RBE 1001 Homework #4 **Name:** SOLUTIONS

Problem statement:

For Questions 1-3:

Your robot needs to lift itself up on a "pull-up" bar at the end of the match. The robot weighs 140 pounds and it needs to raise itself 5 feet in no more than 5 seconds. You plan on using a cable winch to accomplish the pull, with a transmission between the winch motor and winch drum. This transmission is 90% efficient and has a "speed ratio" of 1/30 (meaning its output speed is 1/30 of the input speed and its output torque is 30 times the input torque times the transmission efficiency). The following data sheet represents the motor you will use.

Speed (rpm)	Torque (N m)	Torque (in lbs)	Current (A)	Power (wt)	Efficiency	Heat (wt)
0	2.43	21.5	133.0	0.0	0%	1396
354	2.26	20.0	124.3	83.9	6%	1408
708	2.10	18.6	115.6	155.8	11%	1232
1062	1.94	17.2	106.9	215.7	17%	1068
1416	1.78	15.7	98.2	263.7	22%	915
1770	1.62	14.3	89.6	299.6	28%	775
2124	1.46	12.9	80.9	323.6	33%	647
2478	1.29	11.4	72.2	335.6	39%	531
2832	1.13	10.0	63.5	335.6	44%	427
3186	0.97	8.6	54.8	323.6	49%	334
3540	0.81	7.2	46.1	299.6	54%	254
3894	0.65	5.7	37.4	263.7	59%	186
4248	0.49	4.3	28.8	215.7	63%	129
4602	0.32	2.9	20.1	155.8	65%	83
4956	0.16	1.4	11.4	83.9	61%	53
5310	0.00	0.0	2.7	0.0	0%	32

30 Amp

Motor Type	CIM 801-001	
Desired Volt	12	V
Ref Volt	12	V
Ref Free Spd	5310	RPM
Ref Stal Torq	21.483	in lbs
Ref Stal Cur	133	A
Ref Free Cur	2.7	A

Conversion factor 1 hp = 746W = 550 lb·ft/sec

1) How much power (W) do you need to do this operation? (Ans ~185W)

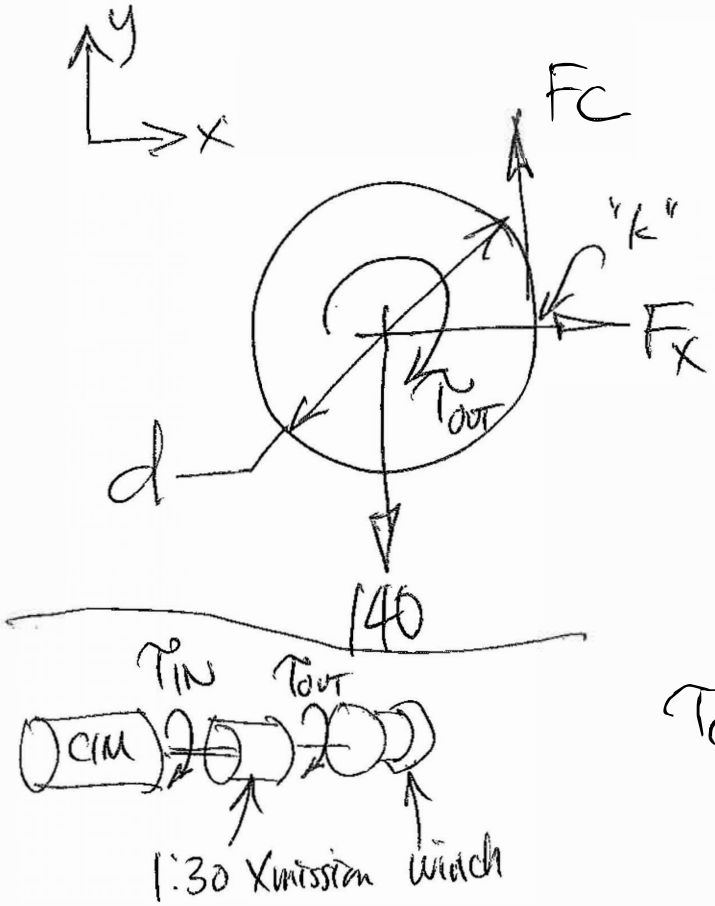
$$P = \frac{\Delta W}{\Delta t} = \frac{1406 \cdot 5\,ft}{5\,sec} = \frac{1406 \cdot ft}{sec}\left(\frac{746W}{550\,lb \cdot ft/sec}\right)$$

$$= 190W \quad \leftarrow 1$$

2) Due to heating concerns you wish to limit this motor to 30A current draw. How much torque can it provide (use linear interpolation). (Ans ~ 5 inlb)

$$\tau_{@30} = \left(\frac{1.2}{8.6}\right)(5.7-4.3)+4.3 = \boxed{4.5\text{ inlb}}$$

