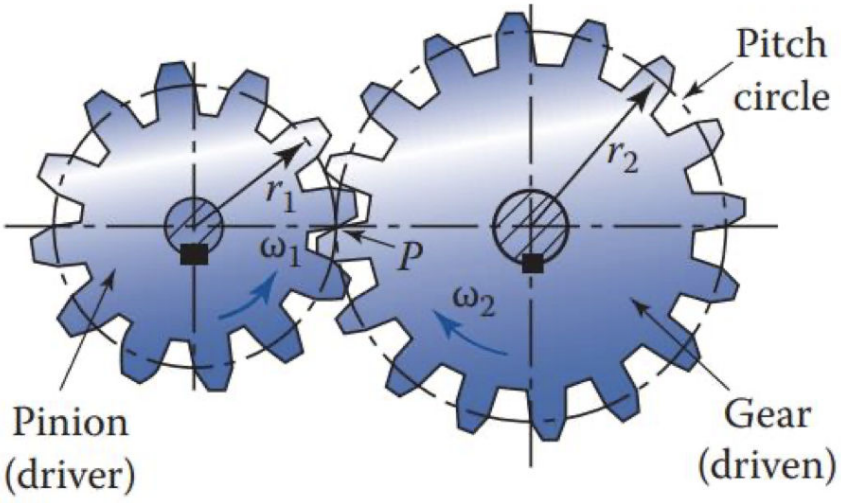
Question 1

Find the module of a pair of gears having 32 and 84 teeth, respectively, whose center distance is 87 mm



Solution

We don't know the diameter of either of the gears and therefore we can calculate the module for the pair. The module of each gear in the pair must be the same.

Centre distance

$$c_d = \frac{d_p + d_g}{2}$$

Module

$$m = \frac{d_g}{N_g} = \frac{d_p}{N_p}$$

So that

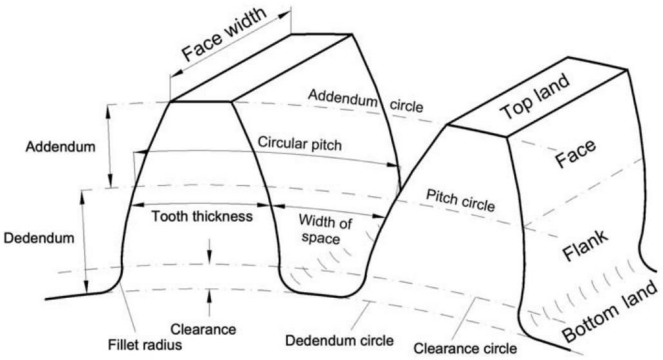
$$m = \frac{2c_d}{N_g + N_p}$$

```
% Write out what is known

c_d = 87;   %[m]
N_g = 32;   %[]
N_p = 84;   %[]

% Calculate the module
m = (2 * c_d) / (N_p + N_g)
```

```
m = 1.5000
```

Question 2

Find the number of teeth and the circular pitch of a 150 mm pitch diameter gear whose module is 2.5mm



Solution

$$m = \frac{d_g}{N_g}$$

```
m = 2.5;    %[m]
d_g = 150;  %[m]

N_g =  d_g / m
```

```
N_g = 60
```

$$p_c = \frac{\pi d}{N} = \frac{\pi d_p}{N_p} = \frac{\pi d_g}{N_g}$$

```
p_c = pi * d_g / N_g  %[mm]
```

```
p_c = 7.8540
```

Question 3

Find the module and the pitch diameter of a 40 tooth gear whose circular pitch is 37.7 mm/tooth.

Solution

$$p_c = \frac{\pi d}{N} = \frac{\pi d_p}{N_p} = \frac{\pi d_g}{N_g}$$

$$d_g = \frac{p_c N_g}{\pi}$$

```
d_g = (40 * 37.7)/pi  % [mm]
```

```
d_g = 480.0113
```

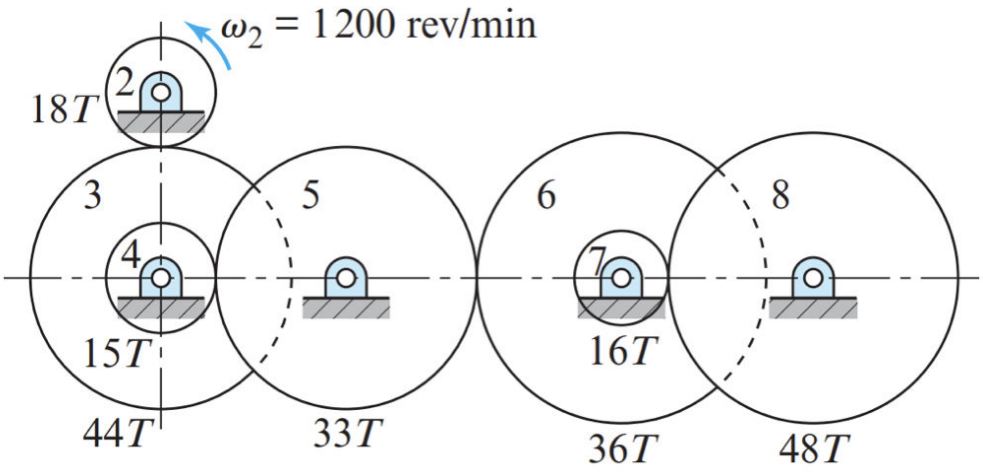
$$m = \frac{d_g}{N_g}$$

```
m = d_g / 40  % [mm] per tooth
```

```
m = 12.0003
```

