

PROGRAM

" ROCKET 1. "

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by

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## I. INTRODUCTION

"ROCKET1" is a BASIC computer program which can be used to determine the flight performance of model rockets. A mathematical prediction of burnout conditions, maximum altitude and total flight time can help a rocketeer select a model rocket engine, choose a safe launch site and improve the design of his or her model rockets.

This program solves the problem of vertical model rocket motion by using several assumptions which allow the equation of motion to be solved exactly or "analytically". These assumptions involve the boost phase of flight where an average thrust and average model rocket mass are assumed. The atmospheric density and drag coefficient are also assumed to be constant during the entire model rocket flight. Program "ROCKET1" also compensates for "non-standard" launch sites which are not at sea level and launchings on hot or cold days.

## II. USER INPUTS AND SELECTIONS

Program "ROCKET1" will prompt the user for several inputs necessary for the software to work properly. This is a description of these requests and a discussion of how the user should respond. Information which pertains to the model rocket engine characteristics is available from manufacturers' catalogs.

### LAUNCH SITE ALTITUDE (METERS)?

The user should respond with the altitude of the launch site relative to sea level. This altitude is input in meters and is positive for sites above sea level and negative for sites below sea level.

### LAUNCH SITE TEMPERATURE (DEG F)?

The user should respond with the temperature at the launch site in decimal degrees Fahrenheit.

### THRUST DURATION (SECONDS)?

The user should input the total thrust duration of the model rocket engine in seconds.

### TOTAL IMPULSE (NEWTON-SECONDS)?

The user should respond with the total impulse of the model rocket engine in the units of newton-seconds.

### INITIAL MASS (GRAMS)?

The user should input the lift-off or gross mass of the entire model rocket in grams.

### PROPELLANT MASS (GRAMS)?

The user should respond with the propellant mass of the model rocket engine in grams.

### FRONTAL DIAMETER (MM)?

The user should input the maximum body tube diameter of the model rocket in millimeters.

### DRAG COEFFICIENT?

The user should respond with the drag coefficient of the complete model rocket. This number is non-dimensional.

After the program has run it will prompt the user for another selection. This is a description of each prompt. The user should respond with "1" if he desires the particular selection or "0" if not.

ANOTHER SELECTION (1=YES, 0=NO)?

The user should respond with "0" to exit the program.

ANOTHER LAUNCH SITE (1=YES, 0=NO)?

The user should respond with "1" to compute the model rocket flight performance at another launch site.

ANOTHER ROCKET ENGINE (1=YES, 0=NO)?

The user should respond with "1" to compute a model rocket's flight performance with a different model rocket engine.

DIFFERENT MASS OR DRAG (1=YES, 0=NO)?

The user should respond with "1" to compute the flight performance of a model rocket with different mass or drag characteristics.

If another selection is made, the program will again execute the prompts necessary for the new selection. If the user answers "YES" to the prompt "ANOTHER SELECTION" but does not actually make a different selection, the program will stop after cycling through all the selection questions.

### III. PROGRAM OUTPUT

Program "ROCKET1" outputs the model rocket altitude performance in units of the metric system. The burnout altitude and the maximum altitude are printed in meters and the burnout velocity is printed in meters per second. Coast time and total flight time are printed in seconds.

For users who may want to see other variables used in the software, "R1" is the launch site density in kilograms per cubic meters. The variable "X2" is the coast altitude increment in meters and "K2" is the variable  $1/2 \rho C_d A$  in the units of kilograms per meter. "F1" is the average thrust of the model rocket engine in newtons.

#### IV. TECHNICAL DISCUSSION

Program "ROCKET1" first converts the lift-off and propellant masses to kilograms and determines the cross-sectional area of the model rocket in square meters. The atmospheric density at the launch site is then computed as a function of the launch site altitude and temperature.

The burnout altitude and velocity are computed with the following equations,

$$X_{bo} = (m/k) \ln[\cosh(td/m \sqrt{k(F-mg)})]$$

$$V_{bo} = \sqrt{(F-mg)/k} \tanh[td/m \sqrt{k(F-mg)}]$$

where,

$$m = \text{average mass} = \text{lift-off mass} - (\text{propellant mass} / 2)$$

$$k = 1/2 \rho C_d A$$

$$\rho = \text{atmospheric density}$$

$$C_d = \text{drag coefficient}$$

$$A = \text{cross-sectional area}$$

$$F = \text{average thrust} = \text{total impulse} / \text{thrust duration}$$

$$td = \text{thrust duration}$$

The altitude gained during the coast flight and the coast time are determined using the next set of equations,

$$X_c = (m/2k) \ln(kV_{bo}^2/mg + 1)$$

$$t_c = (m/kg) \operatorname{atan}(V_{bo} \sqrt{k/mg})$$

where,

$$m = \text{burnout mass} = \text{lift-off mass} - \text{propellant mass}$$

$$g = \text{acceleration of gravity}$$

The maximum altitude and total flight time are given by,

$$X = X_{bo} + X_c$$

$$T = td + tc$$

## V. PROGRAM EXAMPLE

The following is an example of the Program printout which illustrates the features of Program "ROCKET1".

### Program ROCKET1

Launch site altitude (meters)

? 0

Launch site temperature (deg f)

? 59

Thrust duration (seconds)

? 1.2

Total impulse (newton-seconds)

? 5

Initial mass (grams)

? 40

Propellant mass (grams)

? 8.33

Frontal diameter (millimeters)

? 18

Drag coefficient

? .321

Burnout altitude (meters)            74.07

Burnout velocity (m/s)               119.36

Coast time (seconds)                 7.93

Total flight time (seconds)         9.13

Maximum altitude (meters)           451.39