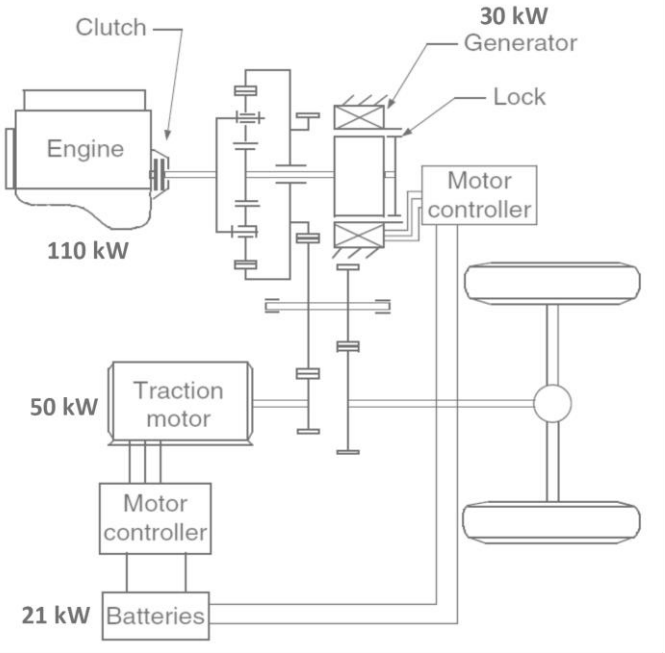
EE 7566 - Power Split Hybrid Exercise Calculations

Answer following questions according the following configuration and given information in Table 1.



a)

Fig. 2. Configuration of the 1st generation Toyota Prius.

Table 1 – Prius information

Radius of wheels	0.3 m
Gear ratio (electric motor to wheels)	4
Gear ratio (Ring gear to wheels) G_{r-w}	2
Gear ratio (Electric motor to ring gear) G_{GM2-r}	2
Number of ring gear teeth N_r	80
Number of sun gear teeth N_s	32

$$\omega_{GM2} = \omega_w G_{GM2-r} G_{r-w}$$

$$T_{GM2} G_{GM2-r} + T_r = \frac{T_w}{G_{r-w}}$$

$$\frac{\omega_{GM2}}{G_{GM2-r}} = (1 + \frac{N_s}{N_r})\omega_{engine} - \frac{N_s}{N_r}\omega_{GM1}$$

$$T_{ring} = \left(\frac{N_r}{N_r + N_s}\right) T_{engine} = \frac{N_r}{N_s} T_{GM1}$$

1. Calculate the torque and rotational speed of the wheels, electric machine, ring gear, internal combustion engine, and generator when the electric machine produces 15 kW power and the internal combustion engine is **idle** (zero torque and speed), at 21.6 km/h. All losses in the system are ignored and required configuration information is given above.

	Front wheels total	Electric machine	Ring gear	ICE	Generator
Rot. speed in rad/sec					
Torque in Nm					
Power in kW					

2. When the battery is critically low, the energy management system runs the internal combustion engine both to drive the wheels and charge the battery. The vehicle speed is 43.2 km/h, total power required on driven wheels is 30 kW, battery charging power is set to be 10 kW and the electric motor is **freewheeling** (zero output torque). All losses in the system can be ignored. Fill the following table for this operating point.

	Front wheels total	Electric machine	Ring gear	ICE	Generator
Rot. speed in rad/sec					
Torque in Nm					
Power in kW					

3. Calculate an alternative power distribution among components for the operation when the total power required on driven wheels is 30 kW and the battery charging power is set to be 10 kW at 43.2 km/h such that the ICE operates at its maximum efficiency. Fill the following table for this optimal operation.

Hint: Efficiency of the ICE is an important criteria in power management. In Prius, the ICE is the main power source but its shaft is not directly coupled to the wheels. Therefore, the speed of the ICE can be chosen independent of the driving speed. Once the power and speed of ICE are known, power distribution between generator and ring gear can be calculated. This configuration is also called power-split hybrid because the power of ICE splits between ring and sun gears. The power versus speed characteristic at maximum efficiency of the internal combustion engine is shown in Fig. 3. Select the optimal operating point for the ICE according to the characteristic line, then calculate the other torque and rotational speed values.

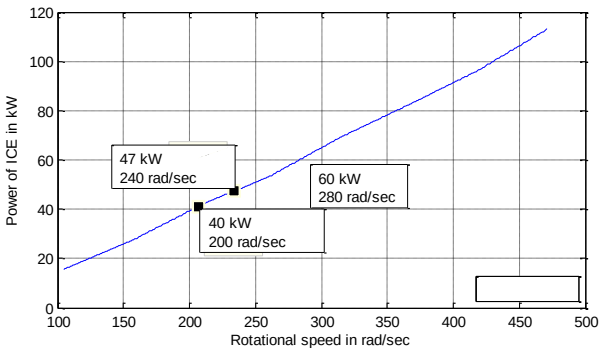


Fig. 3. Maximum efficiency line of the ICE.

	Front wheels total	Electric machine	Ring gear	ICE	Generator
Rot. speed in rad/sec					
Torque in Nm					
Power in kW					

4. Repat part 3 for P_{wheels}: 35 kW, P_{charge}: 5 kW

	Front wheels total	Electric machine	Ring gear	ICE	Generator
Rot. speed in rad/sec					
Torque in Nm					
Power in kW					