ECE 398GG

Gross

Homework 2 Solution

- 1. Consider the *Nissan Leaf EV* we have been exploring in Lecture 3 with the following technical data: $C_d = 0.28$; $A_f = 2.28 m^2$; 40-*kWh* battery pack; final drive ratio 8.193:1; motor with a continuous rating of 110 kW (3,283 to 9,795 *r.p.m.*); and, a torque rating of 320 *N-m* (0 to 3,283 *r.p.m.*). You may assume a 90-% drivetrain efficiency and 1-*kW* hotel load in your analysis.
 - a. Estimate and compare range based on loaded masses of 1,800 kg, 1900 kg and 2000 kg, respectively, at 70 mph continuous cruise. Compare these three estimates and comment about the impacts of mass on the vehicle range.
 - b. For the 2,000-kg mass, estimate the range based on continuous speeds of 60 mph, 70 mph and 80 mph, respectively. Compare these three estimates and comment on the impacts of speed on the vehicle range.

Solution:

- a. Traction outputs at 1,800 kg, 1,900 kg and 2,000 kg are 16.13 kW, 16.38 kW and 16.63 kW, respectively. Under the assumption of 90-% drivetrain efficiency and 1kW hotel load, the corresponding power input values are 19.04 kW, 19.31 kW and 19.59 kW. The corresponding *fuel economy* or *FE* values are 272 Wh/mi, 276 Wh/mi and 280 Wh/mi. In order to maintain the health of the battery pack, we do not allow the battery pack state of charge or *s.o.c.* to go below 20 %, *i.e.*, the consumable energy is 80 % of the 40-kWh battery pack or 32 kWh. Under this constraint, the respective ranges are 118 mi, 116 mi and 114 mi. We note that, for the mass values considered, the range decreases linearly with the mass increase, with about 2 mi of range reduction per 100 kg of mass increase.
- b. The traction outputs at 60 mph, 70 mph and 80 mph are 11.59 kW, 16.63 kW and 23.10 kW, respectively. Under the assumption of 90-% drivetrain efficiency and 1-kW hotel load, the corresponding power input values are 13.99 kW, 19.59 kW and 27.78 kW. With respect to 32 kWh, these values result in FE of 233 Wh/mi, 280 Wh/mi and 335 Wh/mi, respectively. The corresponding range estimates are 137 mi, 114 mi and 95.6 mi. The 20 mph increase in the cruise speed leads to around a 30 % drop in the range.

- 2. Some experts suggest that values such as 100-kW continuous rating, 200-kW peak, 400-N-m torque are excessively high for passenger car motor specifications. As an alternative, consider a car such as the Nissan Leaf EV, loaded to 2,000 kg, with a motor rated for 60-kW continuous, 120-kW peak, and 200-N-m torque.
 - a. Estimate the final drive ratio required to support a 30-% gradability for this car.
 - b. **Determine** the attainable acceleration at 50 *mph* with the 120-*kW* limit.
 - c. Estimate the top speed under the assumption of no limit on motor rotational speed.

Solution:

a. A 30-% grade faced by an *EV* with 0.008 tire loss coefficient and 2,000 kg load, requires 6,039 N of force for traction. For 0.3-m radius tires, the required torque is 1,812 *N*-m. For a motor rated at 200 *N*-m, the final drive ratio is 9.06.

b.

$$f_{traction} = mgR_t + \frac{1}{2}\rho C_d A_f v^2$$

$$f_{traction} = 2000 \ [kg] * 9.8 \ [m/s^2] * 0.008 + \frac{1}{2} * 1.2 \ [kg/m^3] * 2.28 * 0.28 \ [m^2] * (22.4 \ [m/s])^2$$

$$f_{traction} = 349 \ [N]$$

$$P = fv$$

$$P_{drive} = 349 [N] * 22.4 [m/s]$$

$$P_{drive} = 7817 [W]$$

$$P_{unused} = P_{max} - P_{drive}$$

 $P_{unused} = 120000 - 7817 = 112182 [W]$

$$P = fv; f = ma$$

$$P = mav$$

$$a^{max} = \frac{P_{unused}}{mv}$$

$$a^{max} = \frac{112182 [W]}{2000 [kg] * 22.4 [m/s]}$$

$$a^{max} = 2.50 [m/s^2]$$

c.

$$P^{max} = f_{traction} (v^{max}) * v^{max}$$

$$60000 = \left[2000 \ [kg] * 9.8 \ [m/s^2] * 0.008 + \frac{1}{2} * 1.2 \ [kg/m^3] * 2.28 * 0.28 \ [m^2] * (v^{max} \ [m/s])^2 \right] * v^{max}$$

$$Use \ either \ a \ grapher \ or \ the \ provided \ spreadsheet, \ as \ this \ equation \ is \ not \ trivial \ to \ solve \ by \ hand$$

$$v^{max} = 51.38 \ [m/s] = 115 \ [mph]$$

