Midterm Exam

10/22/2019

1. We will solve the initial value problem, $\frac{du}{dx} = x^2 e^{-(u+1)}$, $u(0)=1$ to obtain $u(0.3)$ using $\Delta x = 0.3$ (i.e., we will march forward by just one Δx) (15 pts)
   (1) Use Euler's explicit method.
   (2) Use 3rd order Runge-Kutta method. [Hint: $\phi = \frac{1}{6}(k_1 + 4k_2 + k_3)$ where $k_3 = f(x_i + h, y_i - k_1 h + 2k_2 h)$]
   (3) Compare both with the exact solution.

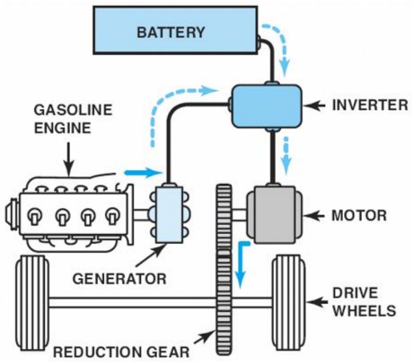
2. Write the matrix equation to obtain a numerical solution of the following boundary value problem, $\frac{d^2u}{dx^2} + (15+8x)u = 0,\ u'(0) = 0.5$ and $u(1) = 0.3$ for $u(x)$ over the interval $0 \le x \le 1$. Use the 3-point central difference scheme to represent in the differential equation and 2-point forward finite difference scheme to represent in the first boundary condition. Choose $h = 0.25$. [Do NOT solve the equation.] (15 pts)

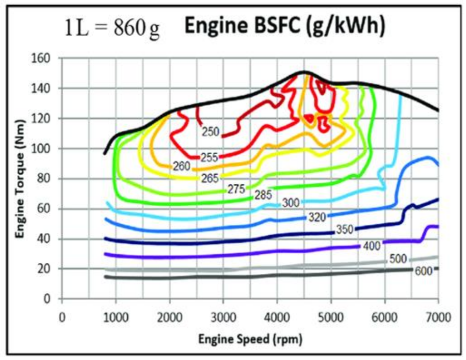
3. Drive the relation forward in t to solve the partial differential equation, $\frac{\partial u}{\partial t} = 0.5\frac{\partial u}{\partial x} - 0.4u$ defined on the semi-infinite domain, $-\infty \le x \le \infty$ and $0 \le t < \infty$, with the boundary condition given at $t = 0$ as $u(x,0) = 1$ if $3.5 \le x \le 4$ and $u(x,0) = 0$ otherwise. Use the 2-point forward difference scheme to discretize both $\partial u/\partial t$ and $\partial u/\partial x$. Expect the solution $u(x,t)$ at $t = 0.5$, 1 and 2 and plot these solutions (as a function of x) along with the "initial" state, $u(x,0)$, over the interval of $0 \le x \le 5$. [Do NOT solve the equation.] (15 pts)

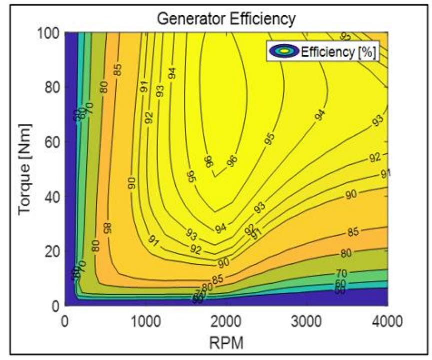
4. Find the general solution of the following PDE by the method of separation of variables: $\frac{\partial^2 u}{\partial x \partial y} - xyu = 0$. (15 pts)

5. Answer the following questions about eco-vehicles.
   (1) What are two representative technologies for eco-vehicles? (2 pts)
   (2) What are the advantage/disadvantage things of fuel cell electric vehicle? (2 pts)
   (3) Why does the Controller Area Network (CAN) apply to the vehicle control system? (2 pts)

6. Consider the following series hybrid electric vehicle system. Be sure to check the units of parameter values.







Inertia/mass : $J_{motor} = 0.05\,\text{kg}\bullet\text{m}^2$, $J_{wheel} = 1\ \text{kg}\bullet\text{m}^2$ (sum of wheels), $m_{body} = 1{,}500\ \text{kg}$

Motor : $T_{\max} = 300\ \text{Nm}$, $P_{\max} = 120\ \text{kW}$, $\omega_{\max} = 8000\ \text{RPM}$

Driveline : $GR_{reduction} = 6$, $R_{tire} = 0.3\ \text{m}$

Resistance: $C_d = 0.3$, $A_{front} = 2\,\text{m}^2$, $\rho_{air} = 1.2\,\text{kg/m}^3$, $\mu_{roll} = 0.01$, $g = 9.8\ \text{m/s}^2$

Battery: $C_{nom} = 50{,}000\ \text{As}$, $V_{OCV} = 300\ \text{V}$, $R_{in} = 0.1\ \Omega$, $\eta_{motor} = 0.9$

(1) Calculate the total equivalent inertia at wheel. (3 pts)

(2) When the vehicle speed is 72 km/h, calculate a motor speed. How much is the maximum motor torque allowed at this speed? At first, check the maximum motor torque curve according to the motor speed. (4 pts)

(3) When the traction motor torque and vehicle speed are 50 Nm and 36 km/h, respectively, calculate a vehicle acceleration speed. (6 pts)

(4) Assume that the vehicle is driving with a constant speed of 36 km/h and that the motor torque is also constant at 50 Nm. After 5 minutes under this condition, calculate the final SOC. (initial SOC is 50%.) (6 pts)

(5) After driving as (4), to evaluate the fuel efficiency, the vehicle stops and the battery is charged up to the initial SOC where the engine torque and RPM are 80 Nm and 2500 RPM, respectively. The engine directly connects to the generator, which supplies the negative (-) current to the battery. Assume the battery voltage is constant at 300 V and calculate the fuel efficiency (km/L). At first, calculate the fuel and SOC consumption per second. (11 pts)

(6) Calculate the maximum vehicle speed (km/h) and the ascendable slope (%). (4 pts)