MA4825 Robotics

Quiz 1

(Solutions)

QUIZ 1

Student Name:

S/N	Question	Answer
1	A robot arm manipulator repeatedly moves its tool tip from point C(0, 0) (cm) to point D(10, 10) (cm) and then from point D back to point C during a process of manufacturing. Assume that the robot's maximum acceleration is 2.5 cm/s². What is the shortest cycle time?	a) 2.3784 s b) 4.7568 s c) 9.5137 s ✓ d) 19.0273 s e) None of the above Answer: c
2	A robot arm manipulator's tool tip is at rest at point C(-3, -5) (cm). Then, it moves its tool tip to, and stops at, point D(10, -5) (cm) within 5 seconds. Assume that the robot undergoes two motions, that is: speed-up motion followed by slow-down motion. What is the tooltip's linear position when t = 4?	a) (8.86, -5) (cm) b) (8.96, -5) (cm) ✓ c) (9.86, -5) (cm) d) (9.96, -5) (cm) e) None of the above Answer: b
3	A robot manipulator moves its tooltip at rest from A(0.0, 0.0) (cm) to B(20.0, 30.0) (cm) and stops at B on a plane. Assume that the robot undergoes two motions, that is: speed-up motion followed by slow-down motion. If the shortest travelling time is to be 8.0 s, what should be the maximum acceleration/deceleration vector to be delivered by the robot?	a) (1.250, 1.250) cm/s² b) (1.875, 1.875) cm/s² c) (1.875, 1.250) cm/s² d) (1.250, 1.875) cm/s² ✓ e) None of the above Answer: d
4	A robot arm manipulator changes the orientation of its tool from an initial pose (at rest) to a final pose (at rest) within 10 seconds. Assume that the total rotated equivalent angle about the equivalent axis is 30.0 degrees. If the continuous change of orientation is done in two phases: speed-up rotation and slow-down rotation, what is the orientation (i.e. angular position) of the robot's tool when t = 7?	a) 24.6 degrees ✓ b) 12.6 degrees c) 9.6 degrees d) 27.6 degrees e) None of the above Answer: a

(1) distance $= \sqrt{10^2+10^2}$

$= 14.142\text{ cm}$

shortest time: no cruise

$\frac{14.142}{2} = 0 + \frac{1}{2}(a)(t)^2$

$\Rightarrow$ for $a = 2.5$, $t = 2.3784$ ✓

$1 \text{ cycle} = \cancel{2}\,4 \times t = 4.76s$ ✗

9.51

(2) assuming const. acc.,

$S_x = \frac{1}{2}at^2$

$\frac{10-(-3)}{2} = \frac{1}{2}a(2.5)^2 \Rightarrow a = 2.08$

$V_{max} = at = 2.08 \times 2.5$

$S_2 = ut + \frac{1}{2}at^2 = 2.08 \times 2.5 \times 1.5 + \frac{1}{2}(-2.08)(1.5)^2$

$= 5.46$

$x_{final} = -3 + \left(\frac{10+3}{2}\right) + 5.46 = 8.96 \quad \therefore (b)$ ✓

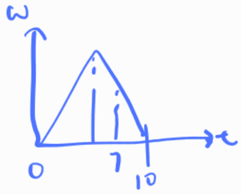
(3) x-direction: $\frac{(20-0)}{2} = \frac{1}{2}(a_x)\left(\frac{8}{2}\right)^2$

$a_x = 1.25$

y-dir: $\frac{(30-0)}{2} = \frac{1}{2}(a_y)\left(\frac{8}{2}\right)^2$

$a_y = 1.875 \quad \therefore (d)$ ✓

(4)

