國立臺北科技大學九十七學年度碩士班招生考試

系所組別：1320 車輛工程系碩士班乙組

第一節 自動控制 試題

填准考證號碼

第一頁 共一頁

注意事項：
1. 本試題共三題，配分共 100 分。
2. 請標明大題、子題編號作答，不必抄題。
3. 全部答案均須在答案卷之答案欄內作答，否則不予計分。

1. A cruise control system is to be designed for an electric vehicle (EV). The nonlinear vehicle longitudinal dynamics can be described by the following equation:

$$m\frac{du}{dt} = F_x - mg\sin\theta - f_r mg\cos\theta - 0.5\rho A C_d u^2$$

where m is the vehicle mass; f_r is the rolling resistance coefficient; g is the acceleration of gravity; ρ is the air density; A is the frontal cross sectional area; C_d is the drag coefficient; u is the longitudinal vehicle speed; F_x is the longitudinal traction force; θ is the inclination angle of the slope. On the right hand side of the equation, the second term denotes the gravity component along the slope; the third term denotes the rolling resistance along the slope; the last term denotes the aerodynamic drag.

(a) If the EV is required to maintain its speed at $u = u_0$ on a slope with $\theta = \theta_0$, what is the required traction force F_{x0} for this equilibrium point? (5%)

(b) Assuming $u = u_0 + u'$, $\theta = \theta_0 + \theta'$, and $F_x = F_{x0} + F_x'$, please show that the linearized dynamics around the equilibrium point can be expressed as $\tau\dot{u}' + u' = K(F_x' + d)$. (15%) You need to show the expressions of τ, K, and d.

(c) Please show how to design a PI controller $C(s) = K_p + K_I/s$ such that the desired characteristic equation is equal to the denominator of a standard second order system as shown below. (10%) u_r' is the reference speed deviation, i.e. $u_r = u_0 + u_r'$, where u_r is the desired vehicle speed.

$$\frac{U'(s)}{U_r'(s)} = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n + \omega_n^2}$$

(d) What is the effect of the extra zero of the closed-loop transfer function in problem 1.(c)? (5%)

(e) How to design a pre-compensator $P(s)$ to remove the effect of the zero such that the overall system behaves like a standard second order system exactly? (5%) You need to draw the block diagram and show the transfer function of the pre-compensator to support your answer.

2. Please describe how to apply the following approaches to analyze the stability of a system.
   (a) Routh stability criterion (5%)
   (b) Root-locus technique (5%)
   (c) Nyquist stability analysis (5%)
   (d) Bode plot (5%)

3. A servomechanism position control has the plant transfer function as follows.

$$G(s) = \frac{10}{s(s+1)(s+10)}$$

A lead compensator in the unity feedback configuration is needed to meet the following closed-loop specifications:

– The response to a reference step input is to have no more than 15% overshoot.
– The response to a reference step input is to have a rise time of no more than 0.9 sec.

(a) Please design a lead compensator to satisfy the above requirement. (30%)

(b) After we obtain the lead compensator, how should you design the lag compensator such that the steady-state error with respect to the ramp input is less than 1%? (10%)

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