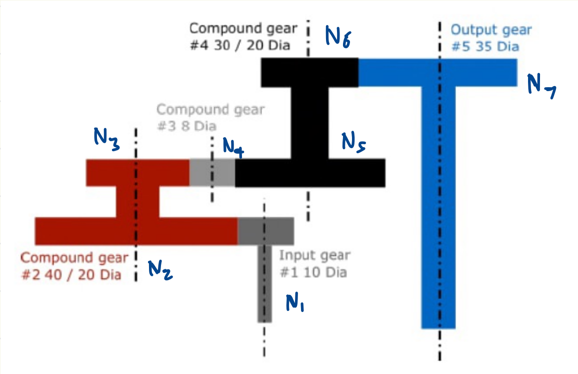
1.1)

Deliverables **Written:** What is the total transmission ration? For an input torque of 1 N-cm, what is the output torque? For an input speed of 10 rotations per second, what is the speed at the output?



$$\frac{n_7}{n_1} = \left(-\frac{N_1}{N_2}\right)\left(-\frac{N_3}{N_4}\right)\left(-\frac{N_4}{N_5}\right)\left(-\frac{N_6}{N_7}\right)$$

$$= \frac{N_1 N_3 N_6}{N_2 N_5 N_7}$$

$$= \frac{10(20)(20)}{40(30)(35)} = 0.0952$$

$$T_1 n_1 = T_7 n_7$$

$$T_7 = \frac{n_1}{n_7} \cdot T_1$$

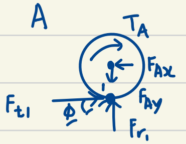
$$= \frac{1}{0.0952} \cdot 1 = 10.5 \text{ N-cm}$$

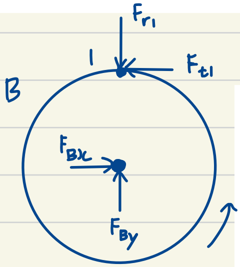
$$10 \text{ rps} = 600 \text{ rpm}$$

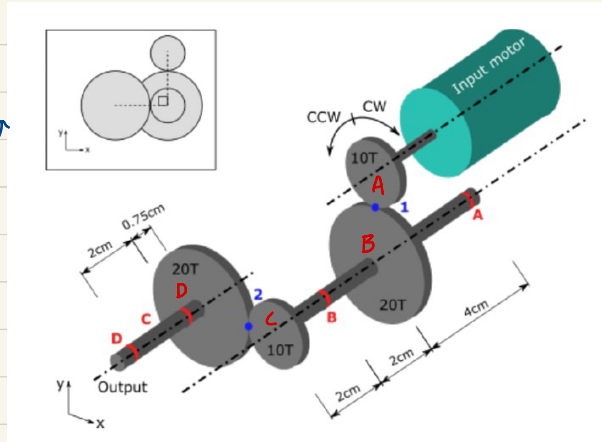
$$n_7 = 0.0952(600) = 57.1 \text{ rpm}$$

Deliverables **Written:** For an input torque of 0.1 N-m in the clockwise (CW) direction. What are the forces acting at the teeth of the compound gear at points 1 and 2, represented in the righthanded x-y-z frame shown in the image?

1.2)





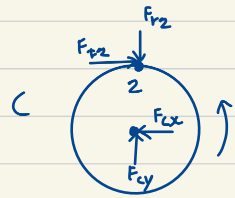


$$\Sigma T = 0 : \quad F_{t1}(0.01) - T_A = 0$$

$$F_{t1} = \frac{0.1}{0.01} = 10\text{ N}$$

$$\tan\phi = \frac{F_{r1}}{F_{t1}}$$

$$F_{r1} = 10\tan 20^\circ = 3.64\text{ N}$$



$$T_B\, n_B = T_A\, n_A$$

$$\frac{T_B}{T_A} = \frac{n_A}{n_B} = \frac{N_B}{N_A}$$

$$T_B = 0.1\left(\frac{20}{10}\right) = 0.2\text{ N}\cdot\text{m}$$

$$T_C = T_B = 0.2\text{ N}\cdot\text{m}$$

$$\Sigma T = 0 : \quad F_{t2}(0.01) - T_C = 0$$

$$F_{t2} = \frac{0.2}{0.01} = 20\text{ N}$$

$$\tan\phi = \frac{F_{r2}}{F_{t2}}$$

$$F_{r2} = 20\tan 20^\circ = 7.28\text{ N}$$

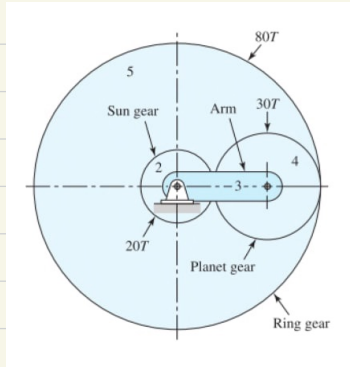
Deliverables **Written:** Now take out the gear motor from the lab kit. Take a close look at the gearbox. How does the diameter of the shaft change along the gear train? Why is that?

Diameter increases along the gear train. This is because when diameter increases from the input to the output, the torque increases, allowing the gear train to output a higher torque.

Deliverables **Written:** Derive the gear ratio formula for the given condition. Then use that and compute the gear ratio for the above planetary gear.

