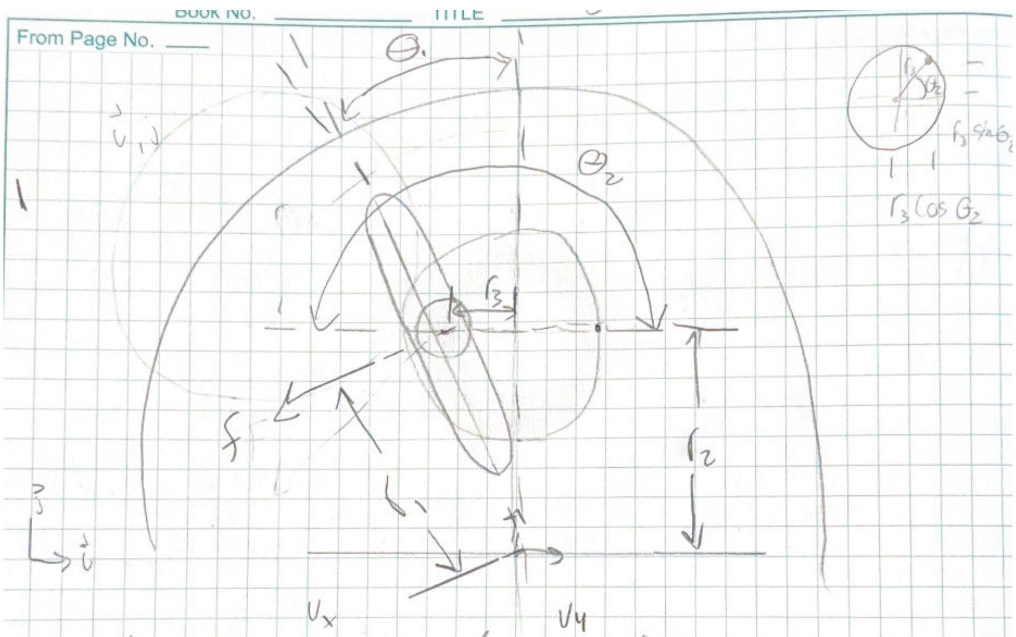


$$\vec{r}_1 = r_3 \cos\theta_2 \vec{i} + (r_2 + r_3 \sin\theta) \vec{j}$$

$$\theta_1 = \arctan\left(\frac{r_3 \cos\theta_2}{r_2 + r_3 \sin\theta_2}\right)$$

```
clc;
clear;
% note: theta 1 in drawing should stretch from r1 line to positive x axis
% motor speed, .5 Hz - full cycle is 25 degrees in 2 seconds
w = pi; %rad/s

% diameter, given
d = .718; %mm

% time vector, 0 to 10 seconds,1000 points
%t = linspace(0, 10, 1000); %s
t = linspace(0, 4, 1000); %s

%distance from central axes to center of motor plate
r2 = d/4; %mm

%required distance in 1 second
dis_deg = 12.5; %deg
dis_rad = 12.5*(2*pi)/360; %rad
dis_rad
```

```
dis_rad = 0.2182
```

```
%determine r3 with numerical analysis that yields +/- .2182 rads (12.5 deg)
for n=0:.0001:1
```

```
    [maxxy]=max(atan( (n * cos(w*t)) ./ (n * sin(w*t) + r2) ));
    if maxxy >= dis_rad/2
        disp(n)
        break

    end
end
```

```
0.0196
```