Question 4

Find the speed and direction of gear 8



Solution

$$G = \frac{\omega_{\text{in}}}{\omega_{\text{out}}} = \frac{\omega_2}{\omega_8} = \frac{N_3}{N_2}\frac{N_5}{N_4}\frac{N_6}{N_5}\frac{N_8}{N_7}$$

```
G = 44/18 * 33/15 * 36/33 * 48/16 %[]
```

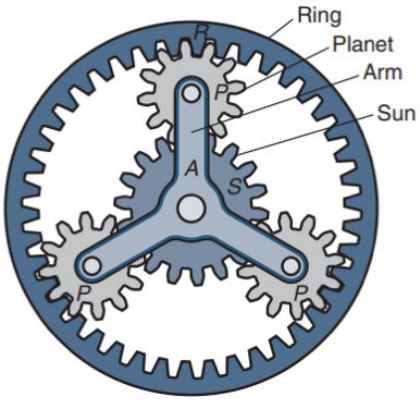
```
G = 17.6000
```

```
omega_8 = 1200 / G  %[rev/min] ccw
```

```
omega_8 = 68.1818
```

Question 5

The sun gear of the planetary gear train is driven by the engine at 3000 rpm, the ring is bolted to the machine frame, and the armature is connected to the track drive system. The sun has 16 teeth, and there are three planets, each with 34 teeth. Determine the angular velocities of the armature and the planets, and the angular velocity ratio between the arm and the sun.



Solution

Write out what is known

```
omega_sun = 3000;  %[rpm]
N_sun = 16;  %[]
N_planet = 34;  %[]
```

The number of teeth on the ring are

$$N_{\text{ring}} = N_{\text{sun}} + 2N_{\text{planet}}$$

```
N_ring = N_sun + 2 * N_planet  %[]
```

```
N_ring = 84
```

Angular velocities of the armature

$$\frac{\omega_{\text{ring}} - \omega_{\text{arm}}}{\omega_{\text{sun}} - \omega_{\text{arm}}} = -\frac{N_{\text{sun}}}{N_{\text{ring}}}$$

$$\frac{0 - \omega_{\text{arm}}}{\omega_{\text{sun}} - \omega_{\text{arm}}} = -\frac{N_{\text{sun}}}{N_{\text{ring}}}$$

$$\omega_{\text{arm}} = \frac{\frac{N_{\text{sun}}}{N_{\text{ring}}}\omega_{\text{sun}}}{1 + \frac{N_{\text{sun}}}{N_{\text{ring}}}}$$

```
omega_arm = (N_sun/N_ring * omega_sun)/(1 + N_sun/N_ring) %[rpm]
```

```
omega_arm = 480
```

$$\frac{\omega_{\text{planet}} - \omega_{\text{arm}}}{\omega_{\text{sun}} - \omega_{\text{arm}}} = -\frac{N_{\text{sun}}}{N_{\text{planet}}}$$

$$\omega_{\text{planet}} = -\frac{N_{\text{sun}}}{N_{\text{planet}}}(\omega_{\text{sun}} - \omega_{\text{arm}}) + \omega_{\text{arm}}$$

```
omega_planet = - N_sun/N_planet * (omega_sun - omega_arm) + omega_arm  %[rpm]
```

```
omega_planet = -705.8824
```

Angular velocity ratio

$$Z_p = \frac{\omega_{\text{arm}}}{\omega_{\text{sum}}}$$

```
Z_p = omega_arm / omega_sun
```