1.3)

$$\frac{w_r - w_c}{w_s - w_c} = -\frac{N_s}{N_r}$$



Since the ring gear is fixed, $w_r = 0$.

input : sun

output : carrier

$$\frac{-w_c}{w_s - w_c} = -\frac{N_s}{N_R}$$

$$-w_c = -\frac{N_s}{N_R}(w_s - w_c)$$

$$-\left(1 + \frac{N_s}{N_R}\right) w_c = -\frac{N_s}{N_R} w_s$$

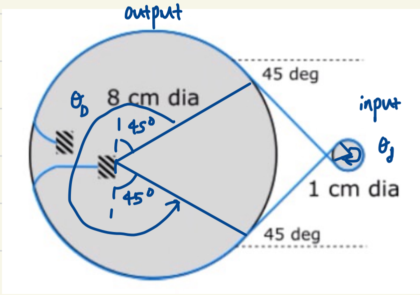
$$\frac{w_s}{w_c} = \frac{-\left(1 + \frac{N_s}{N_R}\right)}{-\frac{N_s}{N_R}}$$

$$\frac{w_s}{w_c} = \frac{N_R}{N_s} + 1 \quad //$$

$$\frac{w_s}{w_c} = \frac{80}{20} + 1 = 5 \quad //$$

Deliverables **Written:** Given a cable pre-tension of 25 N and that there is 0.75 wrap of the cable about the input capstan, how much torque can be transmitted to the output?

1.4)



$$\theta_J = 0.75(2\pi) = 4.712 \text{ rad.}$$

$$\theta_D = \pi + \frac{\pi}{4} + \frac{\pi}{4} = 4.712 \text{ rad.}$$

$$\frac{T_1}{T_2} = e^{\mu\theta}$$

$$= e^{0.7(4.712)} = 27.07$$

$$T_1 = 27.07\, T_2 \quad \text{—①}$$

$$T_1 + T_2 = 2T$$

$$T_1 + T_2 = 2(25) = 50 \quad \text{—②}$$

Sub ① into ②,

$$27.07\, T_2 + T_2 = 50$$

$$T_2 = \frac{50}{28.07} = 1.781 \text{ N}$$

$$T_1 = 27.07(1.781) = 48.21 \text{ N}$$

For output drum,

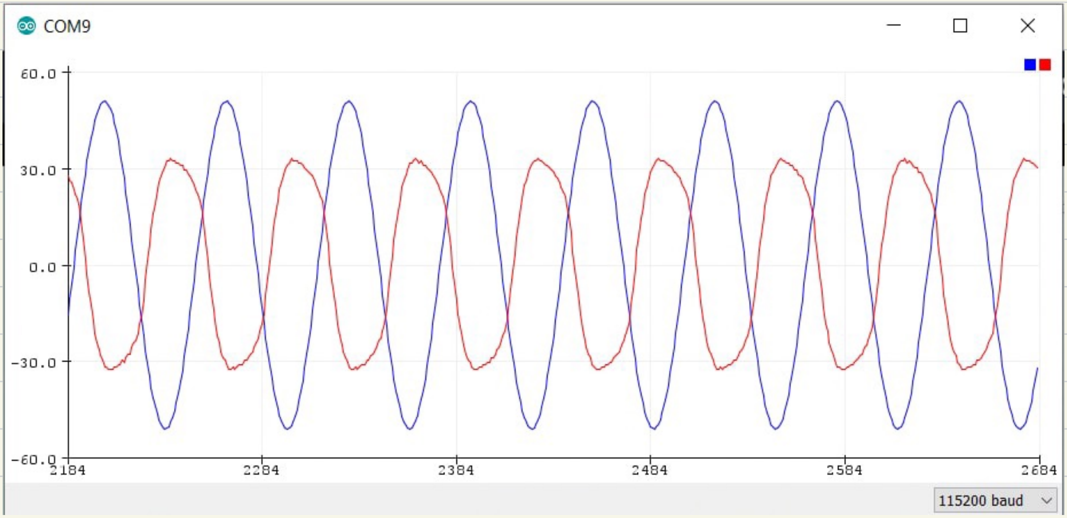
$$\tau = (T_1 - T_2) R$$

$$= (48.21 - 1.781)(0.04)$$

$$= 1.86 \text{ N}\cdot\text{m}$$

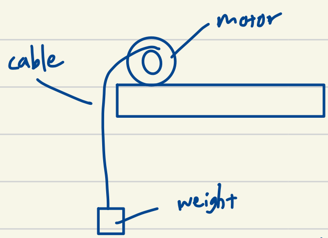
2.4)

Deliverables **Photo:** Take a screenshot of your Serial Plotter plotting the motor speed and motor PWM input with labels.



Deliverables **Written:** Design a simple experiment that measures the efficiency of the gear motor. Describe your method briefly. Note: You do not have to carry out the experiment but you are welcome to do so and let us know what your findings are.

efficiency $\eta = \frac{E_{out}}{E_{in}}$



$E_{in} = Pt = IVt$ (by motor)

$E_{out} = mgh$ (GPE gained by mass)

1) Set up the experiment and measure the mass of the hanging weight and the height between the motor and the starting position of the weight.
2) Turn on the circuit and use a multimeter to measure voltage and current across the motor.
3) Turn on the circuit and start the stopwatch. Stop it when the weight reaches the motor and record the time taken.

4) $\eta = \frac{E_{out}}{E_{in}} = \frac{mgh}{IVt}$