10.015 Physical World

Design 1D – Worksheet 1 (Due: 2359, 22 Oct)

<u>Group : 8 (Cohort Class 9)</u>

<u>Team members :</u>

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Answer the following questions concisely regarding the design of your toy car to meet the challenge and achieve the goal. You may leave any mathematical models used to determine design parameters and data in an attachment if there is any.

1. Describe and briefly explain your choice for the mechanical energy sources to power the toy car and the design of the engine. Give an estimated amount of energy stored that is required of the toy car to complete the obstacle course. Check out the details of the obstacle course in the 1D writeup.

Figure 1 (toy spring motor)

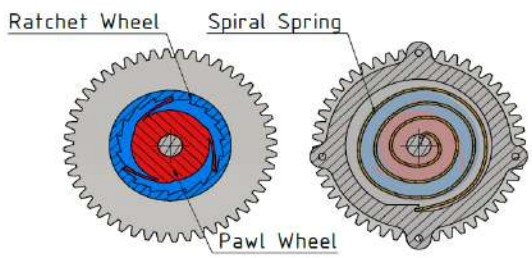

Figure 2 (spring mechanism)

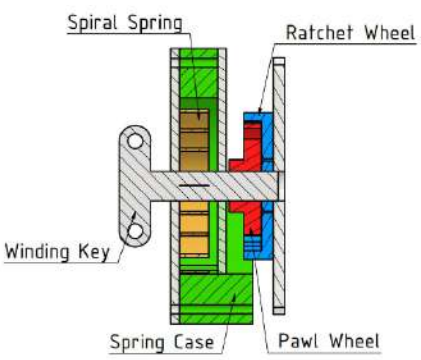

Figure 3 (motor components)

We've opted to employ a spiral spring as the source of power for our car. In *Figure 2*, it provides a visual representation of the motor's fundamental concepts. The spring will be responsible for driving the large pinion gear. The ratchet mechanism serves the dual purpose of enabling us to wind up the spring without causing the gears and wheels to rotate during the winding process. Moreover, the ratchet will securely lock the spring in place after each revolution, facilitating the winding process.

Below are the calculations for the **required force, torque and work done** by each wheel:

Distance that needs to be covered = **2.5m**

We let the mass of the entire car (including wheels, load, and other parts) = **600g**

$$\Delta x = \frac{1}{2}at^2$$

$$2.5 = \frac{1}{2}(a)(5)^2$$

$$\frac{5}{25} = a$$

$$a = 0.2ms^{-2}$$

To cover the distance in 5 seconds, we need an acceleration of **0.2*ms***

By taking 80mm wheels, radius of wheels = $\frac{80mm}{2} = 40mm = 0.04m$

Force generated by wheels: $F = 600g \times 0.2ms^{-2}$

$$= 0.6kg \times 0.2ms^{-2}$$

$$= 0.12N$$

Torque required by each wheel: $\tau = F \times d$

$$= 0.12N \times 0.04m$$

$$= 0.0048Nm$$

Work done by 1 wheel: $W = F \times \Delta x$

$$= 0.12N \times 2.5m$$

$$= 0.3J$$

2. Briefly explain your plan to deliver the energy to the wheels to move the toy car.

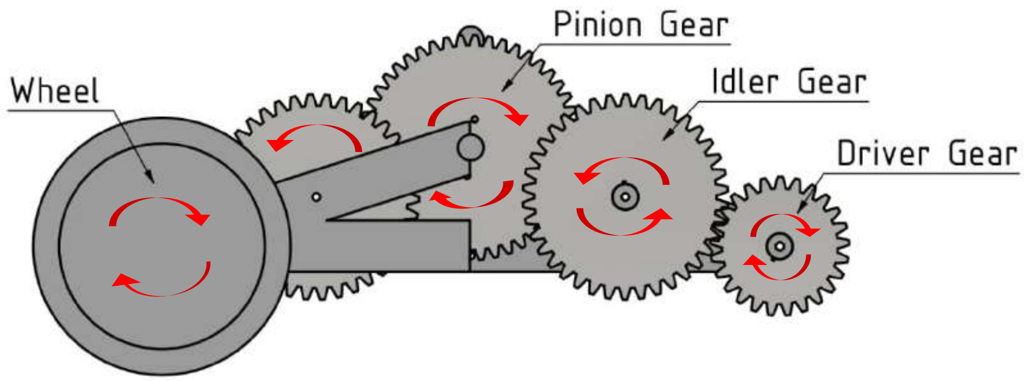

Figure 4 (gear diagram)

We intend to utilize a gear mechanism to transfer the rotational motion generated by the spring motor to propel the wheels. The motor is directly linked to a pinion gear, which, in turn, drives two idler gears. Following the idler gears, there are two driver gears on each side, and these driver gears are connected to the wheels. This sequential arrangement of gears is designed to ensure that the driver gears on both sides rotate in the same direction, guaranteeing that the wheels will also turn in unison.

Beyond the transmission of motion, we can use the gears to adjust both torque and speed output. This means we won't need to alter the motor's power. Instead, we can modify the gear sizes to meet the specific requirements for speed and torque.

3. Explain and describe the engineering solutions you consider to ensure the toy car is able to overcome the challenges such as the upward (1 – 2 cm) and downward vertical step (2 – 4 cm).

- Use wheels with good traction so that the tires can grip on the edges and the climb.
- Ensure that the motor is sufficiently sized by calculating the energy requirement based on the steepest incline of the obstacle so that it can overcome every other obstacle.
- Raise the components to provide adequate ground clearance underneath the car so that it can clear the bumps of the obstacle.
- Opt for larger wheels to ensure the vehicle can surmount higher obstacles and bumps.

