raio interno esfera

$r_{ie} := 0.999$

,999 **(1)**

raio externo esfera

$r_{ee} := 1$

1 **(2)**

espessura esfera

$es := 0.001$

,001 **(3)**

raio furo

$r_{f} := 0.0025$

,0025 **(4)**

raio cilindro

$r_{c} := r_{f}$

,0025 **(5)**

densidade Ferro

$d_{Fe} := 7874.0$

7.874,0 **(6)**

densidade ar

$d_{ar} := 1.204115$

1,204115 **(7)**

volume interno se não houvesse furo

$$V_{i} := \text{evalf}\left(\frac{\pi \cdot \left(2 \cdot r_{ie}\right)^{3}}{6}\right)$$

4, **(8)**

1762363963538559660495701367962277743649701313173456392725024831863003842783370986305834751233758904

volume externo se não houvesse furo

$$V_{e} := \text{evalf}\left(\frac{\pi \cdot \left(2 \cdot r_{ee}\right)^{3}}{6}\right)$$

4, **(9)**

1887902047863909846168578443726705122628925325001410946332594564104218750482786648373797671228227573

volume Ferro se não houvesse furo

$V_{Fe} := \text{evalf}\left(V_{e} - V_{i}\right)$

, **(10)**

0125538084325350185672877075764427378979224011827954553607569732241214907699415662067962919994468669

distância centro esfera até face interna cilindro

$$d_{ic} := \sqrt{r_{ie}^2 - r_f^2}$$

, **(11)**

9989968718669743662532229534179504076462357410552975346536079227042265159221917622236397260712600031

distância centro esfera até face externa cilindro

$$d_{ec} := \sqrt{r_{ee}^2 - r_f^2}$$

, **(12)**

9999968749951171722411513325944530661157841372953047889730142643212454885634957750605598403574619259

altura capa interna

$$h_{ci} := r_{ie} - d_{ic}$$

, **(13)**

0000031281330256337467770465820495923537642589447024653463920772957734840778082377763602739287399969

altura capa externa

$$h_{ce} := r_{ee} - d_{ec}$$

, **(14)**

0000031250048828277588486674055469338842158627046952110269857356787545114365042249394401596425380741

volume capa externa

$$V_{ce} := \text{evalf}\left(\frac{1}{6}\cdot\pi\cdot h_{ce}\cdot\left(3\cdot r_f^2 + h_{ce}^2\right)\right)$$

, **(15)**

0000000000306796796738036916493269300331170567127100819205707987617685866415176055204224500965168677

volume capa interna

$$V_{ci} := \text{evalf}\left(\frac{1}{6}\cdot\pi\cdot h_{ci}\cdot\left(3\cdot r_f^2 + h_{ci}^2\right)\right)$$

, **(16)**

0000000000307103901920203489780714509522919416367371645403091837274230874727459337535860465959736571

altura cilindro

$$h_c := d_{ec} - d_{ic}$$

, **(17)**

0010000031281428059879283791765026584695483962400072543194063416170189726 41

304012836920114286201922 8

volume cilindro

$$V_{cil} := \text{evalf}\left(\pi \cdot r_c^2 \cdot h_c\right)$$

, **(18)**

000000019635015505876574436877012572619273608704316671588919237167825908287460103279443904897603665 6

volume orifício

$$V_o := V_{cil} + V_{ce} - V_{ci}$$

, **(19)**

000000019634984795358357779548268051700098723780289588969180852202171407456231775046280308398146876 2

volume Ferro sem cilindro

$$V_{\text{Fesem}_{Vo}} := V_{Fe} - V_o$$

, **(20)**

012553788797550223208929928028174686197823677402505866391576121021950083313709791160515983601299990 7

volume ar dentro esfera antes fechar

$$V_{ar} := V_i + V_o - V_{ce}$$

4, **(21)**

176236415958161081734124224695168896031951798384925146321112536626703205093051268156441333425005898 9

volume externo esfera depois fechar

$$V_{ef} := V_e - V_{ce}$$

4, **(22)**

188790204755711304943054152723343582229775475787431012712688657648653288406761059316957317026305889 6