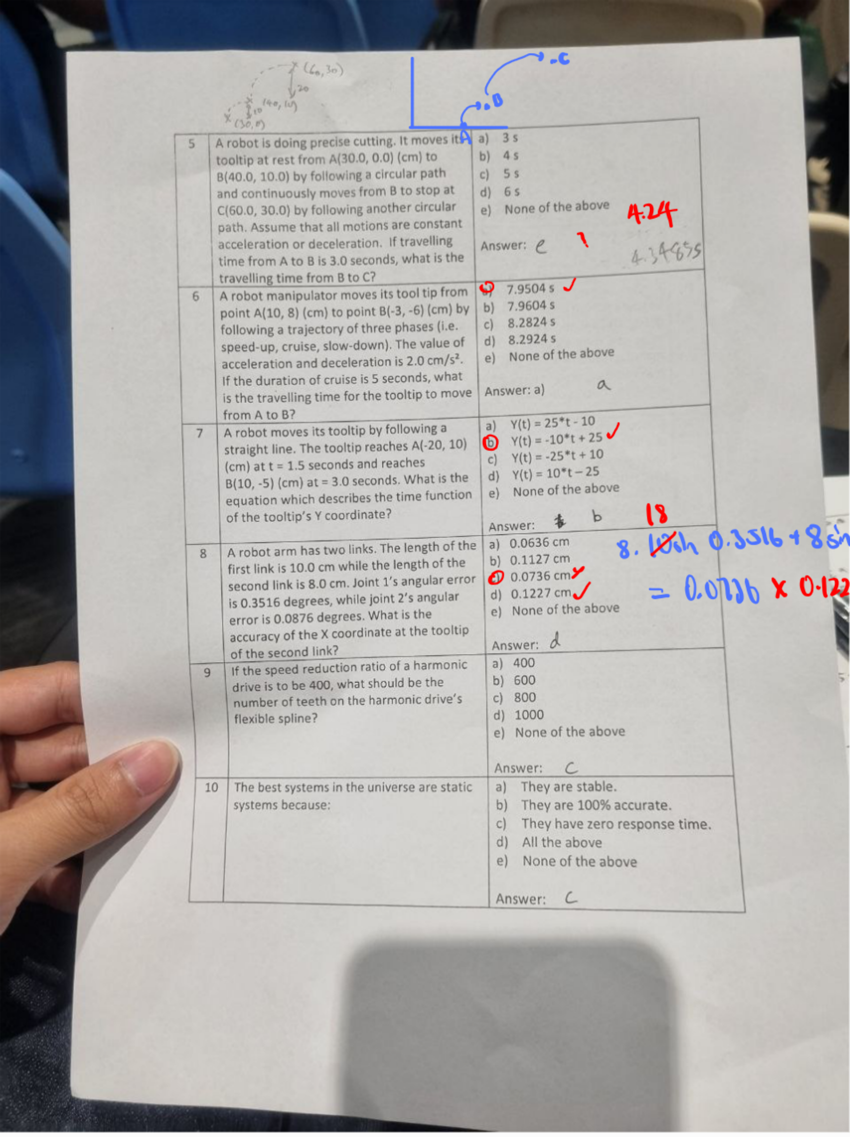


$\theta = \omega t + \frac{1}{2}\alpha t^2$

$15° = \frac{1}{2}(\alpha)(5)^2 \Rightarrow \alpha = 1.2°/s^2$

$\omega_{max} = 1.2 \times 5 = 6°/s$

$15° + 6 \times 2 + \frac{1}{2}(-1.2)(2)^2 = 24.6° \quad \therefore (a)$ ✓



5	A robot is doing precise cutting. It moves its tooltip at rest from A(30.0, 0.0) (cm) to B(40.0, 10.0) by following a circular path and continuously moves from B to stop at C(60.0, 30.0) by following another circular path. Assume that all motions are constant acceleration or deceleration. If travelling time from A to B is 3.0 seconds, what is the travelling time from B to C?	a) 3 s b) 4 s c) 5 s d) 6 s e) None of the above 4.24 Answer: e ? 4.34855
6	A robot manipulator moves its tool tip from point A(10, 8) (cm) to point B(-3, -6) (cm) by following a trajectory of three phases (i.e. speed-up, cruise, slow-down). The value of acceleration and deceleration is 2.0 cm/s². If the duration of cruise is 5 seconds, what is the travelling time for the tooltip to move from A to B?	a) 7.9504 s ✓ b) 7.9604 s c) 8.2824 s d) 8.2924 s e) None of the above Answer: a) a
7	A robot moves its tooltip by following a straight line. The tooltip reaches A(-20, 10) (cm) at t = 1.5 seconds and reaches B(10, -5) (cm) at = 3.0 seconds. What is the equation which describes the time function of the tooltip's Y coordinate?	a) Y(t) = 25*t - 10 b) Y(t) = -10*t + 25 ✓ c) Y(t) = -25*t + 10 d) Y(t) = 10*t – 25 e) None of the above Answer: ~~a~~ b 18
8	A robot arm has two links. The length of the first link is 10.0 cm while the length of the second link is 8.0 cm. Joint 1's angular error is 0.3516 degrees, while joint 2's angular error is 0.0876 degrees. What is the accuracy of the X coordinate at the tooltip of the second link?	a) 0.0636 cm b) 0.1127 cm c) 0.0736 cm ✗ d) 0.1227 cm ✓ e) None of the above Answer: d
9	If the speed reduction ratio of a harmonic drive is to be 400, what should be the number of teeth on the harmonic drive's flexible spline?	a) 400 b) 600 c) 800 d) 1000 e) None of the above Answer: c
10	The best systems in the universe are static systems because:	a) They are stable. b) They are 100% accurate. c) They have zero response time. d) All the above e) None of the above Answer: c

