Ryerson University

Department of Aerospace Engineering

AER403 Mechanisms and Vibrations

Midterm Test - Winter 2012 Solution

Date: Tuesday, February 28, 2012

Time: 5:00 am - 6:00pm

Place: ENGLG14

Examiner: Professor Jeff Xi

Instruction:

1. Open book and notes.
2. Drawing tools and calculator is needed.
3. Answer all questions in the space provided.
4. Marking scheme indicated.

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Student #: ____________________________

Section #: ____________________________

Total: _______ /30

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Questions (30 points)

Circle an appropriate answer for each problem unless indicated otherwise. The mark for each question is indicated.

1. The linkage in Figure 1 is of
(1) (a) 1 DOF. (Degree-of-freedom)
(b) 2 DOFs.
(c) 3 DOFs.
(d) 4 DOFs.

2. In Figure 1, the force from link 5 (actuator) is transferred to
(1) (a) Link 4.
(b) Link 3.
(c) Link 2. → where the wheels are attached.
(d) Link 1.

3. The linkage in Figure 1 is
(1) (a) a 4 bar linkage with one loop.
(b) a 6 bar linkage with two loops.
(c) a 6 bar linkage with one loop.
(d) a 5 bar linkage with two loops.

4. Link 1 in the linkage shown in Figure 1 is
(1) (a) a binary link.
(b) a ternary link.
(c) a quaternary link.
(d) none of all.

5. For the linkage shown in Figure 1, the DOFs of all the links when free are
(1) (a) 13
(b) 14
(c) 15 $3x(n_L - 1) = 3x5=15$
(d) 16

6. On the same linkage, the constraints provided by all the joints are
(1) (a) 14. 2x7=14
(b) 15.
(c) 16.
(d) 13.

7. In Figure 1, if link 6 is connected to the middle of link 3, then
(1) (a) Watt II is changed to Stephenson II.
(b) Watt I is changed to Stephenson I.
(c) Watt II is changed to Stephenson III. Two side-by-side
(d) Watt I is changed to Stephenson II.

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8. Refer to Figure 1, indicate all the links undergo rotation only.

(1)
(a) link 2, 3, 4
(b) link 2, 3, 5
(c) link 2, 4, 6
(d) link 2, 4, 5

9. Refer to Figure 1, indicate all the links undergo general motion.

(1)
(a) link 3, 4
(b) link 3, 6 non-fixed points
(c) link 5, 6
(d) link 3, 5

10. Refer to Figure 1, if ω_2 of input link 2 is constant, then

(1)
(a) coupler ω_3 is constant in general.
(b) output link ω_4 is constant in general.
(c) coupler ω_3 is not constant in general. $\omega_3 = \omega_2$ r2 sin $(\theta_4\text{-}\theta_2)$ / r3 sin $(\theta_3\text{-}\theta_4)$
(d) output link ω_4 is zero in general.

11. Choose a set of correct absolute joint coordinates for the 4-bar linkage and **draw** these

(2) angles on Figure 1.
(a) $\theta_2=85^o$, $\theta_3=5^o$, $\theta_4=100^o$
(b) $\theta_2=80^o$, $\theta_3=110^o$, $\theta_4=85^o$
(c) $\theta_2=85^o$, $\theta_3=110^o$, $\theta_4=95^o$
(d) $\theta_2=80^o$, $\theta_3=10^o$, $\theta_4=95^o$ → θ_3=80–(180-110)=10, θ_4=180-(360-(80+110+85))=95

12. Choose a set of correct absolute joint coordinates for the slider-crank and **draw** these

(2) angles on Figure 1.
(a) $\theta_2=80^o$, $\theta_5=140^o$
(b) $\theta_4=95^o$, $\theta_5=40^o$
(c) $\theta_2=80^o$, $\theta_5=40^o$
(d) $\theta_4=80^o$, $\theta_5=140^o$

13. Choose a correct position loop equation for the 4 bar linkage and **draw** these vectors on

(2) Figure 1.
(a) $r_1e^{j0} + r_2e^{j85}+r_3e^{j5} +r_4e^{j100}= 0$
(b) $r_1e^{j180} + r_2e^{j80}+r_3e^{j10} +r_4e^{j\text{-}85}= 0$
(c) $r_1e^{j0} + r_2e^{j80}+r_3e^{j5} +r_4e^{\text{-}j80}= 0$
(d) $r_1e^{j180} + r_2e^{j80}+r_3e^{j110} +r_4e^{j85} = 0$

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14. (2) Choose a correct position loop equation for the crank-slider and **draw** these vectors on Figure 1.