massa ar dentro esfera

$$M_{ar} := V_{ar} \cdot d_{ar}$$

5, **(23)**

028668912001461130932284990818823295245513639712264142562446422040262729800619427756193356197050977 9

densidade ar depois

$$d_{ar_2} := \frac{V_{ar}}{V_i - V_{ci}} \cdot d_{ar}$$

1, **(24)**

204115005661273561207945548261655634956384243542796345096925366168137158394

625196955595978311146453052

massa Ferro se não houvesse furo

$$M_{Fe} := V_{Fe} \cdot d_{Fe}$$

98, **(25)**

84868759778073619882340945691011820824098691333141551060040716673261832251989231231400320364463017 91

massa Ferro com furo

$$M_{Fesem_{Mo}} := V_{Fesem_{Vo}} \cdot d_{Fe}$$

98, **(26)**

84853299191045754711425329384747912166363586733119196727037692683495601215089559790285487663612665 19

massa cilindro

$$M_{cil} := V_{cil} \cdot d_{Fe}$$

, **(27)**

00015460611209327214711596959699680416039493778947209115007345946120185546085322234130716373126265 36

massa total Ferro inclusive cilindro

$$MT_{Fe} := M_{cil} + M_{Fesem_{Mo}}$$

98, **(28)**

84868759802255081926136926344447592582403080512066405842045038629615786761174882024416204036738930 55

massa total esfera P2

$$M_{P2} := MT_{Fe} + M_{ar}$$

103, **(29)**

87735651002401195019365425426329922106954444483292820098289680833642059741236824800035539656444028 34

massa total esfera P1

$$M_{P1} := M_{Fesem_{Mo}}$$

98, **(30)**

84853299191045754711425329384747912166363586733119196727037692683495601215089559790285487663612665 19

densidade P2

$$d_{P2} := \frac{M_{P2}}{V_{ef}}$$

24, **(31)**

79889214601572554799310585731232169752127766037707478386353887929289441481 6

977541753533062431251166

densidade P1

$d_{P1} := d_{Fe}$

7.874,0 **(32)**

densidade P1 com empuxo

$d_{P1e} := d_{P1} - d_{ar}$

7.872,795885 **(33)**

densidade P2 com empuxo

$d_{P2e} := d_{P2} - d_{ar}$

23, **(34)**

594777146015725547993105857312321697521277660377074783863538879292894414816
977541753533062431251166

fator densidade P1

$$fd_{P1} := \frac{d_{P1e}}{d_{P1}}$$

, **(35)**

999847077089154178308356616713233426466852933705867411734823469646939293878
587757175514351028702057 4

fator densidade P2

$$fd_{P2} := \frac{d_{P2e}}{d_{P2}}$$

, **(36)**

951444806771601802546967200491441533146810184115848623855546082958348298531
595850580464421102139881 4

peso P1

$p_{P1} := fd_{P1} \cdot M_{P1}$

98, **(37)**

833416786512495360095032633559833559392543410015673615960284245870610587581
607932719610173042047313 7

peso P2

$p_{P2} := fd_{P2} \cdot M_{P2}$

98, **(38)**

833571392624588632242148603156830363552938347805145707110357705331812443042
461155060917336773309967 2

diferença peso |P1 − P2|

$resp_{incompleta} := p_{P2} - p_{P1}$

, **(39)**

000154606112093272147115969596996804160394937789472091150073459461201855460
85322234130716373126265 36