8. $\cancel{10}\sin 0.3516 + 8\sin 0.0876$
$= 0.0736$ ✗ 0.1227

(5) constant $\underline{\text{tangential}}$ acceleration / deceleration

$a \to b$: assume $r = 10$,

$$\phi_1 = \frac{1}{4}\pi(2\times10) = 5\pi \text{ cm}$$

$$= \frac{1}{2}(a_t)(3)^2$$

$$\Rightarrow a_t = 3.49 \text{ cm s}^{-2}$$

$b \to c$: assume $r = 20$,

$$\phi_2 = \frac{1}{4}\pi(2\times20) = 10\pi \text{ cm}$$

$$= \frac{1}{2}(3.49)(t)^2$$

$$t = 4.24 \text{ s} \;\#$$

6. total distance $= \sqrt{13^2 + 14^2} = 19.105 \text{ cm}$

$$\frac{1}{2}(2)(t)^2 + (2t)\times5 + \frac{1}{2}(2)(t)^2 = 19.105$$

$$2t^2 + 10t = 19.105$$

$$t = 1.475$$

total $t = 1.475\times2 + 5 = 7.95 \;\#$ $\therefore$ (a)

7. $y(t) = mt + c$: $10 = m(1.5) + c$

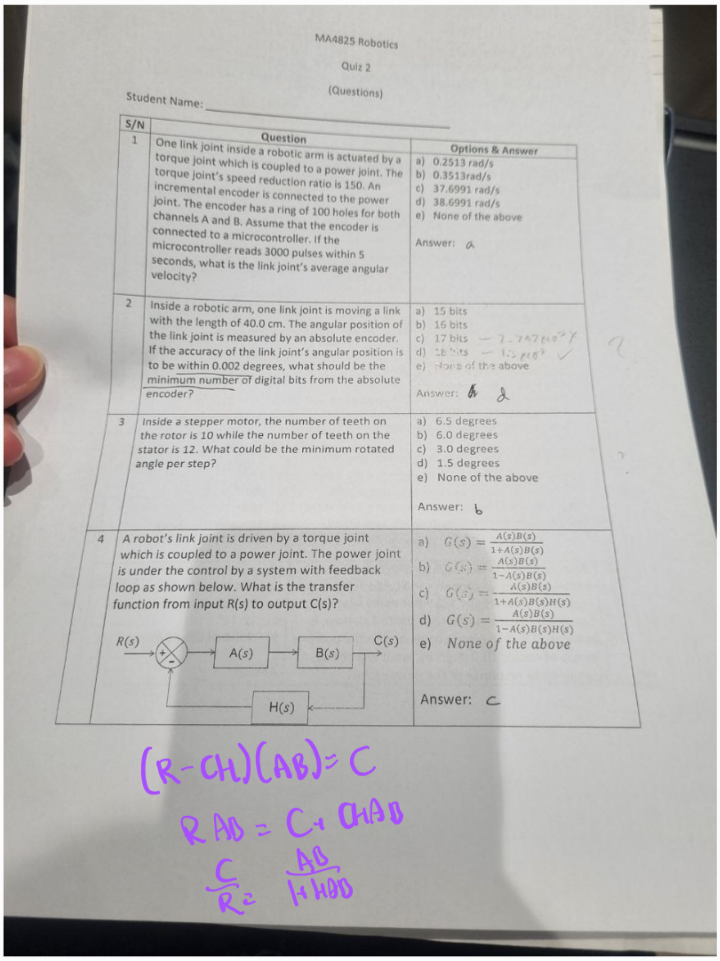
$-5 = m(3) + c$

$$\Rightarrow 1.5m = -15$$

$$m = -10$$

$$c = -5 + 30 = 25$$

i.e. $y(t) = -10t + 25 \;\#$ (b)



