

Experimente mit dem Smartphone

Experimentelle Mechanik Wintersemester 2019/20
Steffen Mittelman

17.10.2019

Experimentelle Mechanik Wintersemester 2019/20

Das Smartphone



<https://www.apple.com>



<https://www.movetix.com>



<https://www.o2online.de>

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Das Smartphone

Sensoren

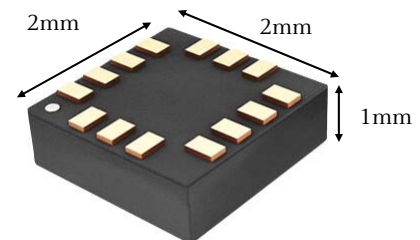
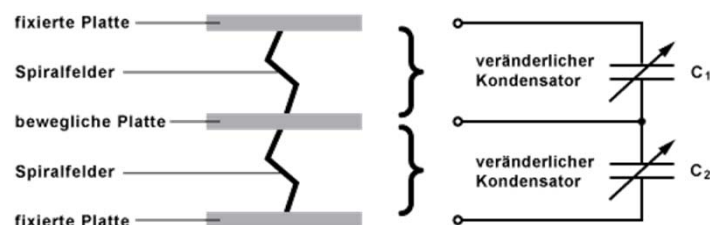
- Beschleunigungssensor
- Gyroskop
- Magnetfeldsensor
- Drucksensor
- Näherungssensor
- Luftfeuchtigkeitssensor
- Temperatursensor
- Lichtsensor (Kamera)
- GPS
- Bluetooth
- NFC
- ...



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Beschleunigungssensor



<https://www.elektronik-kompodium.de/sites/bau/1503041.htm>

<https://www.reichelt.de>

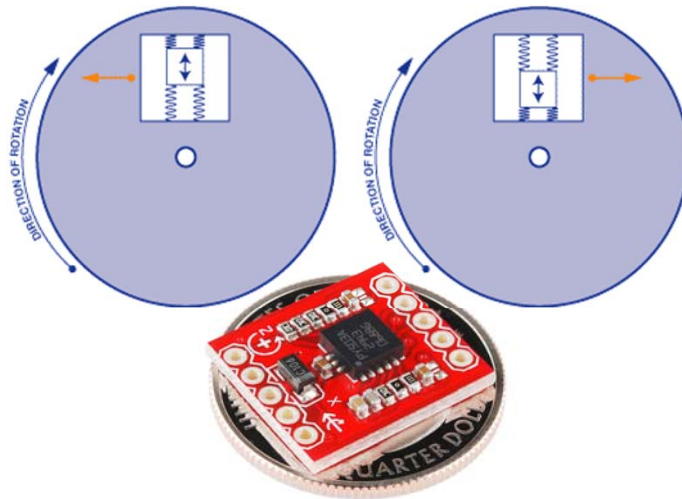
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Gyroskop

MEMS-Gyroskop

- MEMS:
mikroelektromechanisches
System
- Messung der
Winkelgeschwindigkeit
- Testmasse bewegt sich im
Kondensator



<https://learn.sparkfun.com/tutorials/gyroscope/all>

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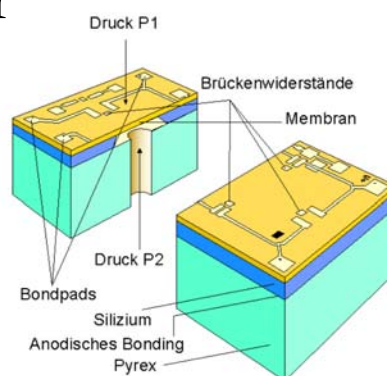
Luftdrucksensor

Funktion

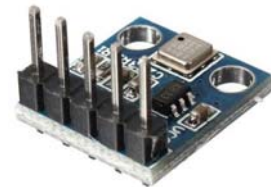
- 12 μm Membran
- 5 μm Hohlraum
- Luftdruck ändert
Verbiegung
- Widerstand ändert sich
bei Verspannung

