Q1.

Robot arm moves repeatedly from A (0,0) cm to B (10,10) cm and back to A (0,0) cm

Robot has a max acceleration of 2.5 cm/s²

What is the shortest cycle time

correction

A to B : $\sqrt{10^2 + 10^2} = 14.14$

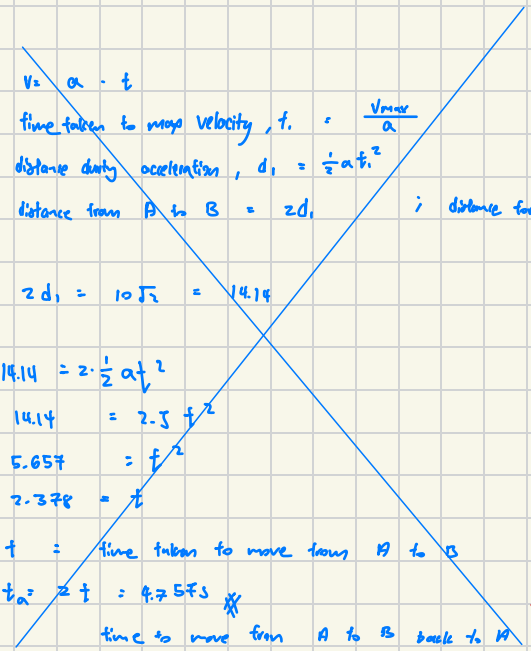
$\frac{d^2x}{dt^2} = 2.5$

$\frac{dx}{dt} = 2.5t + C_1$

$x(t) = 1.25t^2 + C_1 t + C$

$x(0) = 0$; $C_1 = 0$, $C = 0$

$x(t) = 1.25t^2$



$V = a \cdot t$

time taken to max velocity, $t_1 = \frac{V_{max}}{a}$

distance during acceleration, $d_1 = \frac{1}{2} a t_1^2$

distance from A to B = $2d_1$; distance for acceleration and deceleration

$2d_1 = 10\sqrt{2} = 14.14$

$5\sqrt{2} = 1.25t^2$

$4\sqrt{2} = t^2$

$2.38 = t$

acceleration part only

$14.14 = 2 \cdot \frac{1}{2} a t_1^2$

A to B : $2t = 4.76$

A to B to A : $4t = 9.51$ s

$14.14 = 2.5\, t^2$

$5.657 = t^2$

$2.378 = t$

t : time taken to move from A to B

$t_a = 2t = 4.757$ s

time to move from A to B back to A

Q2. from position A (-3,-5) cm to B (10,-5) within 5s

undergo acceleration and deceleration

find position when t of 4s

2.5s for acceleration and deceleration each.

$d = \sqrt{13^2 + 0^2} = 13$ cm

$d_a = 6.5$ cm

time during acceleration, $t_a = \frac{V}{a}$

$d_a = \frac{1}{2} a t_a^2$

$6.5 = \frac{1}{2} a (2.5)^2$ ∴ $a = 2.08$

deceleration = $-a$

$6s - 2.5s = 1.5s$

$t_d = 1.5s$

$d_d = V_{max} \times t - \frac{1}{2} a t_d^2$; $V_{max} = 5.2$

$= 5.2 \times 1.5 - \frac{1}{2}(2.08)(1.5)^2$

$= 5.46$

$d = d_a + d_d = 6.5 + 5.46 = 11.96$

$-3 + 11.96 = 8.96$

Ans : (8.96, -5)

Q3. Robotic Arm move from B(0.0, 0.0)cm to B(20.0, 30.0)cm

uniformed acceleration and deceleration

$t = 8s$

$t_a = t_d = 4s$

$d_a = \frac{V_{max}}{2} = d_d$

$d_a = \frac{1}{2} a t_a^2$

x axis :	y axis :
$d_x = \frac{20}{2} = 10$	$d_y = \frac{30}{2} = 15$
$10 = \frac{1}{2} a_x t_a^2$	$15 = \frac{1}{2} a_y t_a^2$
$\therefore \frac{1}{2} a_x (4)^2$	$= \frac{1}{2} a_y (4)^2$
$\frac{10}{8} = a_x$	$\frac{15}{8} = a_y$
$1.25 = a_x$	$1.875 = a_y$
$a = (1.25, 1.875)$ ✱	