4. Explain your plan to ensure there is sufficient tractions and stability as the car moves (moving in straight line without toppling and wheel slipping easily, able to face bouncy surfaces) on the obstacle course.

Material	Approximate Coefficient of Static Friction Against Wood
Rubber	0.95
Wood	0.4
Steel	0.2 – 0.6
Styrofoam	0.6

Table 1

To identify the most suitable tire material for our car, we created a list of potential materials that we can use. We compiled the coefficient of static friction between these materials and wood, which serves as the primary obstacle material. After analyzing the data in Table 1, we determined that rubber is the optimal choice for our tires due to its highest coefficient of static friction against wood. Moreover, the rubber's slight softness enables it to absorb minor surface impacts, preventing excessive bouncing and ensuring the car's stability. In addition to the coefficient of friction, we also decided to make the tires as wide as possible so that the amount of surface area in contact with the road is greater, providing more traction.

Figure 5 (rubber used as material for tires)

5. Provide the simple, clear and informative schematic diagrams (top view and side view) of your design, label all key components, dimensions, and materials of choice. You may consider hand-drawing, to use CAD or etc., provided your diagram is clear and illustrative.

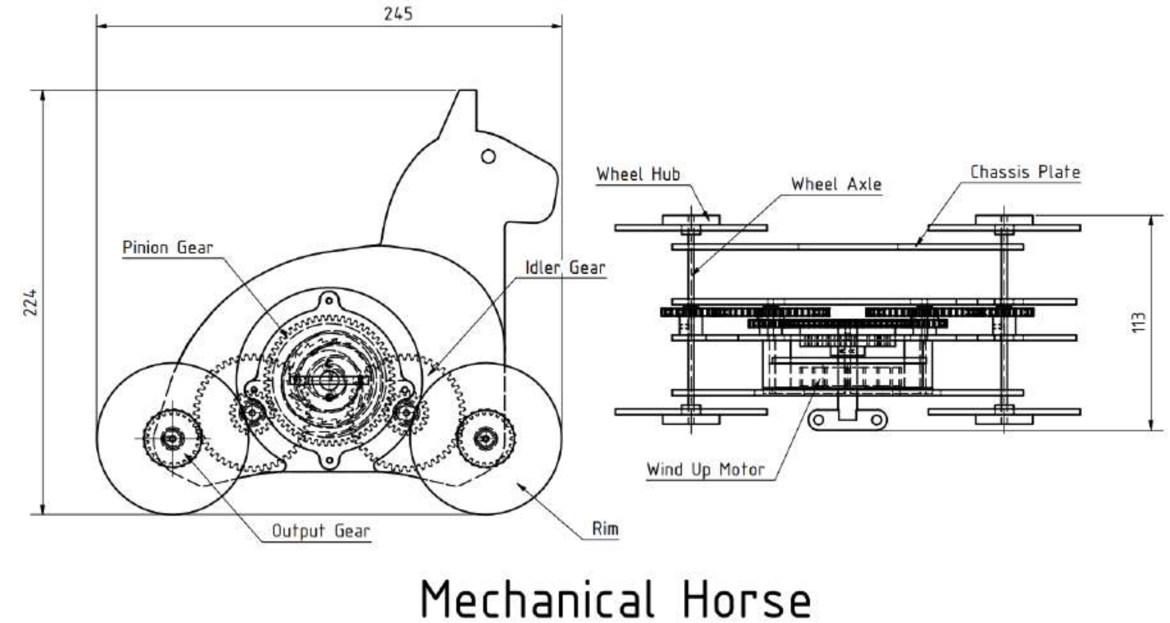

Figure 6 (toy car diagram)

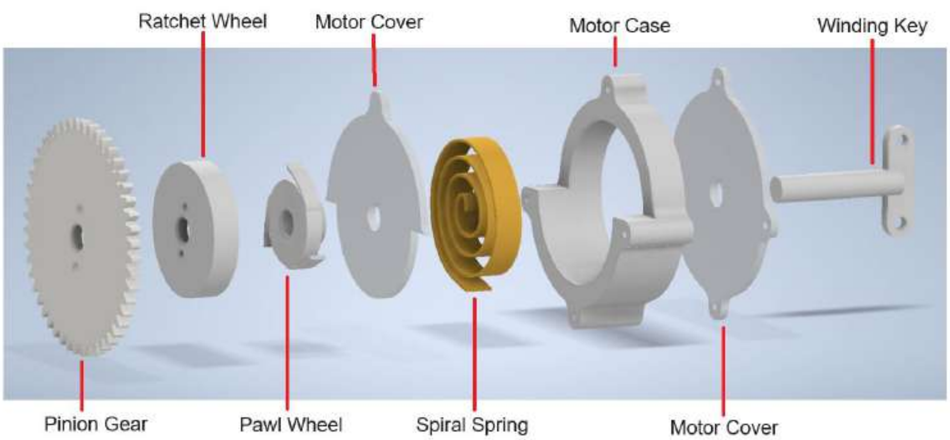

Figure 7 (wind-up motor components)

Materials:
- All flat plates like the chassis plate, wheels, and motor cover are to be made out of sheet acrylic.
- All gears are to be made out of acrylic.
- the wheel hub, and motor case is to be 3D printed.
- The Wheel Axle is to be made out of hexagonal steel rod.
- Spiral spring to be made out of spring steel.
- Winding key to be made out of copper.

Design Notes:
- Tire design to be finalized.
- Method to Fasten all layers together to be finalized.