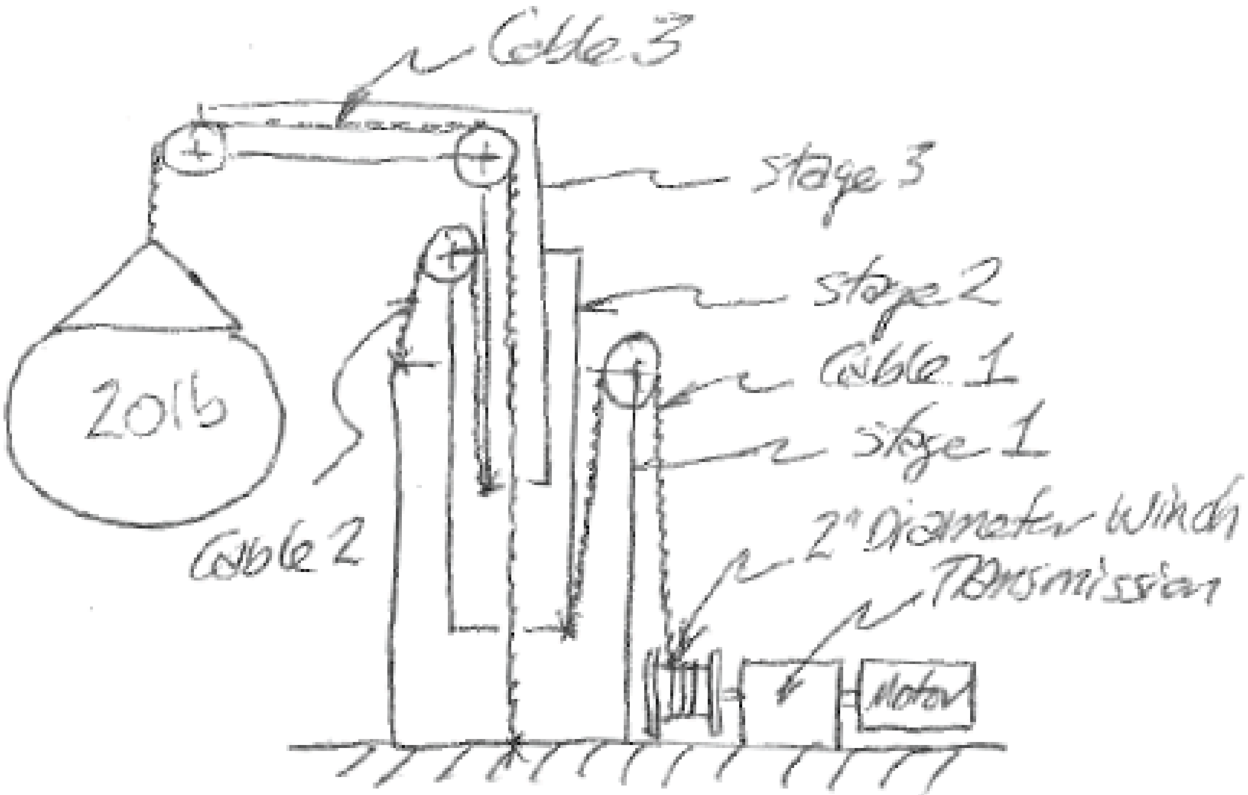
RBE 1001 Homework 12

Name: Solution

Problem statement:

As in the video shown in class, your robot is required to lift a large 20. lb ball and apparatus 5.0 ft high in 2.5 seconds. You decide to use a 3-stage telescopic elevator crane to do this. The upper stage weighs 10. lb; the middle stage weighs 5.0 lb. You use a controlled sequencing cable arrangement as shown. You use ball-bearing sliders throughout the mechanism and decide to ignore friction and design a 2.0 inch dia winch drum to power it.



