Racing Cars

This problem is about writing a program to help a Formula 1 Racing Car team to evolve a racing plan. Please note that this is a hypothetical problem and many factors considered here may not be a true reflection of a real life Formula 1 racing scenario. However, for this problem the requirements documented here will be taken to be final.

The objective of each team participating in a Formula 1 Car Racing event is to complete the race in the shortest possible time ahead of the competition. Though this objective sounds very simple, the dynamics of a race is anything but simple. It is a true test of endurance of man and his machine supported by extreme team work. Time is of utmost importance and a loss of as less as 0.1 second at any stage during a race may make a difference between victory and defeat.

Each race comprises of a certain number of laps, say **N**. For this problem we will assume that the distance covered by a car in a single lap in different race tracks is the same. No car is able to complete the entire race (all the **N** laps) without taking a few very short breaks known as 'pit stops'. The time consumed by a car during a pit stop adds to the total time taken by the car to complete the race. Thus the intent is to keep the pit stops to a minimum and also the time consumed during a pit stop to a minimum. Let's say the number of pit stops for a car in a race is indicated by **P** and the minimum time the car spends at a pit stop is $\mathbf{P_t}$.

During a pit stop the support team for the car may do two major tasks. They are, replacing the tyres of the car and refuelling the car. Additionally they may carry out minor repairs that do not consume too much time.

The performance of a racing car, apart from multiple other factors, depends primarily on the condition of its tyres and the weight of the fuel it carries. Additionally, the amount of fuel a car carries is a key deciding factor on how many pit stops the car would need for refuelling. Typically, no car is able to complete all the laps in a race without a change of tyres or without having to take a pit stop for refuelling.

The theoretical *actual* time taken by a car, in seconds, to complete a single lap, say **T**, is given by the following formula. (The actual time will vary depending on other conditions like the driving skills of the driver, the wind speed on the race track and other driving conditions, position of other cars, etc.)

$$\mathbf{T} = \mathbf{T_O} + (0.015 \times \mathbf{W_s}) - (9.0 \times (1-\mathbf{T_f})) + (0.35 \times ((1-\mathbf{T_f}) \times \mathbf{N_t})^2)$$

Where,

$\mathbf{T_O}$ is the *likely* minimum time that may be taken by a car to complete a lap which is a constant for each lap and is an input to the program. (The actual time taken by the car for a lap is given by the above formula. A car may take lesser than $\mathbf{T_0}$ for a lap depending on the values of the other factors in the above equation)

$\mathbf{W_S}$ is the weight of the fuel in the car at the start of a lap,

$\mathbf{N_t}$ is the number of laps for the tyres; this number is reset to **0** each time the tyres are changed, (For example, the value of $\mathbf{N_t}$ used in the formula to compute the time for the first lap of the race is 0; a car always starts a race with new tyres.)

$\mathbf{T_f}$ is known as the tyre factor and is another factor that influences the speed of the car and the fuel consumed by it in each lap. The value of $\mathbf{T_f}$ depends on the type of tyre that is used in a car.

A racing team may use three types of tyres with different values of $\mathbf{T_f}$ for a given race. A car may run a single race with different types of tyres after each pit stop.

The value of $\mathbf{T_f}$ may range between **0.85** to **0.95** (in steps of **0.005** only) inclusive of the bounds. A lower value of $\mathbf{T_f}$ reduces the initial lap times but increases the fuel consumption. Also tyres with lower value of $\mathbf{T_f}$ wear out faster giving lesser number of laps and slower and slower lap times in each subsequent lap in the later laps.

The value of $\mathbf{W_S}$ itself may be computed using the following formula.

For the first lap or the lap after the car is refuelled, $\mathbf{W_S}$= Weight of the fuel filled in the car + the weight of fuel already present in the car

For the subsequent laps, $\mathbf{W_S} = \mathbf{W_{S-1}} – 2.5 – (0.1 \times (\mathbf{N_t}^2) \times (1-\mathbf{T_f}))$

Where,

$\mathbf{W_{S-1}}$ is the weight of fuel in the car at the start of the previous lap. *A car must start a lap only if it has enough fuel to complete the lap*. A pit stop is possible only at the start of a lap. A car cannot take a pit stop in the middle of a lap.

Additionally, the tyres become unusable and must be replaced before beginning a lap when the value computed by the equation $(1-\mathbf{T_f}) \times \mathbf{N_t}$ exceeds or equals **2.85** at the start of the lap. We will represent this value by $\mathbf{T_S}$.

$\mathbf{T_S} = (1-\mathbf{T_f}) \times \mathbf{N_t}$

Thus, for safety reasons, a car is not allowed to run a lap on tyres whose $\mathbf{T_S}$ value is greater than or equal to **2.85** at the start of the lap. All four tyres wear out at the same rate and all of them need to be replaced simultaneously.