Q4. rotated 30° in 10s

underwent acceleration and deceleration

$t_a = \frac{\omega_{max}}{2}$; $t = 10$; $t_a = 5$; $\theta = 30°$; $\theta_a = 15°$

$\theta_a = \frac{1}{2} \alpha t_a^2$

$15 = \frac{1}{2} \alpha (5)^2$

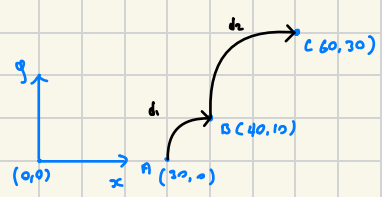
$\alpha = 1.2 \text{ deg/s}$; $5 \times 1.2 = \omega_{max} = 6$

$\theta(7) = \theta_a + \theta_d(2)$; $\theta_d = \omega_{max} \times t_d - \frac{1}{2} \alpha (t_d)^2$

$= 15 \text{ deg} + 9.6$ $= 6 \times 2 - \frac{1}{2}(1.2)(4)$

$= 24.6 \text{ deg}$. ✱ $= 9.6$

Q5. At rest from A(30,0) to B(40,10) then to C(60,30) in circular path



$d_1 = \frac{1}{4} \pi \cdot 2 \cdot r$

$= \frac{1}{4} \pi \cdot 2 \cdot 10$

$= 5\pi$

$d_2 = \frac{1}{4} \pi \cdot 2 \cdot r$

$= \frac{1}{4} \pi \cdot 2 \cdot 20$

$= 10\pi$

$5\pi = \frac{1}{2} a t^2$

$\frac{5\pi}{2} = \frac{1}{2} a (1.35)^2$

$a = 6.98$

$\frac{10\pi}{2} = \frac{1}{2} a t_1^2$

$10\pi = a t_1^2$

$\sqrt{\frac{10\pi}{6.98}} = t_1 = 2.12$

$t = 2t_1 = 4.24s$ ✱

Q6. move from A(10,8) to B(-3,-6)

accelerate, const. velocity, deceleration

↓ 2cm/s² (da) | ↓ 5sec | ↓ -2cm/s² (dd)

$t = \frac{V_{max}}{a}$ ↗

$t + 5 + t$ = total time

$d_a = \frac{1}{2} a t^2 = d_d$

$\frac{1}{2} a t^2 + 5 V_{max} = d_t$

$2 \cdot \frac{1}{2} a t^2 + 5 a t = d_t$

$a t^2 + 5 a t = \sqrt{13^2 + 14^2}$

$2t^2 + 10t - \sqrt{365} = 0$

$t = 1.475$ or -6.975 (rej)

$2t + 5 = 7.95$ s

$t = 1.5$ s, $t = 3$

Q.7 origin to A(-20,10) to B(10,-5)

$y(t) = mt + c$

$y(1.5) = m(1.5) + c = 10$ — ①

$y(3) = m(3) + c = 5$ — ②

① − 2② = 0

$1.5m + c + [6m + 2c] = 0$

$7.5m + 3c = 0$

$3c = -7.5m$

$-\frac{3}{7.5} c = m$

$\left[-\frac{4.5}{7.5}\right] c + c = 10$

$\frac{3}{5} c = 10$

$c = 25$

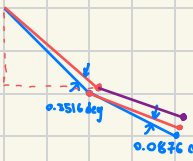
$m = -10$

$y(t) = -10t + 25$

Q8. Two links.

Link₁ = 10 cm

Link₂ = 8 cm



$x_{coord} = L_1 \sin(\theta_1) + L_2 \sin(\theta_1 + \theta_2)$

$= 10 \sin(0.2516) + 8 \sin(0.2516 + 0.0876)$

$= 0.123$

$y_{coord} = L_1 \cos(\theta_1) + L_2 \cos(\theta_1 + \theta_2)$

$= 18$

Q9. speed reduction ratio of harmonic drive = 400 (Flexspline)

N of harmonic drive's flexible spine?

Ans: teeth of outer circular spline + teeth of inner flexible spline is 2. Circular spline = 2 Flexspline = 800

Q10. Real systems are static system, 100% stable, 100% accurate, 0 response time

most systems in universe are dynamic, can be stable & accurate, will have response time.

make dynamic closer to static. using error control