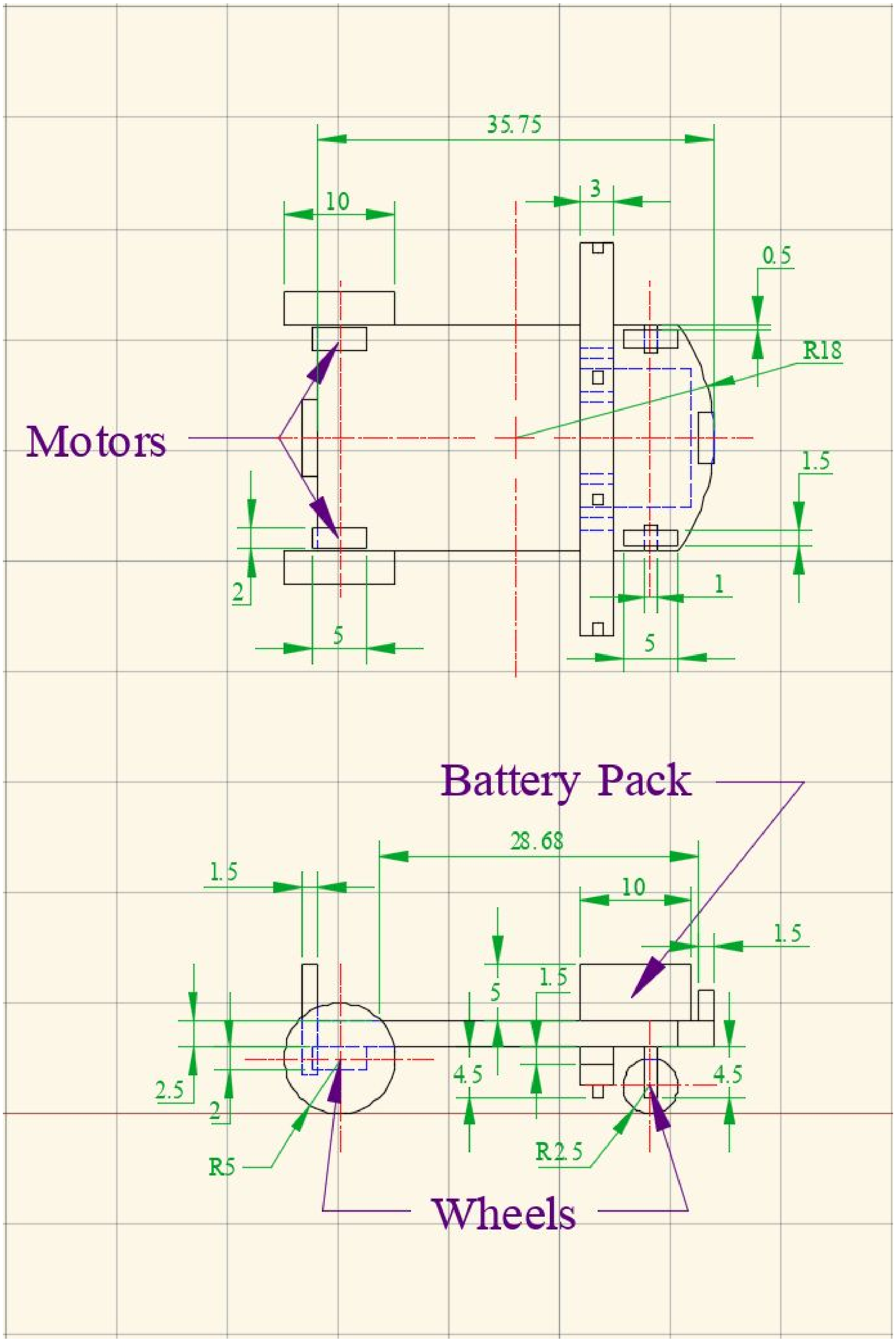
*7.1 Vehicle Design Blueprint*

These are blueprints for the physical construction of the vehicle, measurements in cm.

