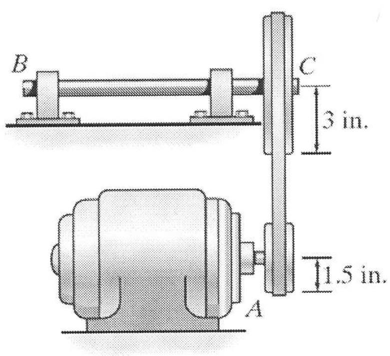
CME 260 – Mechanics of Materials
Exam #4 (02/28/2024)

StarID or TechID (no names) Grading

Do one of the two problems shown below (the second problem is on the back).
Show your work (you will not receive any credit if all you have is a final answer, right or wrong).

1. The motor delivers 15 hp to the pulley at A while turning at a constant rate of 1800 rpm. Determine to the nearest 1/8 inch the smallest diameter of the shaft BC if the allowable shear stress for the steel shaft is τ_{max} = 12 ksi. Assume there is no slippage between the belt and the pulley.



pulley A → 1,800 rpm
pulley C → ? rpm
circumference A = $2\pi(1.5\,in)$
circumference C = $2\pi(3\,in)$
2 turns of A = 1 turn of C
pulley C → 900 rpm (1)

$P = 2\pi f T \rightarrow T = \frac{P}{2\pi f}$

$P = 15\,hp\left(\frac{550\,\frac{ft\text{-}lb}{s}}{1\,hp}\right) = 8{,}250\,\frac{ft\text{-}lb}{s}$ (1)

$T = \frac{8{,}250\,\frac{ft\text{-}lb}{s}}{\left(2\pi\,\frac{rad}{rev}\right)\left(900\,\frac{rev}{min}\right)\left(\frac{1\,min}{60\,s}\right)} = 87.535\,lb\text{-}ft$ (3)

$\tau_{allow} = \frac{Tc}{J} \rightarrow \frac{J}{c} = \frac{T}{\tau_{allow}}$

$\frac{\frac{\pi}{2}c^{4\,3}}{c} = \frac{87.535\,lb\text{-}ft\left(\frac{1\,kip}{1000\,lb}\right)\left(\frac{12\,in}{1\,ft}\right)}{12\,\frac{kip}{in^2}}$

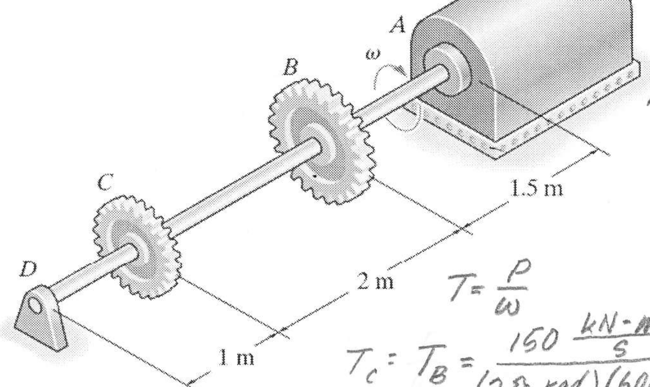
$\frac{\pi}{2}c^3 = 0.087535\,in^3$

$c = 0.382\,in$ (3)

$d = 2c = 0.764\,in$ (1)

to nearest $\frac{1}{8}$ inch → $\boxed{d = \frac{7}{8}\,inch}$ (1)

2. The gears at B and C each transmit 150 kW of power developed by the turbine at A. If the rotation of the 100 mm diameter shaft is ω = 600 rev/min, determine the rotation of end D of the shaft relative to A. The shaft is made of A-992 steel. The journal bearing at D allows the shaft to rotate freely about its axis.



$J = \frac{\pi}{2} c^4 = \frac{\pi}{2}(0.050\ m)^4 = 9.817 \times 10^{-6}\ m^4$ (1)

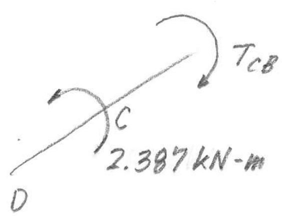
A992 steel, $G = 75\ GPa = 75 \times 10^6\ \frac{kN}{m^2}$ (1)

$T = \frac{P}{\omega}$

$T_C = T_B = \dfrac{150\ \frac{kN \cdot m}{s}}{\left(2\pi\ \frac{rad}{rev}\right)\left(600\ \frac{rev}{min}\right)\left(\frac{1\ min}{60\ s}\right)}$

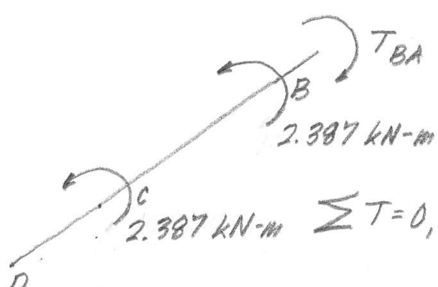
$= 2.387\ kN\text{-}m$ (2)

C-B



$\Sigma T = 0,\ T_{CB} = 2.387\ kN\text{-}m$ (1)

B-A



$\Sigma T = 0,\ T_{BA} = 4.775\ kN\text{-}m$ (1)

$\phi = \frac{TL}{JG}$

$\phi_{C/A} = \phi_{C/B} + \phi_{B/A}$

$= \dfrac{\left((2.387\ kN\text{-}m)(2\ m) + (4.775\ kN\text{-}m)(1.5\ m)\right)}{(9.817 \times 10^{-6}\ m^4)\left(75 \times 10^6\ \frac{kN}{m^2}\right)}$

$= 0.01621\ rad$ (3)

in degrees: $0.01621\ rad\left(\frac{360^\circ}{2\pi\ rad}\right) = \boxed{0.929^\circ}$ (1)