MA4825 Robotics

Quiz 2

(Questions)

Student Name: ____________________

S/N	Question	Options & Answer
1	One link joint inside a robotic arm is actuated by a torque joint which is coupled to a power joint. The torque joint's speed reduction ratio is 150. An incremental encoder is connected to the power joint. The encoder has a ring of 100 holes for both channels A and B. Assume that the encoder is connected to a microcontroller. If the microcontroller reads 3000 pulses within 5 seconds, what is the link joint's average angular velocity?	a) 0.2513 rad/s b) 0.3513rad/s c) 37.6991 rad/s d) 38.6991 rad/s e) None of the above Answer: a
2	Inside a robotic arm, one link joint is moving a link with the length of 40.0 cm. The angular position of the link joint is measured by an absolute encoder. If the accuracy of the link joint's angular position is to be within 0.002 degrees, what should be the minimum number of digital bits from the absolute encoder?	a) 15 bits b) 16 bits c) 17 bits — 2.747×10^{-3} ✗ d) 18 bits — 1.3×10^{-3} ✓ e) None of the above Answer: ~~b~~ d
3	Inside a stepper motor, the number of teeth on the rotor is 10 while the number of teeth on the stator is 12. What could be the minimum rotated angle per step?	a) 6.5 degrees b) 6.0 degrees c) 3.0 degrees d) 1.5 degrees e) None of the above Answer: b
4	A robot's link joint is driven by a torque joint which is coupled to a power joint. The power joint is under the control by a system with feedback loop as shown below. What is the transfer function from input R(s) to output C(s)? R(s) → (+/−) → A(s) → B(s) → C(s); feedback H(s)	a) $G(s)=\frac{A(s)B(s)}{1+A(s)B(s)}$ b) $G(s)=\frac{A(s)B(s)}{1-A(s)B(s)}$ c) $G(s)=\frac{A(s)B(s)}{1+A(s)B(s)H(s)}$ d) $G(s)=\frac{A(s)B(s)}{1-A(s)B(s)H(s)}$ e) None of the above Answer: c

$(R-CH)(AB)=C$

$RAB = C + CHAB$

$\frac{C}{R} = \frac{AB}{1+HAB}$

① power → torque

$$\frac{2\pi \text{ rad}}{100 \text{ holes}} = 0.0628 \text{ rad/hole}$$

$3000 \times 0.0628 / 5 = 37.699$ rad/s

$37.699 / 150 = 0.25$ ∴ (A)

② 0.002°

$$\frac{360^\circ}{N_p} \le 0.002^\circ$$

$$N_p \ge \frac{360}{0.002} = 180000$$

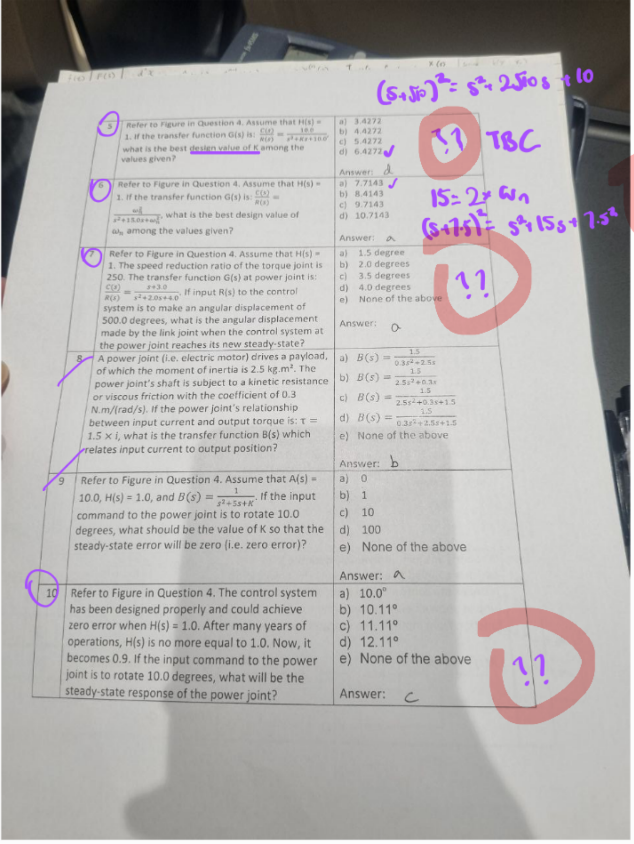
$2^{18} = 262144$ ∴ (D)

$2^{17} = 131072$

③ $\frac{360}{10} - \frac{360}{12} = 6$

(B) TBC half-step?

