EVie's S.T.E.M. Activity

For STEM 10-12 students:

(Appropriate for grade 10, 11 or 12 students)

Glossary:

N = Newton (a fundamental unit of force)

Newton-metre = one Watt-sec = 1 Joule (a fundamental unit of energy)

"KWh" means kilowatt-hour (a bigger unit of energy)

Questions:

An EV contains a **40 kWh** battery and it is traveling at a constant speed on a level, flat highway. At a highway speed of 100km/hr, the EV pushes against aerodynamic forces of air (250N) and the rolling friction of the tires (450N). The combined effect of all this drag results in a **700 N** constant force pushing against the forward motion of the EV while it is travelling at a constant travel speed of **100 km/hr.**

1. How much force from the thrust developed by the motor and wheels is needed to maintain the EV at a constant speed of 100km/h?

2. How much stored energy (in Joules) is removed from the battery during a 36 minute trip at 100km/h if we assume the electric motor and power conversion system has a combined efficiency of 96% ?

3. How many kWh (kilowatt-hours) of energy is consumed during the trip?

4. How much charge remains in the battery after 60km of driving at $100\frac{km}{h}$?

5. Where did that energy consumed from the battery **go to?**

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Answers:

1. According to Newton's 1st law of motion, **700 N** of force is needed by EV drive train to just balance the 700 N drag force to maintain a constant velocity. The net force (the unbalanced force) is zero.

2. By definition: Work is Energy (Joules) = Force (N) x Distance (m) { the MKS system }

   Energy = $700\text{N} * \frac{100\text{km}}{\text{h}} * \frac{1000\text{m}}{\text{km}} * \frac{36\text{m}}{60\frac{\text{m}}{\text{hr}}}$ = 42,000,000 N.m (Joules)

   Factoring in the 96% efficiency, the energy consumed from the battery is $\frac{42{,}000{,}000}{96\%}$ =

   43,750,000 Joules { 43.75 x 10^6 Joules }

   keep track of your units, most units cancel leaving just Newton-metres, Nm, which is energy}

3. 43,750,000 Joules = 43,750,000 Watt-sec
   There are 3,600 seconds in one hour, and 1,000 watts in a kilowatt (kW)
   $\frac{43{,}750{,}000\ \text{W.sec}}{(3600\frac{sec}{hr}\ \text{x}\ 1000\ \frac{W}{kW})}$ = **12.15 kWh** battery storage consumed

   { again notice how the units cancel, leaving just kWh which is a convenient unit of energy }

4. Charge remaining is 40 kWh (initial) – 12.15 kWh (consumed) = **27.85 kWh** or about **70%** battery charge remaining

5. It was all converted to heat. Turbulent air flowing over the vehicle is heated, the tires are heated from frictional losses from contact with the road, and there are ohmic losses in the power converter and in the electric motor of the electric vehicle (EV). No energy is conserved and all forces acting on the EV are non-conservative.
   (*Physics teacher provide examples of conservative and non-conservative forces)*