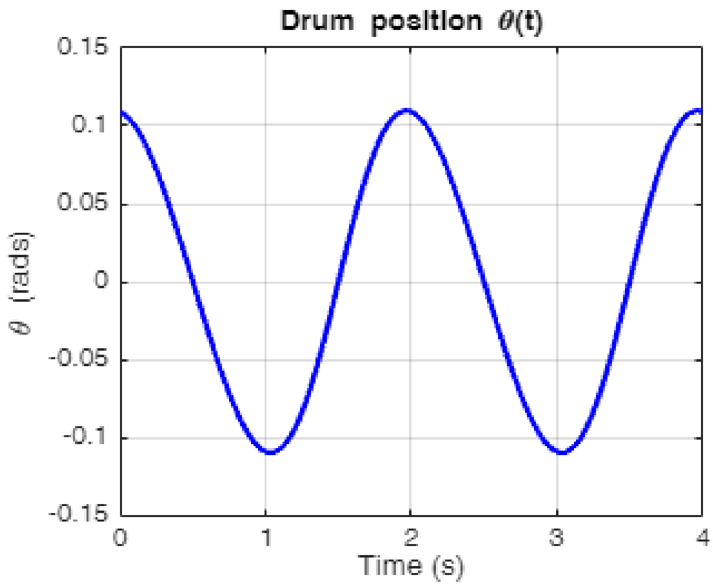
```


r3 = n;
[maxxy2] = max(atan( (r3 * cos(w*t)) ./ (r3 * sin(w*t) + r2) ))
```

```
maxxy2 = 0.1094
```

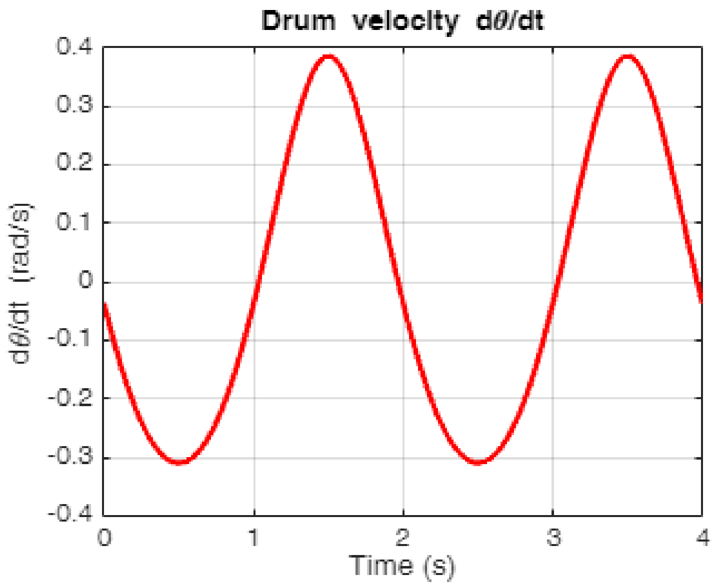
```
maxxy_deg = maxxy2*360/(2*pi) %slightly over 12 degrees but close enough
```

```
maxxy_deg = 6.2687
```

```
%could probably up the precision of the numerical analysis

%%% Angular position as a function of time


theta_t = atan( (r3 * cos(w*t)) ./ (r3 * sin(w*t) + r2) ); %angular position of
drum, rads
%theta_t = atan( (r3 * cos(w*t)) ./ (r3 * sin(w*t) + r2) )*(360/(2*pi)); %angular
position of drum, degrees

% Plot angular position of drum vs time
figure('WindowState', 'maximized');
plot(t, theta_t, 'b', 'LineWidth', 2);
xlabel('Time (s)');
ylabel('\theta (rads)');
title('Drum position \theta(t)');
grid on;
```