diferença entre massa do cilindro e resposta correta pelo método completo

evalf$\left(\text{resp}_{incompleta} - \text{M}_{cil}\right)$

$$3.55151\ 10^{-108} \quad \textbf{(40)}$$

raio da Terra no equador

$a := 6378136.6$

$$6.378.136,600000000 \quad \textbf{(41)}$$

achatamento polar

$$\phi := \frac{1}{298.25642}$$

$$,003352819697896192813 \quad \textbf{(42)}$$

raio polar médio

$b := a \cdot (1 - \phi)$

$$6.356.751,857971647 \quad \textbf{(43)}$$

volume elipsóide terrestre

$$V_T := \text{evalf}\left(\frac{4 \cdot \pi \cdot a^2 \cdot b}{3}\right)$$

$$1,083207106186169154 \times 10^{21} \quad \textbf{(44)}$$

raio da esfera para ter mesmo volume do elipsóide terrestre

$$R_{Tv} := \sqrt[3]{a^2 \cdot b}$$

$$6.371.000,371208768 \quad \textbf{(45)}$$

raio da esfera para ter mesma área superfícial do elipóide terrestre

$$R_{Ta} := \sqrt{\frac{a^2 + \frac{a \cdot b^2}{\sqrt{a^2 - b^2}} \cdot \ln\left(\frac{a + \sqrt{a^2 - b^2}}{b}\right)}{2}}$$

$$6.371.006,762152167 \quad \textbf{(46)}$$

área superfícial do elipóide terrestre

$$A_T := \text{evalf}\left(R_{Ta}^2 \cdot 4 \cdot \pi\right)$$

$$510.065.554.670.863,289165 \quad \textbf{(47)}$$

aceleração gravitacional média (ponderada) = standard gravity

$g_T := 9.797645$

$$9.797645 \quad \textbf{(48)}$$

gravidade standard oficial

$g_0 := 9.80665$

$$9.80665 \quad \textbf{(49)}$$

densidade Hg a zero Celsius

$d_{Hg} := 13595.076$

$$13.595,076000 \quad \textbf{(50)}$$

pressão standard em mmHg

$P_{std} := 0.760 \cdot d_{Hg}$

$$10.332,257760000 \quad \textbf{(51)}$$

pressão atmosférica média

$p_T := P_{std} \cdot g_T$

$$101.231,793580975 \quad \textbf{(52)}$$

pressão atmosférica standard oficial

$p_0 := P_{std} \cdot g_0$

$$101.324,835562104 \quad \textbf{(53)}$$

massa total da atmosfera calculada

$M_{Tatm} := P_{std} \cdot A_T$

$$5,270128785357 \times 10^{18} \quad \textbf{(54)}$$

massa total da atmosfera consultada

$M_{atm} := 5.1480 \cdot 10^{18}$

$$5,148000 \times 10^{18} \quad \textbf{(55)}$$

massa de ar subtraída da atmosfera

$m_0 := V_{cil} \cdot d_{ar}$

$$2.364281669585857142806016399387945664134499826901029148726233669355755502226032759754577803776100063916099546710^{-8} \quad \textbf{(56)}$$

proporção entre densidades externas antes e depois de fechada a esfera

$$ratio_d := \frac{M_{Tatm}}{M_{Tatm} - m_0}$$

$$1.000000000000000000000000044861933472197311970134638092344234240617731385194234067152255269819270503861256944 \quad \textbf{(57)}$$

densidade externa ar depois de fechar a esfera

$$dar_{ext} := \frac{d_{ar}}{ratio_d}$$

$$1.204114999999999999999999945981072977125133697081330495776273421327965890904307940610744234026000862023671244 \quad \textbf{(58)}$$

densidade P2 com empuxo na atmosfera restante

$d_{real_{P2e}} := d_{P2} - dar_{ext}$

23, **(59)**

5947771460157255479931058627142143998087642906689417342859115371600978257265467476924588828405250304

proporção Real densidade P2

$ratio_{dP2} := \frac{d_{real_{P2e}}}{d_{P2}}$

, **(60)**

9514448067716018025469672007092695179810187197257326811843724597894522518738629349109652522131786719

peso Real P2

$p_{real_{P2}} := ratio_{dP2} \cdot M_{P2}$

98, **(61)**

8335713926245886322421486257842256020361221197607252996295172131763389537672056254875239657278770173

diferença Real peso |P1 − P2|

$resp_{certa} := p_{real_{P2}} - p_{P1}$

,000154606112093272147115992224 **(62)**

erro na melhor solução

$err := evalf\left(resp_{certa} - resp_{incompleta}\right)$

$2{,}262739 \times 10^{-26}$ **(63)**

solução em função dFe

$\frac{resp_{certa}}{d_{Fe}}$

,000000019635015505876574436879886 26 **(64)**