3) What diameter winch drum will give you the fastest climb rate? (Hint: You should do a FBD of the winch drum with the tangential force being the robot weight and the drum input torque being the output torque of the motor/transmission. You can solve for the drum radius by invoking the EofE.) (Ans ~2 in)



$$\Sigma M_{Z_K} = 0$$

$$= 140\left(\frac{d}{2}\right) - \tau_{OUT}$$

$$\therefore d = \frac{\tau_{OUT}}{70\text{lb}} \quad (1)$$

$$\tau_{OUT} = 30(.90)\tau_{IN}$$

$$= 27 \cdot 4.5$$

$$= 120\text{ inlb} \quad (2)$$

$\therefore$ from (1) & (2):

$$d = \frac{120\text{ inlb}}{70\text{lb}} = \boxed{1.73\text{ in}}$$

For questions 4-6:

You have a 4WD robot that you wish to be as fast as possible. You realize that there may be other robots blocking your path so you also wish to be able to push them around without overheating your drive motors. Your robot weighs 10 lbs, the wheels have a μ of 1.0, and you are using two of the following motors for the driveline.

Speed (rpm)	Torque (N m)	Torque (in lbs)	Current (A)	Power (wt)	Efficiency	Heat (wt)
0	1.67	14.8	4.8	0.0	0%	35
7	1.56	13.8	4.5	1.1	3%	31
13	1.45	12.8	4.2	2.0	7%	28
20	1.33	11.8	3.9	2.8	10%	25
27	1.22	10.8	3.6	3.4	13%	23
33	1.11	9.8	3.3	3.9	16%	20
40	1.00	8.9	3.0	4.2	19%	18
47	0.89	7.9	2.7	4.3	22%	15
53	0.78	6.9	2.4	4.3	25%	13
60	0.67	5.9	2.1	4.2	27%	11
67	0.56	4.9	1.8	3.9	29%	9
73	0.44	3.9	1.6	3.4	31%	8
80	0.33	3.0	1.3	2.8	31%	6
87	0.22	2.0	1.0	2.0	29%	5
93	0.11	1.0	0.7	1.1	23%	4
100	0.00	0.0	0.4	0.0	0%	3

Motor Type	VEX393	
Desired Volt	7.2	V
Ref Volt	7.2	V
Ref Free Spd	100	RPM
Ref Stall Torq	14.76	in-lbs
Ref Stall Cur	4.8	A
Ref Free Cur	0.37	A

4) What is the combined torque (in-lbs) for the two drive motors when limited to a max continuous current of 2.5A/motor (interpolate as required)? (Ans ~ 15inlb)

$T_{2.5} = \frac{1}{3}(1) + 6.9 = 7.2$ in lb

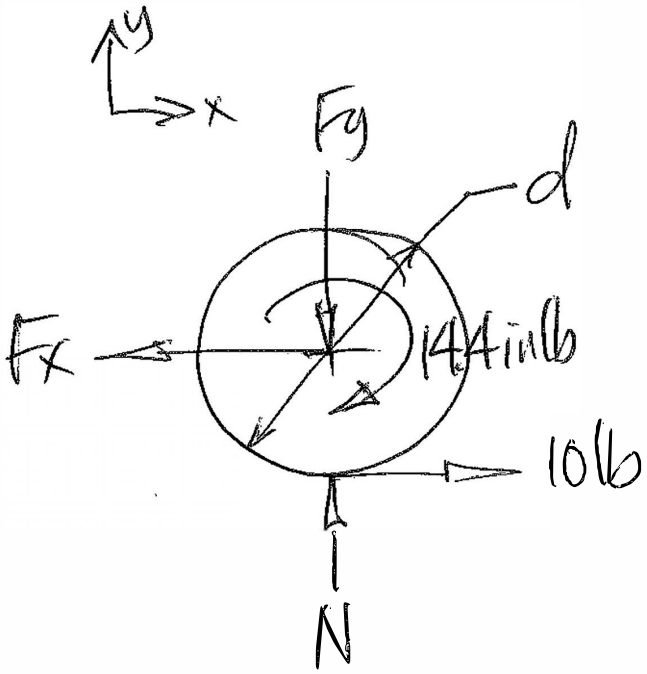
$\times 2$ motors

144 in lbs

5) Independent of input torque or stability concerns (ie: consider only the traction limit), what is the maximum "tractive force" (pounds) that this robot can produce? (Ans ~ 12lb)

$F_f = \mu N \quad \therefore F_{f(max)} = 1.0(10) = \boxed{10\text{lb}}$

6) If you wish to limit the motor currents to 2.5A even when in a "pushing match", what is the maximum diameter wheels you can use (assume direct drive from motors to wheels)? (Ans ~ 3 in)



$\Sigma M_{Z+} = 0$

$= 10\frac{d}{2} - 14.4$

$\therefore d = \frac{14.4}{5}$

$= \boxed{2.88\text{in}}$