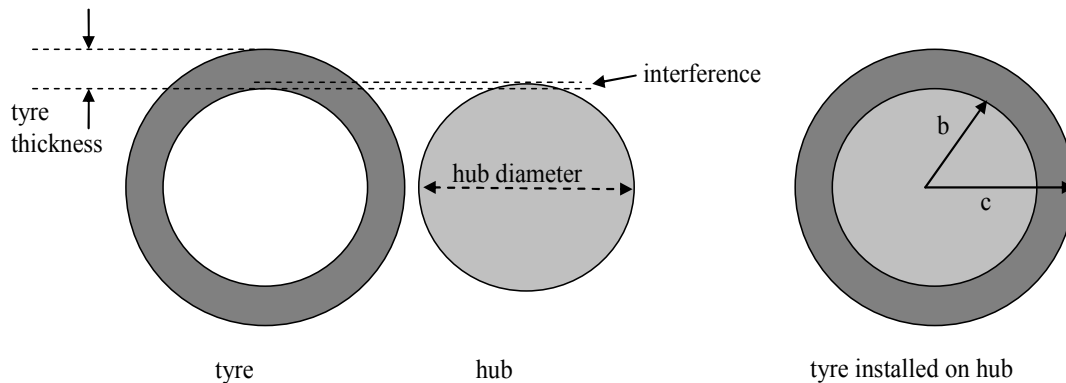


The wheels of railway locomotives are typically fitted with replaceable steel tires. The tires, which when cold are slightly too small to fit on the wheel hubs, are installed by being heated. The heating causes the tires to expand, allowing them to be placed on the hubs. When they cool, they shrink, and the resulting *interface pressure* firmly holds them in place.



The interface pressure can be calculated using the following formula:

$$p = \frac{\delta / b}{\left(\frac{1}{E_T} \right) \left(\frac{c^2 + b^2}{c^2 - b^2} + \nu_T \right) + \left(\frac{1}{E_H} \right) (1 - \nu_H)}$$

- where p is the interface pressure (in Pa)
- b is the radius of the hub (in m)
- c is the radius of the hub plus the tire thickness (in m)
- δ is the amount of interference (in m)
- E_T is Young's modulus for the tire material (in Pa)
- ν_T is Poisson's ratio for the tire material
- E_H is Young's modulus for the hub material (in Pa)
- ν_H is Poisson's ratio for the hub material

Assume that both the tire and the hub are made of steel ($E = 207e9$ Pa, $\nu = 0.28$).

Write a **function**, *computePressure*, that takes the hub diameter, the interference, and the tire thickness (all in m), and computes and returns the corresponding interface pressure (in Pa). Your function must conform exactly to this specification.

Write a C++ **program** ("*labfinal.cpp*") that uses the above function and repeatedly reads in hub diameters and interference values (both in m) until 0 0 is entered. For each pair of values entered your program should either i) output an error message (if the values are unreasonable -- see next paragraph) or ii) output a table showing the interface pressure

for tire thicknesses from 6.0 cm to 12.0 cm in steps of 0.5 cm. See the paragraph after next for details on the table.

Hub diameters must be between 0.5 m and 2.5 m (inclusive of these values) and interference values must be greater than zero and no more than 0.5% of the hub diameter.

Tables must be properly formatted. Columns must be lined up, tire thicknesses (in cm) must be displayed with one decimal place, and interface pressures (in MPa) must be displayed with four decimal places. **Note the units:** tire thicknesses are in cm and pressures must be displayed in MPa. The ideal interface pressure is 20 MPa and that pressures more than 5 MPa from this value are unacceptable. Each table produced should end with a message giving the tire thickness that comes closest to producing the ideal interface pressure or, if all of the thicknesses are unacceptable, a message to this effect.

Note: The Greek letter used is delta (δ).

Test Run #1

Enter hub diameter and interference: 1.5 0.0008

Thickness (cm)	Pressure (MPa)
6.0	15.7498
6.5	16.9076
7.0	18.0443
7.5	19.1603
8.0	20.2563
8.5	21.3326
9.0	22.3898
9.5	23.4283
10.0	24.4484
10.5	25.4508
11.0	26.4357
11.5	27.4036
12.0	28.3548

A tire thickness of 8.0 cm comes closest to giving a pressure of 20 MPa.

Enter hub diameter and interference: 1.5 0.001

Thickness (cm)	Pressure (MPa)
6.0	19.6872
6.5	21.1345
7.0	22.5553
7.5	23.9504
8.0	25.3204
8.5	26.6658
9.0	27.9872
9.5	29.2853
10.0	30.5606
10.5	31.8135
11.0	33.0446
11.5	34.2545
12.0	35.4435

A tire thickness of 6.0 cm comes closest to giving a pressure of 20MPa.

Enter hub diameter and interference: 1.2 0.00005

Thickness (cm)	Pressure (MPa)
6.0	1.4969
6.5	1.6037
7.0	1.7081
7.5	1.8102
8.0	1.9100
8.5	2.0077
9.0	2.1033
9.5	2.1968
10.0	2.2883
10.5	2.3778
11.0	2.4655
11.5	2.5514
12.0	2.6354

All of the tire thicknesses are unacceptable.

Enter hub diameter and interference: 0 0

Press any key to continue . . .

Test Run #2

Enter hub diameter and interference: 0.5 2.5001

Invalid values ignored.

Enter hub diameter and interference: 0.499 2.5

Invalid values ignored.

Enter hub diameter and interference: 1 0

Invalid values ignored.

Enter hub diameter and interference: 0 1

Invalid values ignored.

Enter hub diameter and interference: 1 0.05

Invalid values ignored.

Enter hub diameter and interference: 1 0.0051

Invalid values ignored.

Enter hub diameter and interference: 2.5 0.0125002

Invalid values ignored.

Enter hub diameter and interference: 2.5 0.0125

Invalid values ignored.

Note to students: this is due to C++'s representation error.

Your program will be considered correct whether it accepts or rejects this case.

Enter hub diameter and interference: 1 0.005

Thickness (cm)	Pressure (MPa)
6.0	209.9043

6.5	224.4432
7.0	238.6011
7.5	252.3913
8.0	265.8264
8.5	278.9185
9.0	291.6791
9.5	304.1194
10.0	316.2500
10.5	328.0811
11.0	339.6224
11.5	350.8834
12.0	361.8730

All of the tire thicknesses are unacceptable.

Enter hub diameter and interference: **0 0**

Press any key to continue . . .