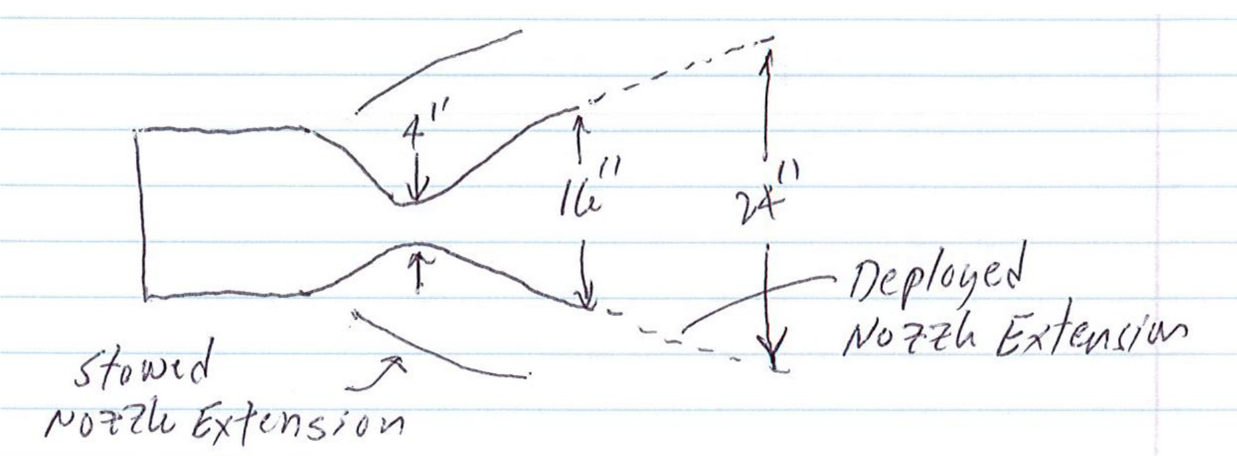
AAE 439 Hourly Exam #1
Fall, 2018 Semester

Open Book & Notes
Attempt all Problems

1. (25 pts) Spinlaunch is one of over 100 small companies supported by venture capital funds to develop small launch vehicles for future orbital constellations of smallsats. Their approach is to reduce launcher size by accelerating the payload and an upper stage propulsion system in a giant centrifuge/catapult to launch the rocket from the Earth's surface at velocities of the order of 5000 mph (2.2 km/s). Assume that the firm sets up a launch site at the 28 deg. latitude of Kennedy Space Center and that the upper stage rocket system has an Isp of 300 sec and a propellant mass fraction of λ=0.9.

   i) If the rocket is to place payloads in 150 km circular orbit what is the total Δv that must be imparted by the upper stage system neglecting any gravity, drag or steering losses?
   ii) If the desired spacecraft payload has a mass of 100 kg, ~~that~~ what is the gross mass that must be accelerated by the catapult?
   iii) The mass fraction of 0.9 is likely ambitious given that the entire system is exposed to high acceleration loads by the catapult. At what λ does the entire concept become unviable?

2. (30 pts) The sketch below shows a launch vehicle engine that operates with a chamber pressure of 1200 psi and delivers a c* value of 5000 f/s. Engineers have developed a translating nozzle extension that can be deployed at high altitudes to augment thrust in the latter portions of the boost trajectory. Assuming ideal performance and an average ratio of specific heats of 1.2 for the nozzle flow, determine:
   i) Sea level thrust and specific impulse
   ii) Vacuum thrust and specific impulse
   iii) In order to maximize performance, what altitude should the nozzle extension be deployed?