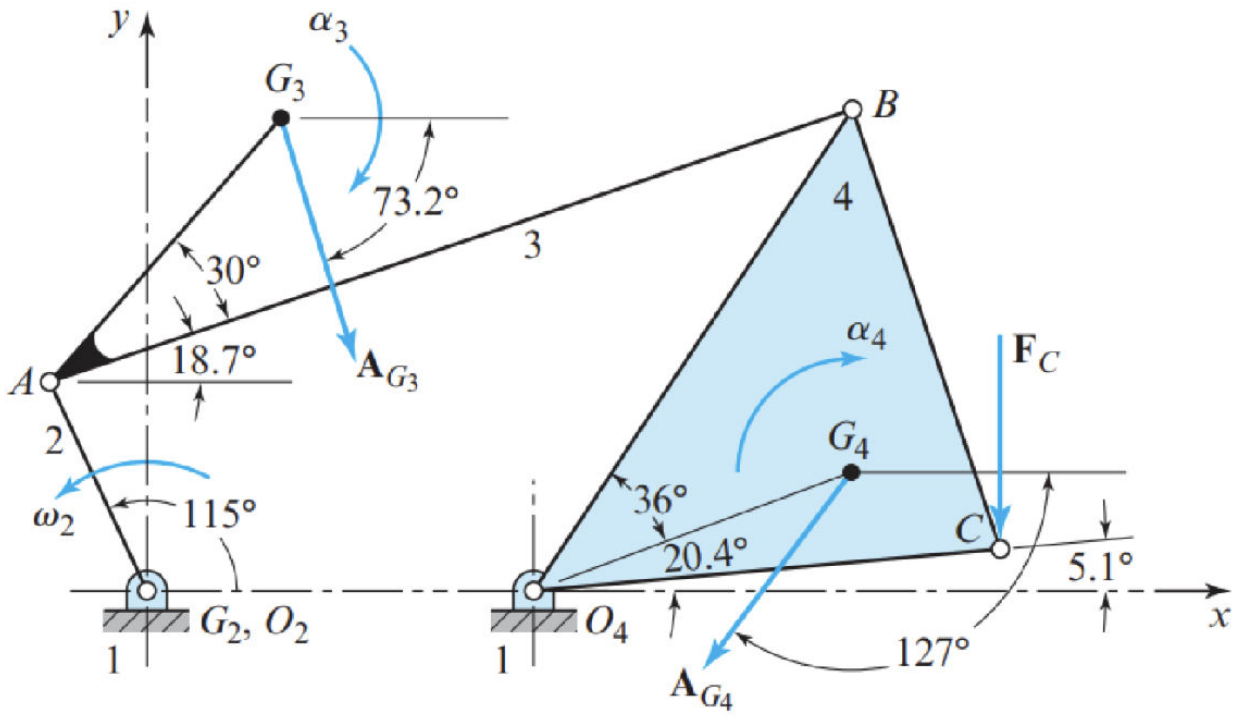
```
Z_p = 0.1600
```

```
gear_ratio = 1 / Z_p
```

```
gear_ratio = 6.2500
```

Question 6

Given the driving torque $T_{12} = 19.2\text{Nm}$ and $\omega_2 = 48\ \frac{\text{rad}}{s}$, design the actuation (motor and gear) for the driving joint O_2.



Solution

Step 1

Estimate the power required and select the actuator

$P = T\omega$

```
P = 19.2 * 48 %[W]
```

```
P = 921.6000
```

Rated Power	1200 W
Rated Voltage	three phase 220V AC
Rated Current	5 A
Rated Speed	3000 rpm
Rated Torque	4 Nm
Peak Torque	12 Nm

Step 2

Estimate the gear ratio

$G = \frac{\omega_{\text{in}}}{\omega_{\text{out}}}$

```
% calculate speed in rpm
rpm = 48 * 60 / (2 * pi)
```

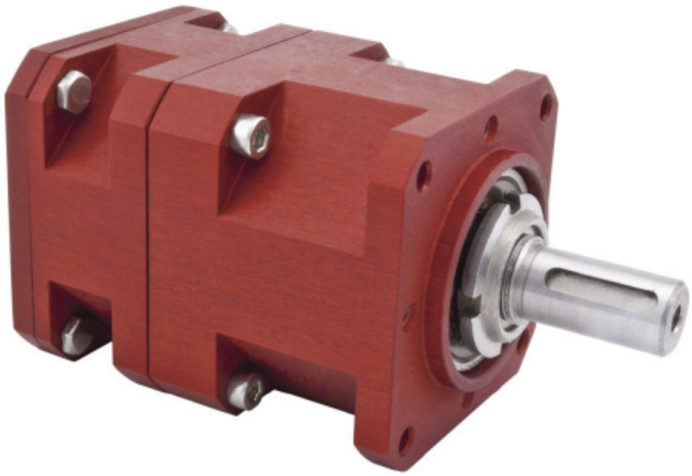
```
rpm = 458.3662
```

```
G = 3000 / rpm  %[]
```

```
G = 6.5450
```

Step 3

Possible solution 1 - select off-the-shelf gearbox given an input speed of 3000 rpm, transfer power 0.9 - 1.2 kW and gear ratio of 6:1.



https://www.ondrivesus.com/in-line-gearboxes/epicyclic-servo/ehd08-6

Possible solution 2 - select the pinion gear based on parameters above.

Pinion gear - KHG2-15LJ12 https://khkgears2.net/catalog4/KHG2-15LJ12

Helical gear - KHG2-90L https://khkgears2.net/catalog4/KHG2-90L