Additionally, the following conditions apply.

1. A racing car cannot take more than (lesser pit stops are allowed) a fixed number of pit stops **P** which is given as an input to the program. The value of **P** cannot be lesser than the integer value of (total number of laps in the race (**N**)/ 15)+1

   P >= Integer value of {(**N**/15) + 1}

2. A car can refuel **12** weight units of fuel in **1** second. This is a constant for any race and any car.

3. A typical change of tyre (all four) takes **6** seconds. This too is a constant for any race and any car. Thus if a racing car takes a pit stop for change of tyres, it has to stop for at least **6** seconds.

4. The minimum time that must be taken by a car at a pit stop, $\mathbf{P_t}$, is **4** seconds. However if the tyres of a car are changed the minimum time is **6** seconds as indicated in **3** above.

5. The maximum units of fuel that can be loaded into a car is indicated by the variable $\mathbf{W_O}$ and is specified as an input to the program. The maximum permissible value is **120** units.

6. Laps for the car are counted starting at 1.

7. The replacement tyres used in the car during a pit stop can have the same $\mathbf{T_f}$ value as the previous set of tyres. It is *not* mandatory that a racing car should use tyres of all the three $\mathbf{T_f}$ values that are permitted for the race.

8. The minimum permissible value of $\mathbf{T_O}$ is **30**.

9. The minmum total number of laps in a race (minimum value of **N**) is **60**.

The program should take the following values as inputs subject to constraints specified so far in the problem statement. (Validation of these input parameters in the program is optional)

1. The total number of laps in the race (**N**)

2. The three different values of $\mathbf{T_f}$ for the tyres that may be used by the racing team for the race. The valid values are (0.85, 0.855, 0.86, 0.865, 0.87, 0.875, 0.88, 0.885, 0.89, 0.895, 0.90, 0.905, 0.91, 0.915, 0.92, 0.925, 0.93, 0.935, 0.94, 0.945, 0.95)

3. The maximum number of pit stops allowed for a car (**P**)

4. The maximum fuel that a car can carry ($\mathbf{W_O}$)

5. The value of $\mathbf{T_O}$

The output from the program should give the following details for the solution that takes minimum time to complete the race. Should there be multiple solutions that take the same minimum time for the specified input values it is sufficient to output any *one* solution.

For each lap:

1. The lap number ($\mathbf{N_C}$)
2. The weight of the fuel at the start of the lap ($\mathbf{W_S}$)
3. The value of $\mathbf{T_S}$ at the start of a lap
4. The lap number for the tyres ($\mathbf{N_t}$)
5. The value of $\mathbf{T_f}$
6. The time taken by the car to complete the lap (**T**)

For each pit stop:

1. Pit stop number
2. Weight of fuel added
3. If tyres are changed, the $\mathbf{T_f}$ value for the new tyres
4. Time taken for the pit stop
5. Total number of laps completed

Race Summary:

1. The total time taken to complete the race
2. Total number of pit stops

3. Total pit stop time
4. Total race time (Total time to complete the race – total pit stop time)
5. Total fuel consumed
6. Total number of tyre changes (One tyre change = change of all four tyres)

Additionally, as a *mandatory* requirement, a delimited text output file should be created by the program where each line in the file has the following format.

N_C:**W_S**:**T_S**:**N_t**:**T_f**:**T**;

A sample output file is as follows. (Only to illustrate the format)

```
1:100:0:0:0.9:10.6;
2:97.49:0.1:1:0.9:10.56585;
3:94.95:0.2:2:0.9:10.53825;
4:92.36:0.3:3:0.9:10.5169;
5:89.7:0.4:4:0.9:10.5015;
... ... ... ... ... ... ...
... ... ... ... ... ... ...
... ... ... ... ... ... ...
... ... ... ... ... ... ...
```

Since this program involves many floating point operations, end results of all computations should be rounded off to 5 digits.

The solutions will be evaluated based on the following criteria. Please note that a program will be considered for the 'Optional Evaluation' only if the program passes all the test cases under the 'Mandatory Evaluation' section. (No requests to publish the test cases for the Mandatory Evaluation section will be entertained when the qualifying round is in progress)

Mandatory Evaluation:

1. Correctness of program (Determined by analyzing the output file) - 25

2. Ability to provide the 'best / near best' solution (Determined by test cases) - 20

3. Performance of the Program (Determined by test cases) - 15

Optional Evaluation:

4. Algorithm & Implementation (Determined by code review) - 25

5. Code Readability (Formatting, comments, style, coding standards, etc.) - 07

6. Ease of use (Including ease of specifying inputs, etc) - 08

Total: 100

Good Luck and Happy Programming!