1) How much mechanical output power is required to accomplish this task? *(Hint: in 2.5 secs, how much vertical dist does the ball, the upper stage, and the middle stage travel respectively?)* (ANS: ~ 80W)

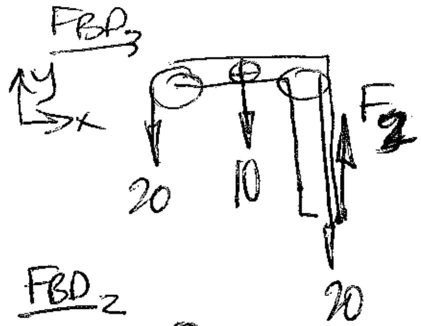
Power = Work / Time = (20 lb x 5 ft + 10 lb x 2.5 ft + 5 lb x 1.25 ft) / 2.5 sec
= 52.5 ft-lbs / sec

52.5 ft-lbs / sec x 746 W / 550 ft-lbs/sec = 71 W

2) Using **FBD's** of stage 3 and stage 2, what are the cable tension loads (F_3, F_2, F_1)? (ANS: ~ 15, 45, 100 lbs)

$F_3 = \boxed{20\,lbs}$

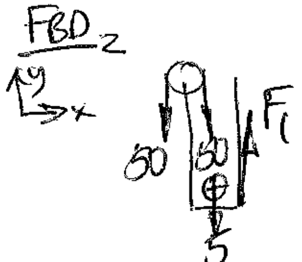
FBD$_3$



$\Sigma F_y = 0 = F_2 - 20 - 20 - 10$

$\therefore F_2 = \boxed{50\,lbs}$

FBD$_2$

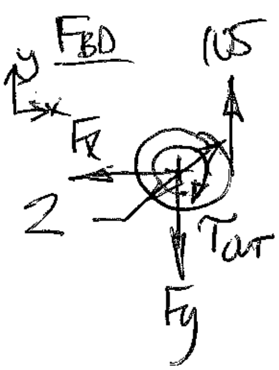


$\Sigma F_y = 0 = F_1 - 50 - 50 - 5$

$\therefore F_1 = \boxed{105\,lbs}$

3) You choose the motor that has the attached performance. You wish to operate it at fewer than 30 amps. With an overall gearbox system efficiency of 85%, what is the minimum gear reduction ("e") you must have? (ANS: ~ 1/30)

FBD



$\Sigma M_Z = 0 = 105\left(\frac{2}{1}\right) - T_{OUT}$

$\therefore T_{OUT} = 105\,in\,lb$

$T_{IN_{30A}} = 4.5\,in\,lb$

$e = \frac{T_{IN}}{T_{OUT}}\eta = \frac{4.5}{105}(.85) = \boxed{.036}$

4) If you do not provide an anti-backdrive mechanism, how much heating power would need to be dissipated by the motor when holding the frictionless loaded mechanism stationary? (*Recall that motor torque is proportional to current regardless of voltage applied and that the base resistance of the motor windings can be determined through Ohm's Law at motor stall.*) (ANS: ~ 75W)

$V = IR, \quad R = \frac{V}{I} = \frac{12}{133} = .090\,\Omega$

4.5 in lb T_{IN} requires 30A per motor chart

$\therefore P = I^2R = (30)^2(.090) = \boxed{81\,W}$

[Actually, once stopped, the current could be reduced to the torque required to just match the T_{OUT} of the "reversed" transmission: ~3.2 in lb ~ 22A ⇒ ~45W]

Speed (rpm)	Torque (N m)	Torque (in lbs)	Current (A)	Power (wt)	Efficiency	Heat (wt)
0	2.426	21.463	133.0	0.0	0%	1596
354	2.264	20.032	124.3	83.9	6%	1408
708	2.102	18.601	115.6	155.8	11%	1232
1062	1.941	17.170	106.9	215.7	17%	1068
1416	1.779	15.739	98.3	263.7	22%	915
1770	1.617	14.308	89.6	299.6	28%	775
2124	1.456	12.878	80.9	323.6	33%	647
2478	1.294	11.447	72.2	335.6	39%	531
2832	1.132	10.016	63.5	335.6	44%	427
3186	0.970	8.585	54.8	323.6	49%	334
3540	0.809	7.154	46.1	299.6	54%	254
3894	0.647	5.723	37.4	263.7	59%	186
4248	0.485	4.293	28.8	215.7	63%	129
4602	0.323	2.862	20.1	155.8	65%	85
4956	0.162	1.431	11.4	83.9	61%	53
5310	0.000	0.000	2.7	0.0	0%	32

At 12V

$$37.4 - 28.8 = 8.6 \qquad 5.723 - 4.293 = 1.430$$

$$\left(\frac{1.2}{8.6}\right)(1.43) = .200$$

$$\therefore T_{@30A} = 4.293 + .200 \cong \underline{4.5 \text{ in lb}}$$