Verwendung

- Indoor-Navigation
- Höhenmessung
- Wettervorhersage



<https://www.amsys.de/>

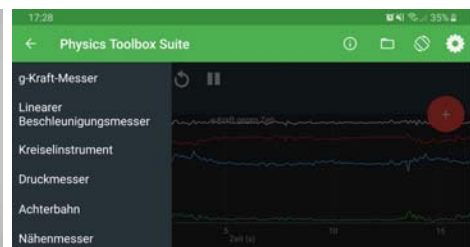
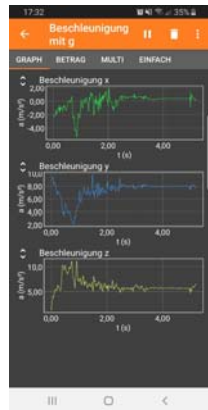


<https://www.mikrocontroller.net/topic/438371>

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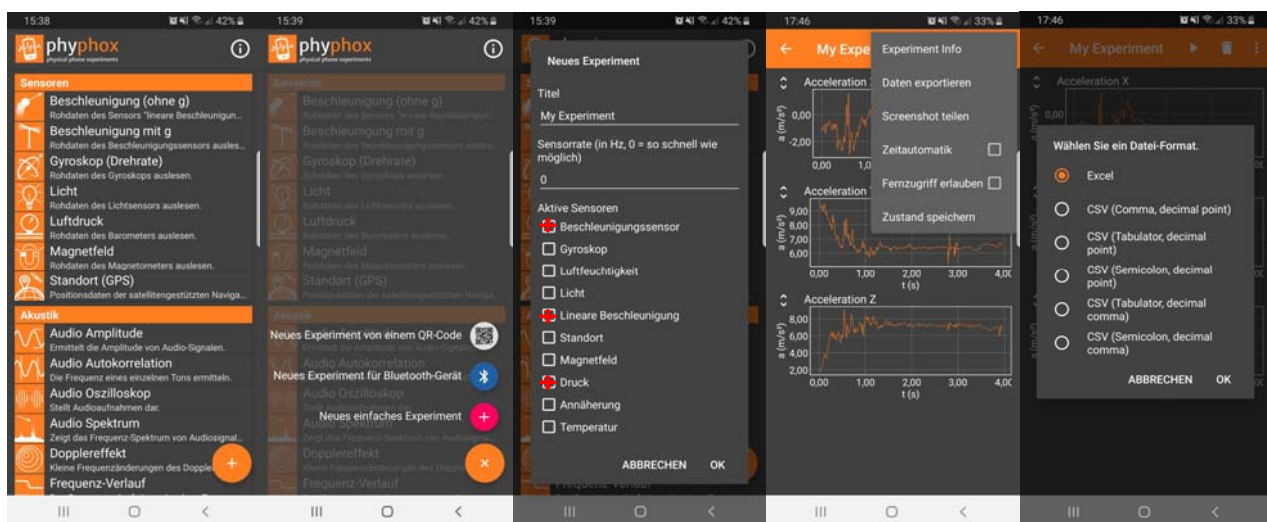
Software



phyphox.org

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Bitte das Smartphone beim Experimentieren nicht zerstören!



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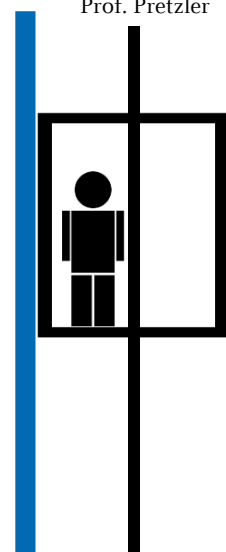
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Aufzugsexperiment

Beschleunigung im Aufzug

Sensoren: Beschleunigungssensor, Luftdrucksensor (falls vorhanden)

- Das Smartphone ruhig auf dem Boden platzieren
- Datenaufnahme starten und eine Fahrt nach oben und eine nach unten machen
- Berechnung der Geschwindigkeit und Höhe
- Berechnung des „Rucks“ (siehe Vorlesung: $j < 2\text{m/s}^3$)
- **Tipp:** Sensorrate nicht zu hoch! ($\approx 10\text{ Hz}$)
- Z.B. Excel, OpenOffice Calc, MATLAB, Octave oder Origin zur Datenauswertung



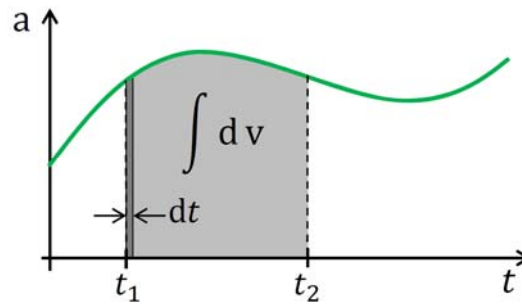
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Aufzugsexperiment

