# 2023 Energy Invitational Score Calculations (TASK)

**Purpose:** To calculate the optimal vehicle speed that will result in the largest score. Knowing the optimal speed will allow us to optimize the vehicle for that speed.

**Who?** → The Electrical and Software Team

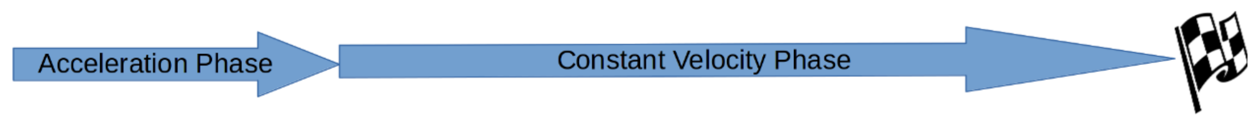
**Formula:** $TOTAL\ SCORE = 10,000,000\ /\ (WattHours\ *\ seconds)$

**Discussion:** The two variables can be calculated as follows

1. **seconds** = Track Distance / velocity
2. **Watt-Hours** is a unit of energy and is used to measure the amount of work performed:

   **Work Performed** = (a) Work to bring vehicle up to final velocity + (b) Work to overcome air resistance + (c) Work to overcome rolling resistance

We will not consider slowing down for corners, etc. We will just look at the simple scenario to bring the vehicle up to a velocity and to maintain that velocity for the entire distance of the track (1000 meters?).




There are two phases where we need to calculate work done:

1. **Acceleration Phase:**
   Work = Work to accelerate vehicle to final velocity + Work to overcome drag while accelerating

   Work of Acceleration Phase = $\frac{1}{2} mv^2 + \int_0^x F_d \cdot dx$
2. **Constant Velocity Phase**
   Work = Work to overcome drag at final velocity

To simplify the calculations at the expense of a little bit less accuracy, we ignore the integral term of the acceleration phase and calculate work to overcome drag over the entire distance of the track as follows:

Total Work = work to accelerate vehicle + work to overcome drag at final velocity

<u>a) Work to accelerate vehicle to final velocity:</u>

$E = 1/2 * m * v^2$

<u>b) Work to overcome air resistance:</u>

Force of Drag (in newtons)
$F_d = c_d * ½ * \rho * v^2 * A$

Where:
$F_d$ = Force of Drag (newtons)
$c_d$ = drag coefficient (est 0.42)
$\rho$ = density of flue (1.2 $kg/m^3$ for air at NTP)
v = final velocity (m/s)
A = frontal area of the body ($m^2$) - [estimated 1.4$m^2$ for 2022 vehicle]

Work to overcome drag (in joules or newton-meters)
$W_d = F_d * d$

Where:
$W_d$ = work done to overcome drag (in joules)
d = distance in meters

<u>c) Work to counteract rolling resistance:</u>
Lets ignore rolling resistance for now (it won't make much of a difference and like above, it exponentially increases with velocity)

**TOT WORK = Work to bring vehicle to velocity + Work to overcome air resistance**

To convert to watt-hours:
Watt-Hours = Total Work (in joules) * 0.00027777777777778

**Notes:**
Let's look at the scoring formula again:
$TOTAL\ SCORE\ =\ 10,000,000\ /\ (WattHours\ *\ seconds)$

The energy requirements (**Watt-Hours**) <u>increase exponentially</u> with velocity, while the **seconds** term <u>decreases linearly</u> with velocity. Therefore, just a quick look at the formula seems to indicate that the lowest velocity will result in the highest score. *Could this be why there were some 2022 teams that were driving very slow (ie. 5mph)?*

You could add rolling resistance and motor + drivetrain inefficiencies, but I don't think it will make a difference.

**TASK → SOFTWARE TEAM**
1. Confirm the above assumptions (could check with Mr. Egan)
2. Write a computer program to plot the score vs velocity graph so we can validate and quantify expected score at a particular speed.