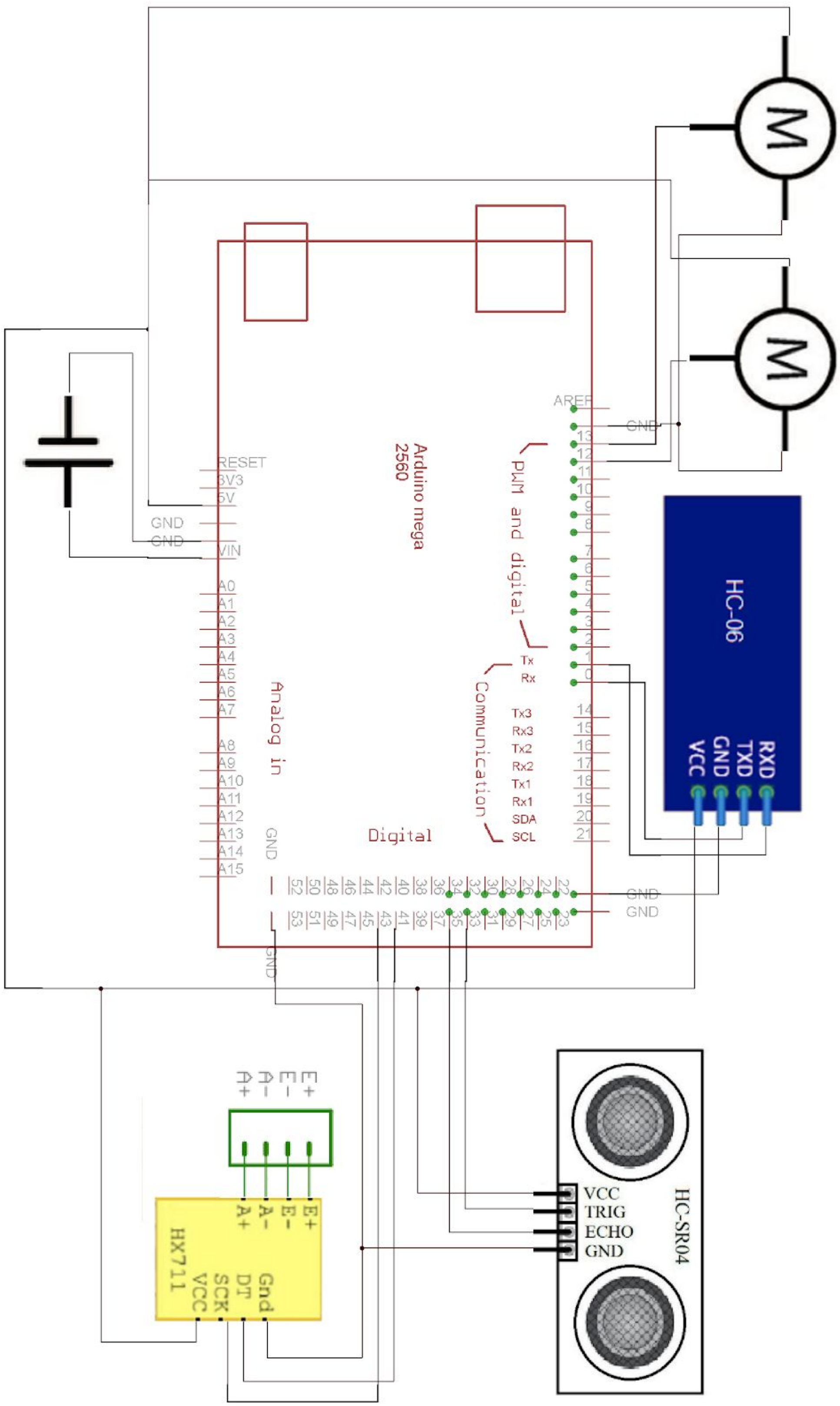
*7.1.1 Top and Front View*



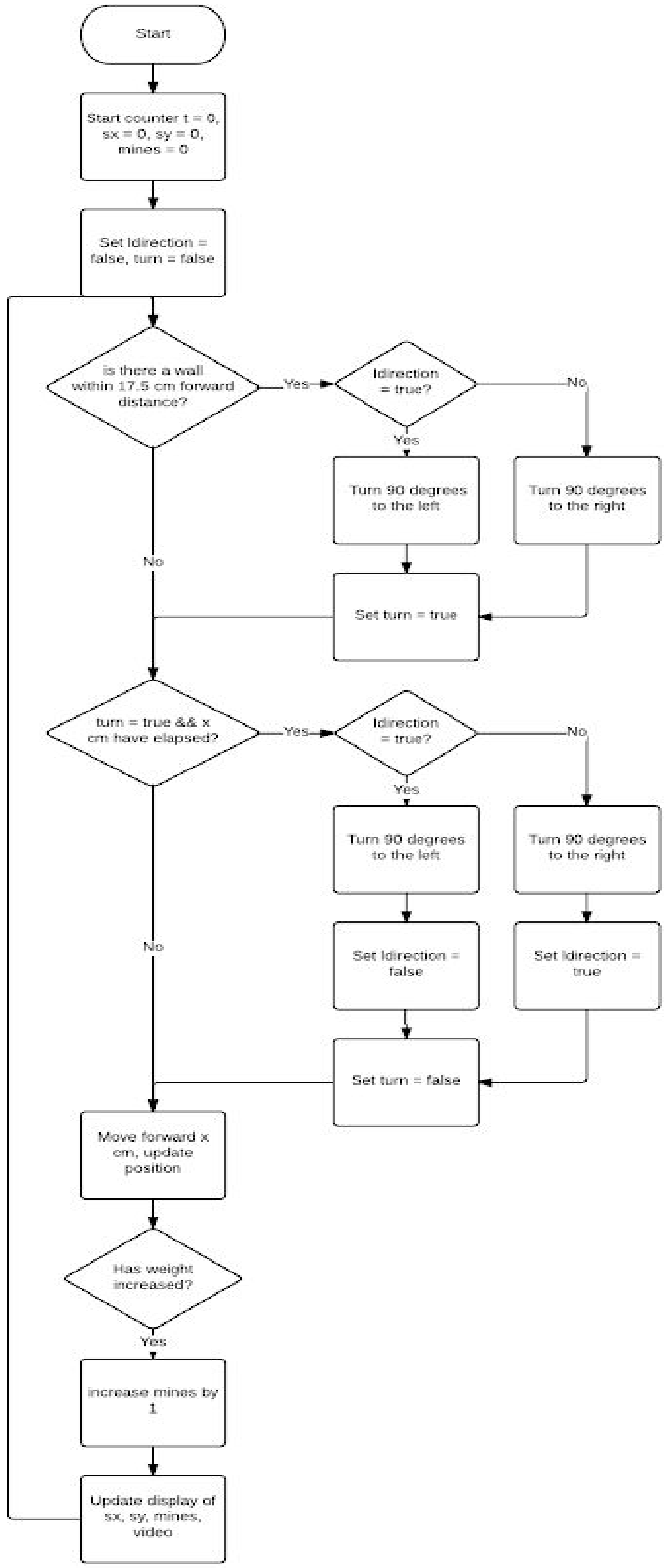
*7.1.2 Bottom and Side View*



*7.2 Circuit Diagram*



### *7.3 Flowchart of Vehicle Logic*



## *8 Sources*

The following sources were used for images, opinions, prices, and research.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