Beschleunigung: $a(t)$ \longrightarrow Sensordaten

Geschwindigkeit: $v(t) = \int a(t) dt$



Skript Experimentelle Mechanik 2019/20 Prof. Pretzler

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Experimentelle Mechanik Wintersemester 2019/20

Aufzugsexperiment

Beschleunigung: $a(t)$ \longrightarrow Sensordaten

Geschwindigkeit: $v(t) = \int a(t) dt \longrightarrow v_i = \sum_{i=1}^N a_i \cdot \Delta t \quad \Delta t = t_i - t_{i-1}$

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Excel spreadsheet showing acceleration data over time. The formula bar displays $f_x = \text{=D2-MITTELWERT(D:D)}$.

Time (s)	Acceleration x (m/s²)	Acceleration y (m/s²)	Acceleration z (m/s²)	Ohne g
0.201952	0.225061834	0.057462595	9.675264359	-0.167578872
0.403926	0.246610299	0.086193889	9.701601982	-0.206577751
0.605901	0.229803262	0.071828246	9.706390381	0.04788399
0.807876	0.234638929	0.069433972	9.677659035	-0.143651956
1.00985	0.229803262	0.064645417	9.69681263	0.004788399
1.211826	0.234638929	0.071828246	9.677659035	-0.167578872
1.413802	0.229803262	0.07422252	9.69681263	0.004788399
1.615776	0.215484738	0.059856869	9.708784103	0.167578872
1.817751	0.220273286	0.059856869	9.680052757	-0.029713146
2.019725	0.251398861	0.069433972	9.672870636	-0.19153595
2.2217	0.234638929	0.043096945	9.739910126	0.04788399
2.423678	0.234638929	0.062251143	9.706390381	0.143651956
2.625652	0.239427477	0.071828246	9.749486923	0.057462595
2.827628	0.232244655	0.076616794	9.636956215	-0.05008016
3.029602	0.205807628	0.026337024	9.677659035	-0.143651956
3.231577	0.229803262	0.016759925	9.703995705	-0.19153595
3.432478	0.258581668	0.071828246	9.64413929	-0.029713146
3.634452	0.241821751	0.07422252	9.63292885	-0.019174714
3.836427	0.196330532	0.071828246	9.703995705	-0.19153595
4.038401	0.191541985	0.079011068	9.668081284	-0.223942947
4.240376	0.244216025	0.071828246	9.672870636	-0.19153595
4.442354	0.241821751	0.059856869	9.663292885	-0.019174714
4.644329	0.241821751	0.047885496	9.69681263	0.004788399
4.846304	0.244216025	0.052674048	9.694418907	0.002394676
5.048278	0.239427477	0.083799616	9.694418907	0.002394676
5.250253	0.208301902	0.098165266	9.677659035	-0.143651956
5.45223	0.122108012	0.009577099	9.675264359	-0.167578872
5.654211	0.246610299	0.059856869	9.672870636	-0.19153595
5.856185	0.280130148	0.064645417	9.668081284	-0.223942947
6.05816	0.2753416	0.05027977	9.668081284	-0.223942947

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Excel spreadsheet showing acceleration and velocity data over time. The formula bar displays $f_x = \text{=E3*(A3-A2) + F2}$.