(a) $r_1 \cdot e^{j180} + (r_5 + r_6)e^{j40} + r_2 e^{-j100} = 0$

(b) $r_1 \cdot e^{j0} + (r_5 + r_6)e^{j40} + r_2 e^{j80} = 0$

(c) $r_1 \cdot e^{j180} + (r_5 + r_6)e^{-j40} + r_2 e^{j80} = 0$

(d) $r_1 \cdot e^{j0} + (r_5 + r_6)e^{-j40} + r_2 e^{-j100} = 0$

15. (2) Which one of the following is the correct velocity equation for the 4 bar linkage?

(a) $\omega_2 r_2 e^{j(\theta 2+90)} + \omega_3 r_3 e^{j\theta 3} = \omega_4 r_4 e^{j(\theta 4+90)}$

(b) $\omega_2 r_2 e^{j(\theta 2+90)} + \omega_3 r_3 e^{j(\theta 3+90)} = \omega_4 r_4 e^{j(\theta 4+90)}$ tangential velocity ⊥ position vector

(c) $\omega_2 r_2 e^{j\theta 2} + \omega_3 r_3 e^{j(\theta 3+90)} = \omega_4 r_4 e^{j\theta 4}$

(d) $\omega_2 r_2 e^{j\theta 2} + \omega_3 r_3 e^{j\theta 3} = \omega_4 r_4 e^{j(\theta 4+90)}$

16. (2) Which one of the following is the correct velocity equation for the slider-crank?

(a) $\omega_2 r_2 e^{j(\theta 2+90)} = \omega_5 (r_5 + r_6) e^{j(\theta 5+90)} + v_6 e^{j(\theta 5+90)}$

(b) $\omega_2 r_2 e^{j\theta 2} = \omega_5 (r_5 + r_6) e^{j\theta 5} + v_5 e^{j\theta 5}$

(c) $\omega_2 r_2 e^{j\theta 2} = \omega_5 (r_5 + r_6) e^{j\theta 5} + v_5 e^{j(\theta 5+90)}$

(d) $\omega_2 r_2 e^{j(\theta 2+90)} = \omega_5 (r_5 + r_6) e^{j(\theta 5+90)} + v_6 e^{j\theta 5}$ sliding velocity // position vector

17. (2) Which one of the following is the correct acceleration equation for the 4 bar linkage?

(a) $(j\alpha_2 r_2 e^{j\theta 2} - \omega^2_2 r_2 e^{j\theta 2} + j\alpha_3 r_3 e^{j\theta 3} - \omega^2_3 r_3 e^{j\theta 3}) \bullet e^{j\theta 3} = (j\alpha_4 r_4 e^{j\theta 4} - \omega^2_4 r_4 e^{j\theta 4}) \bullet e^{j\theta 4}$

(b) $(j\alpha_2 r_2 e^{j\theta 2} - \omega^2_2 r_2 e^{j\theta 2} - \omega^2_3 r_3 e^{j\theta 3}) \bullet e^{j\theta 3} = (j\alpha_4 r_4 e^{j\theta 4} - \omega^2_4 r_4 e^{j\theta 4}) \bullet e^{j\theta 3}$

(c) $(j\alpha_2 r_2 e^{j\theta 2} - \omega^2_2 r_2 e^{j\theta 2} + j\alpha_3 r_3 e^{j\theta 3} - \omega^2_3 r_3 e^{j\theta 3}) \bullet e^{j\theta 4} = (j\alpha_4 r_4 e^{j\theta 4} - \omega^2_4 r_4 e^{j\theta 4}) \bullet e^{j\theta 3}$

(d) $(j\alpha_2 r_2 e^{j\theta 2} - \omega^2_2 r_2 e^{j\theta 2} - \omega^2_3 r_3 e^{j\theta 3}) \bullet e^{j\theta 4} = (j\alpha_4 r_4 e^{j\theta 4} - \omega^2_4 r_4 e^{j\theta 4}) \bullet e^{j\theta 4}$

18. (2) Which one of the following is the correct acceleration equation for the slider-crank linkage?