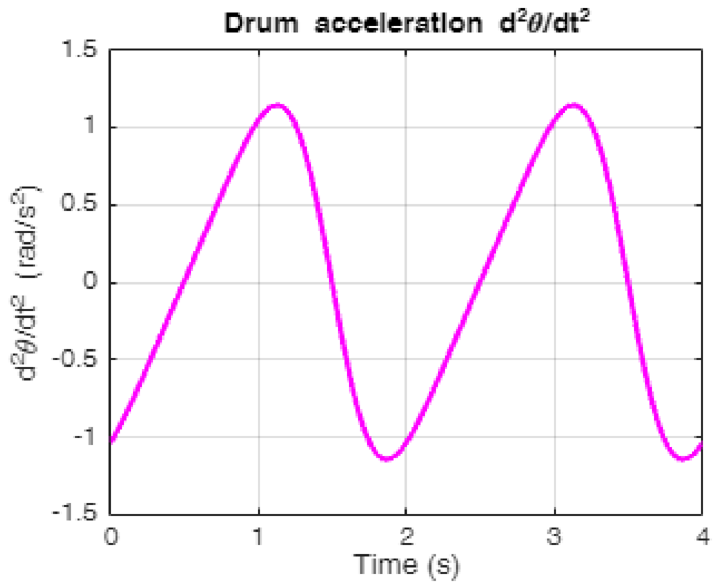



```
%%% Angular velocity as a function of time
%% Find derivative of angular position

% Compute f(t)
f_t = (r3 * cos(w*t)) ./ (r3 * sin(w*t) + r2);

% Compute f'(t) using the quotient rule
numerator = (-r3 * w .* sin(w*t)) .* (r3 * sin(w*t) + r2) - (r3 * w .* cos(w*t)) .*
(r3 * cos(w*t));
denominator = (r3 * sin(w*t) + r2).^2;
f_derivative = numerator ./ denominator;

% Compute (1 + f^2(t))
one_plus_f2 = 1 + f_t.^2;

% Compute d(theta)/dt
dtheta_dt = f_derivative ./ one_plus_f2;

% Plot angular velocity of the drum vs time
figure('WindowState', 'maximized');
plot(t, dtheta_dt, 'r', 'LineWidth', 2);
xlabel('Time (s)');
ylabel('d\theta/dt (rad/s)');
title('Drum velocity d\theta/dt');
grid on;
```

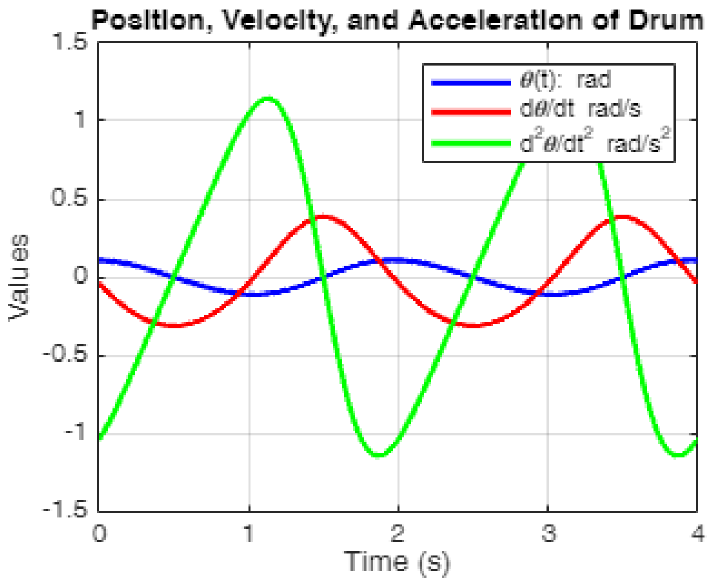



```
%%% Angular acceleration as a function of time
%% Find derivative of angular velocity
% % Compute f(t)
f_t = (r3 * cos(w*t)) ./ (r3 * sin(w*t) + r2);

% Compute f'(t) using the quotient rule
numerator_f1 = (-r3 * w .* sin(w*t)) .* (r3 * sin(w*t) + r2) - (r3 * w .*
cos(w*t)) .* (r3 * cos(w*t));
denominator_f1 = (r3 * sin(w*t) + r2).^2;
f_derivative = numerator_f1 ./ denominator_f1;

% Compute (1 + f^2(t))
one_plus_f2 = 1 + f_t.^2;

% Compute d(theta)/dt
dtheta_dt = f_derivative ./ one_plus_f2;

% Compute f''(t) using numerical differentiation
dt = t(2) - t(1); % Time step
f_second_derivative = diff(f_derivative) / dt;
f_second_derivative = [f_second_derivative, f_second_derivative(end)]; % Maintain
array size

% Compute d^2(theta)/dt^2
d2theta_dt2 = (f_second_derivative .* one_plus_f2 - 2 * f_t .*
(f_derivative.^2)) ./ (one_plus_f2.^2);

% Plot acceleration as a function of time
figure('WindowState', 'maximized');
plot(t, d2theta_dt2, 'm', 'LineWidth', 2);
xlabel('Time (s)');
ylabel('d^2\theta/dt^2 (rad/s^2)');
```

```
title('Drum acceleration d^2\theta/dt^2');
grid on;
```