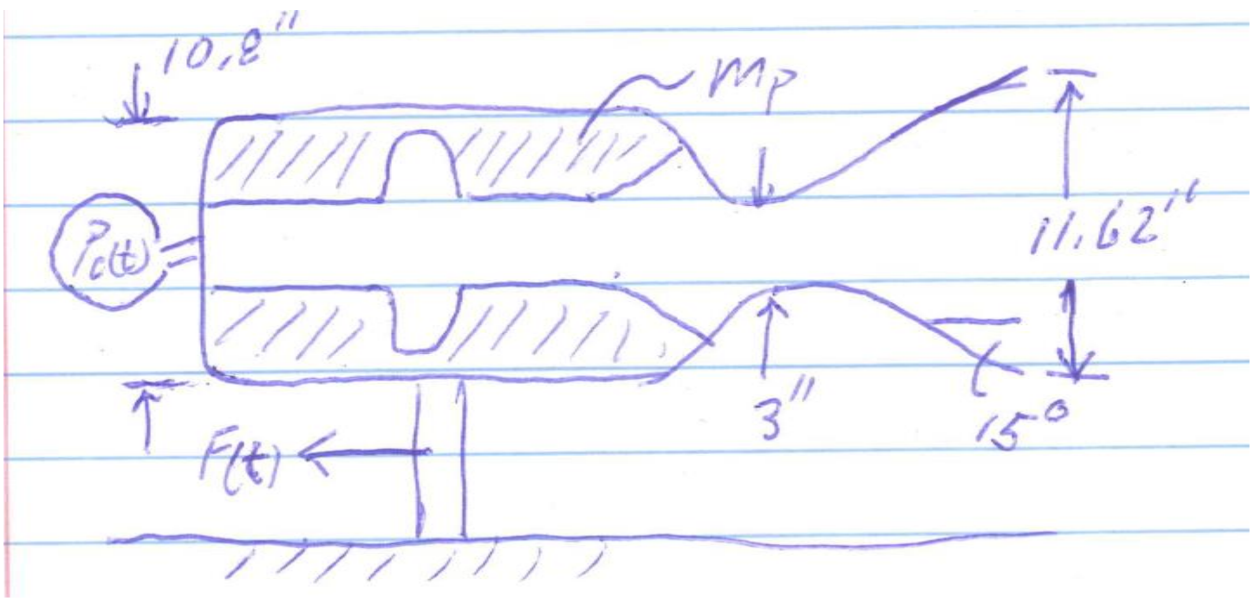
3. (30 pts) The solid rocket motor shown below is fired at sea level on a test stand. Measured pressure and thrust data are curvefit to give the following results:

$$p_c = 600 + 63.3t - 1.22t^2,\ 0 \le \text{t} \le 60 \text{ sec, } p_c \ \square \ \text{psi}$$

$$F = 6600 + 696t - 13.4t^2,\ 0 \le \text{t} \le 60 \text{ sec, } F \ \square \ \text{lbf}$$

The c* value for its propellant is 5000 f/s. Using these data and the motor dimensions in the sketch, determine:

i) The propellant weight in the motor, m_p, in lbf
ii) The sea level specific impulse (in seconds)
iii) The vacuum specific impulse (in seconds)



4. (15 pts) Consider the pros/cons of the Spinlaunch approach described in Problem ~~#2~~ #1. List and briefly discuss three pros and three cons of this approach relative to a conventional two-stage launch vehicle. Specifically address loss mechanisms (gravity, drag, and steering) for this concept in one of your three pros/cons. Are losses greater or less than conventional launch vehicles?

