Physics of Electric Vehicles: Extra Credit Problems

Refer to " ***EVs: Prius Gens, Nissan Leaf, Ford Focus, GM Volt & Bolt & Tesla S***" on the back side of this sheet.

Handy Kinematic Conversion Factors: 60 mph = 88 ft/s = 27 m/s

Calculate the Design Parameters for some All Electric Vehicles.

Chevrolet decides to build a Bolt Electric Vehicle that can accelerate uniformly from **0 to 60 mph (27 m/s)** in **7 s.** The car's mass is to be **1,624 kilograms** (Weight 3580 lb).

1. Acceleration: a. Calculate the required **Acceleration** of a **Chevy Bolt** in gs? $\mathbf{a \equiv \Delta v/\Delta t}$
a = (0 to 60 mph) / 7s **g = 0.391** **b**. Calculate the required 0-60 mph acceleration of a **Ford Focus**.

2. Centripetal Acceleration: $\mathbf{a_{cent} \equiv v^2/r}$
Given: Turning around a curve with speed = 10 m/s and radius = 20 m
What is the **Centripetal Force** on a Chevy Bolt?

3. Newton's Second Law: a. What is the **Force** required to accelerate the **Bolt** ? $\mathbf{F \equiv m * \Delta v/\Delta t}$
F = m * a = 1624 * 3.85 = **6257 N, 4615 lb** **b.** Calculate for force for a **Tesla S** for 60 mph in 3 sec**.**

4. Work: a. What is the amount of **Work** done on a Bolt? **b. Force for the Tesla S?** $\mathbf{d \equiv \frac{1}{2} a t^2}$ $\mathbf{W \equiv F * d}$

5. Kinetic Energy: What is **Kinetic Energy** of a **Chevy Bolt** when traveling at 27 m/s. $\mathbf{KE = \frac{1}{2} m v_f^2}$

Crumple Zone
A part of a motor vehicle, especially the extreme front and rear, designed to crumple easily in a crash and absorb the main force of an impact.

6. Collision **- Conservation of Momentum**
A **Chevy Bolt** runs into the rear of a stopped 2017 Ford F-150 Raptor truck that has a weight of 12,000 lbf. Immediately after the collision, the vehicles are hooked together and have a speed of 4 m/s.
What was the **speed** of the **Chevy Bolt** just before the collision?

7. KE Loss **- Collision - Elastic or Inelastic**
Given Initial KE of Chevy Bolt and Final KE of Bolt plus Truck
What is the Loss of KE in the collision?

8. Collision: Impulse What is the **Peak Force** during the above collision? $\mathbf{\Delta p = p_f - p_i}$ $\mathbf{F_{coll} = \Delta p/\Delta t}$
Most vehicle collisions last about 120 milliseconds.

9. Power: What is the power needed to accelerate the **Bolt** to 27 m/s in 7 sec? **Power** $\equiv \Delta E/\Delta t$
How does this compare to the electric motor's power rating?

For Problems 10 and 11, use the other design factors given in the attached spec sheet.

10. Estimate the Prius Gen IV top speed. Given Max Motor Power, P_{max}, Drag coefficient Cd, and frontal area A_f.
Aerodynamic Force, $F_{Aero} = 0.5 * \rho_{air} * Af * Cd * velocity^2$. Where ρ_{air} is the density of air = 1.293 kg/m^3.
Aerodynamic Power Loss, P_{Aero} is equal to the product of the Aerodynamic Force, F_{Aero} and the velocity.
Hint: Top speed occurs when $\mathbf{P_{Aero} = Efficiency * P_{max}}$. Assume Power **Efficiency** of Vehicle = 75%

11. Electrical Energy and Charging Time:
Calculate how long would it take to recharge a fully depleted **Chevy Bolt's** battery at a charge rate of 240 V and 32 A.

EVs: Toyota Prius Gens, Nissan Leaf, Ford Focus, GM Volt & Bolt & Tesla S

Electric Vehicle Specifications	Prius Gen II	Prius Gen III	Prius Gen IV	Prius Prime Plug In	Chevy Volt Gen II	Nissan Leaf	Ford Focus Electric	Chevy Bolt EV	Tesla S P100D*
Years of manufacture	2003 – 2009	2010 - 2014	2015 - 2017	2017	2010 - 2017	2011 - 2017	2017 Hatch	2016 - 2017	2015 - 2017
Electric Vehicle Type	Full Hybrid	Full Hybrid	Full Hybrid	Plug In Hybrid	Series E-REV	All Electric	All Electric	All Electric	All Electric
Internal Combustion Eng Size	1.5L	1.8 L	1.8L	1.4/1.8L		N/A	N/A	N/A	N/A
ICE Engine HP/kW	76 / 57	98	95		84	None	None	None	N/A
Total Drive Train HP	110	134	121	121		96.3	143	200	570
ICE Torque	115 Nm	105 lb ft	105 lf ft	105 lb ft		None	None	None	N/A
ICE Engine RPM Redline	5000	5200	5200	5200		N/A	NA	NA	N/A
Electric Motor Power (HP)	67	80	71	31/71	149/74	96.3	143	**200**	765
Elt Motor Power, P_{max} (kW)	50		**53**	53	120	80	107	150	570
Max Motor Torque, T_{max} (ft lbf)	295	115	120	30/120	236	207	184	266	707
Fuel Economy(MPG /e)	**42**	**50**	**55**	**75/113**	**42/106**	**/112**	**/118**	**/119**	**/98**
0-60 mph (seconds)	10.1	9.8	9.6	12.2/10.6	9.2	10.2	9.9	7	2.3
Average Acceleration (gs)	0.271	0.279	0.285		0.297	0.268		0.391	**1.4***
Top Speed (mph)			**112**	115	100	93	85	91	217
Braking Distance 60- 0 mph			117 ft		112 ft	124 ft		132 ft	109 ft
All Electric Range (miles)	1.	1.5	1.5	25	53	107	115	200	314
Battery Energy (kWh)	1.3KWh	1.3KWh	1.3KWh	8.8kWh	18.4	30	33.5	**60**	100
Battery-Pack Voltage	201.6	201.6	201.6			360-403		350	394
Battery Amp-hr	6.5	6.5	6.5		50.4	32.5			120
Battery-Pack Weight (lb/kg)	/45				/435			/43C6	1411/640
Battery-Pack Type	NiMH	NiMH	NiMH	Li-Ion	Li-Ion	Li-Ion	Li-Ion	Li-Ion	Li-Ion
Lifetime CO_2 Savings	43%	43%	43%						
Drag Coefficient, Cd	0.26	0.25	**0.24**	0.25	0.28	0.29	0.295	0.32	0.24
Frontal Area, A_f		1.98 m^2	**1.98 m^2**		2.16m^2	24.5 ft^2		25.8 ft^2	25.2 ft^2
Gear Ratio (P-Planetary)	P - 3.27	P - 3.27	Helical	4.11	8	7.939		7.05	9.73
Tires			P195/65R15	P195/65R15	215/50R17	205/55R16	P225/50R17	P215/50R17	245/35R19
Tire Radius			0.287 m	0.287 m	12.7 in	12.44 in			
Length (mm) Width (mm) Height (mm)	4445 1725 1490	4460	4540 1760 1470	4646 1760 1470	4498 1788 1438	4445 1770 1550	4392 1882 1478	4166 1765 1594	4978 1956 1448
Weight/Mass (lbf/kg)	2900	3042	3064	3365	3794	3256	3624	3580	5051

*1.4 sec is Tesla S's maximum acceleration. Fastest production car (1.4 gs) in the world.

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