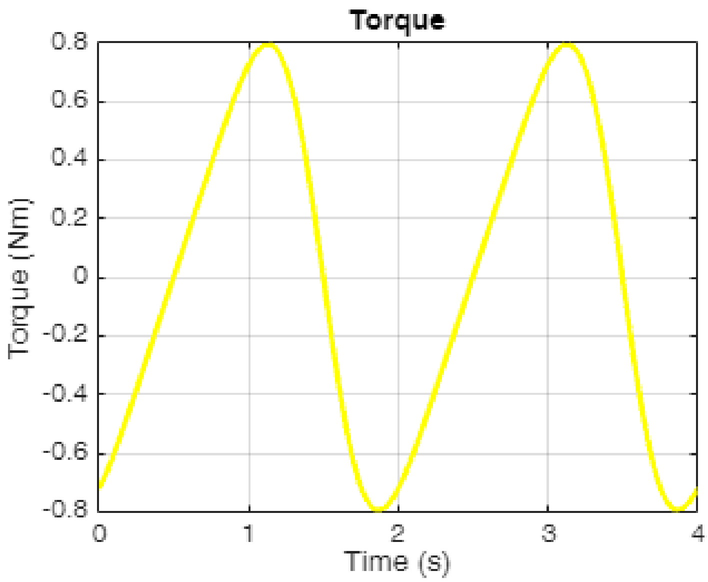

```
%%% Plot all results on top of each other
figure('WindowState', 'maximized');

% Plot theta(t)
plot(t, theta_t, 'b', 'LineWidth', 2);
hold on;  % Keep the plot active for the next plot

% Plot theta_dot(t) (first derivative)
plot(t, dtheta_dt, 'r', 'LineWidth', 2);

% Plot theta_double_dot(t) (second derivative)
plot(t, d2theta_dt2, 'g', 'LineWidth', 2);

% Add labels and grid
grid on;
xlabel('Time (s)');
ylabel('Values');
title('Position, Velocity, and Acceleration of Drum');
legend({'\theta(t): rad', 'd\theta/dt rad/s', 'd^2\theta/dt^2 rad/s^2'});
hold off;  % Release the plot hold
```




```
%%% Calculate Drum Torque
% Moment of Inertia about output coordinate system (true center, not center
% of mass % must this be reviewed? no, it is secured to rotate where the
% coordinate system is
I_z = 6949694.87; %g*cm^2
I_z = I_z*(10^-7); %kg*m^2
T = I_z*d2theta_dt2;
[T_max, t_max] = max(T) %max torque, time of max torque
```

```
T_max = 0.7933
t_max = 782
```

```
figure('WindowState', 'maximized');
plot(t, T, 'y', 'LineWidth', 2);
xlabel('Time (s)');
ylabel('Torque (Nm)');
title('Torque');
grid on;
```




```
% Calculate magnitude of moment arm that stretches from center of disk to
% force, perpindicular to force
rx = r3*cos(w*t_max) %m
```

```
rx = 0.0196
```

```
ry = r2 + r3*sin(w*t_max) %m
```

```
ry = 0.1795
```

```
r1 = sqrt((rx^2) + (ry^2)) %m
```

```
r1 = 0.1806
```

```
r2
```

```
r2 = 0.1795
```

```
r3
```

```
r3 = 0.0196
```

```
% max force exerted on to the drum
F_max = T_max/r1 %N
```