ϵ	M_e	p_e/p_c	$C_{f\text{-}opt}$	C_{fv}
1.0	1.000	0.5643080	0.67753	1.24184
2.0	2.055	0.1207748	1.22420	1.46575
3.0	2.397	0.0656052	1.35714	1.55396
4.0	2.619	0.0435133	1.43312	1.60717
5.0	2.785	0.0319051	1.48482	1.64435
6.0	2.917	0.0248603	1.52331	1.67247
7.0	3.027	0.0201796	1.55359	1.69485
8.0	3.122	0.0168690	1.57833	1.71328
9.0	3.205	0.0144174	1.59911	1.72887
10.0	3.278	0.0125373	1.61693	1.74231
11.0	3.345	0.0110547	1.63247	1.75408
12.0	3.405	0.0098591	1.64620	1.76451
13.0	3.461	0.0088767	1.65847	1.77386
14.0	3.512	0.0080569	1.66952	1.78232
15.0	3.560	0.0073636	1.67957	1.79002
16.0	3.604	0.0067703	1.68875	1.79708
17.0	3.646	0.0062577	1.69721	1.80359
18.0	3.686	0.0058107	1.70502	1.80962
19.0	3.723	0.0054180	1.71229	1.81523
20.0	3.759	0.0050705	1.71906	1.82047
21.0	3.792	0.0047611	1.72540	1.82538
22.0	3.824	0.0044840	1.73135	1.83000
23.0	3.855	0.0042346	1.73696	1.83436
24.0	3.885	0.0040091	1.74226	1.83848
25.0	3.913	0.0038043	1.74728	1.84238
26.0	3.940	0.0036175	1.75204	1.84609
27.0	3.966	0.0034467	1.75656	1.84962
28.0	3.991	0.0032898	1.76088	1.85299
29.0	4.016	0.0031453	1.76499	1.85621
30.0	4.039	0.0030119	1.76893	1.85928
31.0	4.062	0.0028883	1.77270	1.86223
32.0	4.084	0.0027735	1.77631	1.86506
33.0	4.105	0.0026667	1.77978	1.86778
34.0	4.126	0.0025671	1.78312	1.87040
35.0	4.146	0.0024740	1.78633	1.87292
36.0	4.166	0.0023868	1.78943	1.87535
37.0	4.185	0.0023050	1.79241	1.87770
38.0	4.204	0.0022281	1.79529	1.87996
39.0	4.222	0.0021557	1.79808	1.88215
40.0	4.239	0.0020874	1.80078	1.88427

Thrust Coefficient

Ratio of specific heats = 1.2

psl = 14.696 psi = 1.0132x105 Pa, Tsl = 518.6 R = 288.16 K
rhosl = 0.002377 slug/f3 = 1.226 kg/m3,   asl = 1116.4 f/s = 340.0 m/s

U.S. standard atmosphere
sl=sea level

h,kft	h,km	p/psl	rho/rhosl	T/Tsl	a/asl
-1.0	-0.305	1.0370	1.0300	1.0069	1.0034
0.0	0.000	1.0000	1.0000	1.0000	1.0000
2.0	0.610	0.9305	0.9434	0.9862	0.9931
4.0	1.219	0.8645	0.8890	0.9725	0.9861
6.0	1.829	0.8021	0.8366	0.9587	0.9792
8.0	2.438	0.7430	0.7862	0.9450	0.9721
10.0	3.048	0.6880	0.7387	0.9313	0.9650
12.0	3.658	0.6363	0.6935	0.9175	0.9579
14.0	4.267	0.5878	0.6504	0.9038	0.9507
16.0	4.877	0.5424	0.6094	0.8901	0.9434
18.0	5.486	0.4999	0.5704	0.8763	0.9361
20.0	6.096	0.4601	0.5334	0.8626	0.9288
22.0	6.706	0.4229	0.4982	0.8489	0.9214
24.0	7.315	0.3882	0.4648	0.8352	0.9139
26.0	7.925	0.3559	0.4332	0.8214	0.9063
28.0	8.534	0.3257	0.4033	0.8077	0.8987
30.0	9.144	0.2977	0.3750	0.7940	0.8911
32.0	9.754	0.2717	0.3482	0.7803	0.8834
34.0	10.363	0.2475	0.3229	0.7666	0.8756
36.0	10.973	0.2250	0.2985	0.7540	0.8683
38.0	11.582	0.2045	0.2720	0.7519	0.8671
40.0	12.192	0.1858	0.2472	0.7519	0.8671
42.0	12.802	0.1689	0.2246	0.7519	0.8671
44.0	13.411	0.1534	0.2041	0.7519	0.8671
46.0	14.021	0.1395	0.1855	0.7519	0.8671
48.0	14.630	0.1267	0.1685	0.7519	0.8671
50.0	15.240	0.1152	0.1532	0.7519	0.8671