④ $\frac{G}{1 \mp GH}$ (C)



$(s+\sqrt{10})^2 = s^2 + 2\sqrt{10}s + 10$

5	Refer to Figure in Question 4. Assume that H(s) = 1. If the transfer function G(s) is: $\frac{C(s)}{R(s)} = \frac{10.0}{s^2+Ks+10.0}$, what is the best design value of K among the values given?	a) 3.4272 b) 4.4272 c) 5.4272 d) 6.4272 ✓ Answer: d
6	Refer to Figure in Question 4. Assume that H(s) = 1. If the transfer function G(s) is: $\frac{C(s)}{R(s)} = \frac{\omega_n^2}{s^2+15.0s+\omega_n^2}$, what is the best design value of ω_n among the values given?	a) 7.7143 ✓ b) 8.4143 c) 9.7143 d) 10.7143 Answer: a
7	Refer to Figure in Question 4. Assume that H(s) = 1. The speed reduction ratio of the torque joint is 250. The transfer function G(s) at power joint is: $\frac{C(s)}{R(s)} = \frac{s+3.0}{s^2+2.0s+4.0}$. If input R(s) to the control system is to make an angular displacement of 500.0 degrees, what is the angular displacement made by the link joint when the control system at the power joint reaches its new steady-state?	a) 1.5 degree b) 2.0 degrees c) 3.5 degrees d) 4.0 degrees e) None of the above Answer: a
8	A power joint (i.e. electric motor) drives a payload, of which the moment of inertia is 2.5 kg.m². The power joint's shaft is subject to a kinetic resistance or viscous friction with the coefficient of 0.3 N.m/(rad/s). If the power joint's relationship between input current and output torque is: $\tau = 1.5 \times i$, what is the transfer function B(s) which relates input current to output position?	a) $B(s) = \frac{1.5}{0.3s^2+2.5s}$ b) $B(s) = \frac{1.5}{2.5s^2+0.3s}$ c) $B(s) = \frac{1.5}{2.5s^2+0.3s+1.5}$ d) $B(s) = \frac{1.5}{0.3s^2+2.5s+1.5}$ e) None of the above Answer: b
9	Refer to Figure in Question 4. Assume that A(s) = 10.0, H(s) = 1.0, and $B(s) = \frac{1}{s^2+5s+K}$. If the input command to the power joint is to rotate 10.0 degrees, what should be the value of K so that the steady-state error will be zero (i.e. zero error)?	a) 0 b) 1 c) 10 d) 100 e) None of the above Answer: a
10	Refer to Figure in Question 4. The control system has been designed properly and could achieve zero error when H(s) = 1.0. After many years of operations, H(s) is no more equal to 1.0. Now, it becomes 0.9. If the input command to the power joint is to rotate 10.0 degrees, what will be the steady-state response of the power joint?	a) 10.0° b) 10.11° c) 11.11° d) 12.11° e) None of the above Answer: c

?? TBC

?? TBC

$15 = 2 \times \omega_n$

$(s+7.5)^2 = s^2 + 15s + 7.5^2$

??

??

8

$F = ma$

$M = I\alpha$

$R = 0.3\omega$

$I\alpha = \tau - R$

$= \tau - 0.3\omega$

$2.5s^2\theta(s) = 1.5I(s) - 0.3s\,\theta(s)$

$\frac{\theta(s)}{I(s)} = \frac{1.5}{2.5s^2 - 0.3s}$ (B) #

9

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

$= \frac{\frac{10}{s^2+5s+K}}{1+\frac{10}{s^2+5s+K}}$

$= \frac{10}{s^2+5s+K+10}$

$E(s) = R(s) - C(s)$

$= R(s) - G(s)R(s)$

$= R(s)[1 - G(s)]$

$E_{ss} = \lim_{s \to 0} E(s)$

$= \lim_{s \to 0} [1 - G(s)]$

$= 1 - \frac{10}{K+10} = 0$

$\therefore K = 0$ # (A)