(a) $j\alpha_2 r_2 e^{j\theta 2} - j\omega^2_2 r_2 e^{j\theta 2} = j\alpha_5 (r_5 + r_6) e^{j\theta 5} - j\omega^2_5 (r_5 + r_6) e^{j\theta 5} + 2jv_6 \omega_5 e^{j\theta 5} + ja_6 e^{j\theta 5}$

(b) $j\alpha_2 r_2 e^{j\theta 2} + \omega^2_2 r_2 e^{j\theta 2} = j\alpha_5 (r_5 + r_6) e^{j\theta 5} + \omega^2_5 (r_5 + r_6) e^{j\theta 5} + 2jv_6 \omega_5 e^{j\theta 5} + a_6 e^{j\theta 5}$

(c) $j\alpha_2 r_2 e^{j\theta 2} + j\omega^2_2 r_2 e^{j\theta 2} = j\alpha_5 (r_5 + r_6) e^{j\theta 5} + j\omega^2_5 (r_5 + r_6) e^{j\theta 5} + 2jv_6 \omega_5 e^{j\theta 5} + a_6 e^{j\theta 5}$

(d) $j\alpha_2 r_2 e^{j\theta 2} - \omega^2_2 r_2 e^{j\theta 2} = j\alpha_5 (r_5 + r_6) e^{j\theta 5} - \omega^2_5 (r_5 + r_6) e^{j\theta 5} + 2jv_6 \omega_5 e^{j\theta 5} + a_6 e^{j\theta 5}$

19. (2) Refer to Figure 1, for 15 lbf force applied on link 4 at point C, what would be the torque of the motor on joint A if $(\omega_4/\omega_2=1/2)$?

(a) 15 lbf.in

(b) 10 lbf.in

(c) 1.5 lbf.in

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(d) 1 lbf.in

M.A. = (ω_2/ω_4) (r_{in} / r_{out}) = 2/1 x 1.5/2 = 1.5

$F_{in} = F_{out}$/M.A. = 15 / (1.5) = 10 lbf → torque = Fr = 10 x 1.5 = 15 lbf.in

20. Choose a correct transmission angle of the 4 bar linkage and **draw** it on Figure 1.

(2)

(a) 85°

(b) 95°

(c) 100°

(d) 80°

$\theta_4 - \theta_3$ = 95 –10 = 85

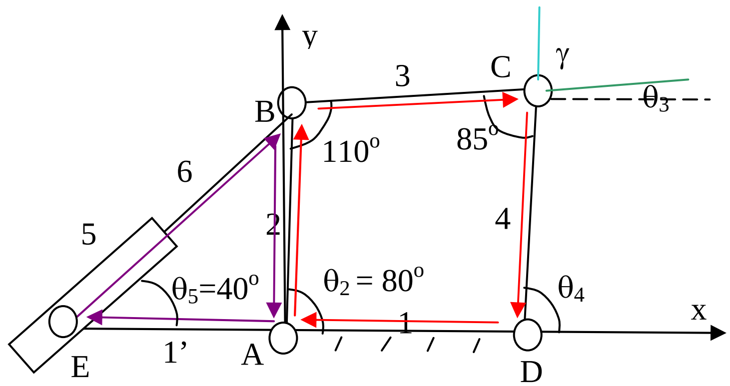

Figure 1: linkage stick diagram (Typical landing gear design)
(link 2 – main strut where the wheels are attached, link 3/4 – drag link, link 5 – actuator)
(link size: r_1 = 1, r_2 = 1.5, r_3 = 2.3, r_4 = 2, all in inch)