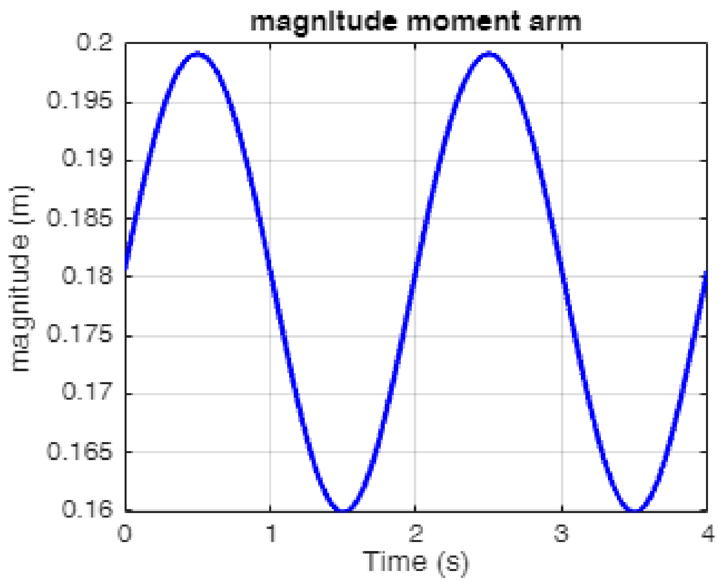
```
F_max = 4.3935
```

```
% max torque felt by the motor
T_mot_max = F_max*r3 %Nm
```

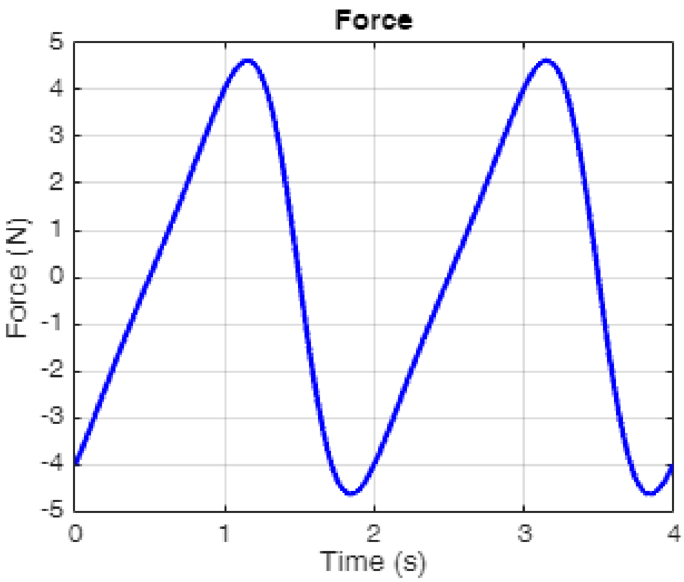
```
T_mot_max = 0.0861
```

```
% can we turn this into a function?
rx = r3*cos(w*t); %m
```

```
ry = r2 + r3*sin(w*t); %m
r1 = sqrt((rx.^2) + (ry.^2)); %m

figure('WindowState', 'maximized');
plot(t, r1, 'b', 'LineWidth', 2);
xlabel('Time (s)');
ylabel('magnitude (m)');
title('magnitude moment arm');
grid on;
```




```
F = T./r1;

figure('WindowState', 'maximized');
plot(t, F, 'b', 'LineWidth', 2);
xlabel('Time (s)');
ylabel('Force (N)');
title('Force');
grid on;
```




```
%%% ANSWER
[Fmax,tmax] = max(F)
```

```
Fmax = 4.6118
tmax = 289
```

```
T_mot_max = Fmax*r3 %Nm
```

```
T_mot_max = 0.0904
```

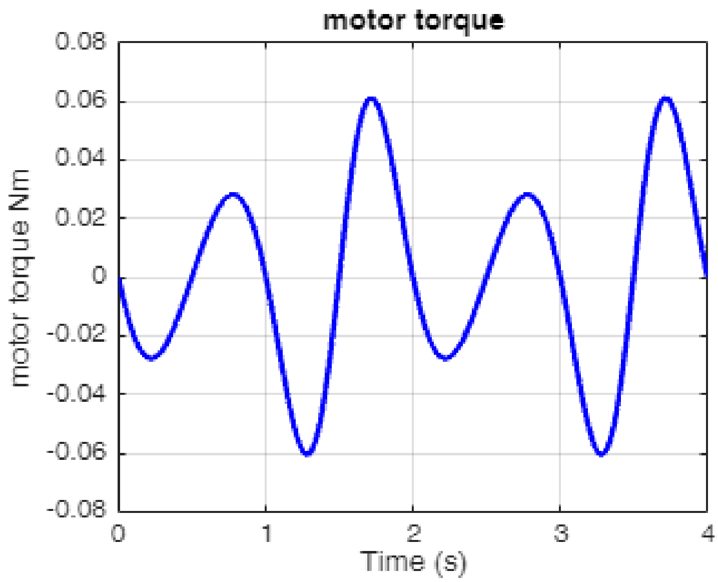
```
F(t_max)*r1(tmax)
```

```
ans = 0.7864
```

```
%T_motor = F*r3
T_motor = F.*r3.*sin(w*t)
```

```
T_motor = 1×1000
         0   -0.0010   -0.0019   -0.0029   -0.0038   -0.0047   -0.0056   -0.0065 ⋯
```

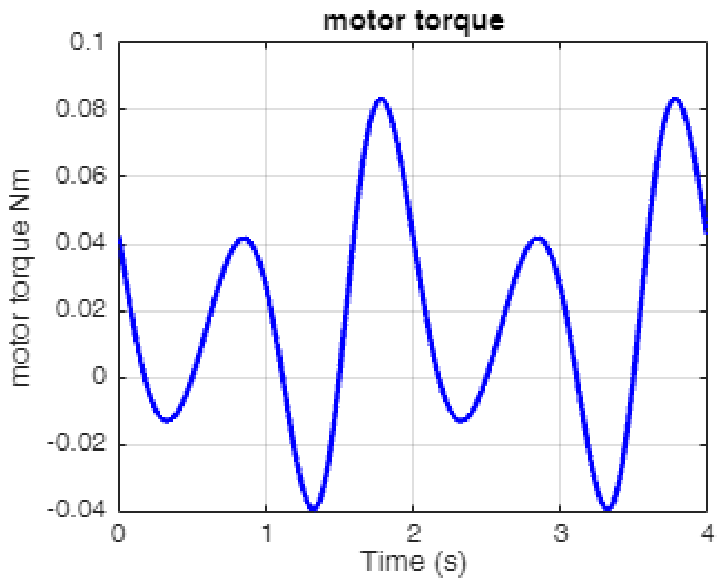
```
figure('WindowState', 'maximized');
plot(t, T_motor, 'b', 'LineWidth', 2);
xlabel('Time (s)');
ylabel('motor torque Nm');
title('motor torque');
grid on;
```




```
%try 2
%motor_moment_arm
theta3 = 360-90-theta_t;
theta4 = 270-theta3;
theta5 = 90-theta4-(180-(w*t));
z = r3*cos(theta5);

Mot_torque = F.*z
```

```
Mot_torque = 1×1000
    0.0424    0.0413    0.0402    0.0391    0.0379    0.0368    0.0357    0.0346 ···
```

```
figure('WindowState', 'maximized');
plot(t, Mot_torque, 'b', 'LineWidth', 2);
xlabel('Time (s)');
ylabel('motor torque Nm');
title('motor torque');
grid on;
```




```
[max_motor_torque,raddy] = max(Mot_torque)
```

```
max_motor_torque = 0.0832
raddy = 446
```