Time (s)	Acceleration x (m/s²)	Acceleration y (m/s²)	Acceleration z (m/s²)	Ohne g	Geschwindigkeit (m/s)
0.201952	0.225061834	0.057462595	9.675264359	-0.167578872	0
0.403926	0.246610299	0.086193889	9.701601982	-0.206577751	-0.167578872
0.605901	0.229803262	0.071828246	9.706390381	0.04788399	-0.335157744
0.807876	0.234638929	0.069433972	9.677659035	-0.143651956	-0.502736616
1.00985	0.229803262	0.064645417	9.69681263	0.004788399	-0.670315488
1.211826	0.234638929	0.071828246	9.677659035	-0.167578872	-0.837894360
1.413802	0.229803262	0.07422252	9.69681263	0.004788399	-1.005473232
1.615776	0.215484738	0.059856869	9.708784103	0.167578872	-1.173052104
1.817751	0.220273286	0.059856869	9.680052757	-0.029713146	-1.340630976
2.019725	0.251398861	0.069433972	9.672870636	-0.19153595	-1.508209848
2.2217	0.234638929	0.043096945	9.739910126	0.04788399	-1.675788720
2.423678	0.234638929	0.062251143	9.706390381	0.143651956	-1.843367592
2.625652	0.239427477	0.071828246	9.749486923	0.057462595	-2.010946464
2.827628	0.232244655	0.076616794	9.636956215	-0.05008016	-2.178525336
3.029602	0.205807628	0.026337024	9.677659035	-0.143651956	-2.346104208
3.231577	0.229803262	0.016759925	9.703995705	-0.19153595	-2.513683080
3.432478	0.258581668	0.071828246	9.64413929	-0.029713146	-2.681261952
3.634452	0.241821751	0.07422252	9.63292885	-0.019174714	-2.848840824
3.836427	0.196330532	0.071828246	9.703995705	-0.19153595	-3.016419696
4.038401	0.191541985	0.079011068	9.668081284	-0.223942947	-3.184000000
4.240376	0.244216025	0.071828246	9.672870636	-0.19153595	-3.351580304
4.442354	0.241821751	0.059856869	9.663292885	-0.019174714	-3.519160608
4.644329	0.241821751	0.047885496	9.69681263	0.004788399	-3.686740912
4.846304	0.244216025	0.052674048	9.694418907	0.002394676	-3.854321216
5.048278	0.239427477	0.083799616	9.694418907	0.002394676	-4.021901520
5.250253	0.208301902	0.098165266	9.677659035	-0.143651956	-4.189481824
5.45223	0.122108012	0.009577099	9.675264359	-0.167578872	-4.357062128
5.654211	0.246610299	0.059856869	9.672870636	-0.19153595	-4.524642432
5.856185	0.280130148	0.064645417	9.668081284	-0.223942947	-4.692222736
6.05816	0.2753416	0.05027977	9.668081284	-0.223942947	-4.859803040

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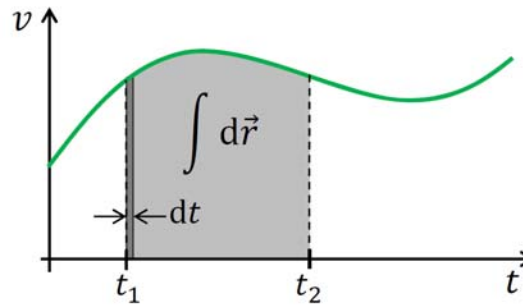
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Aufzugsexperiment

Beschleunigung: $a(t)$ \longrightarrow Sensordaten

Geschwindigkeit: $v(t) = \int a(t) dt$

Position (Höhe): $z(t) = \int v(t) dt$



Skript Experimentelle Mechanik 2019/20 Prof. Pretzler

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Aufzugsexperiment

Beschleunigung: $a(t)$ \longrightarrow Sensordaten

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Position (Höhe): $z(t) = \int v(t) dt \longrightarrow z_i = \sum_{i=1}^N v_i \cdot \Delta t \quad \Delta t = t_i - t_{i-1}$

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Aufzug Stz 2019-10-11 11-22-01.xls (Kompatibilitätsmodus) - Excel

Formeln: $f_x = F3*(A3-A2) + G2$

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Time (s)	Acceleration x (m/s ²)	Acceleration y (m/s ²)	Acceleration z (m/s ²)	Time g	Geschwindigkeit (m/s)	Höhe (m)																								
0.201952	0.225061834	0.057462395	9.675264359	-0.16759872	0	0																								
0.403904	0.246610299	0.086193089	9.701601982	0.18442211	0.001934456	F3*(A3-A2) + G2																								
0.605808	0.229850382	0.071820246	9.706190381	0.014365196	0.004536051																									
0.807716	0.234638929	0.068433972	9.677659035	-0.014365196	0.001934456																									
1.009624	0.229850382	0.064645417	9.69681263	0.004788399	0.004788399																									
1.211528	0.234638929	0.071820246	9.677659035	-0.014365196	0.001934456																									
1.413432	0.229850382	0.07422252	9.69681263	0.004788399	0.000967522																									
1.615336	0.215484738	0.059858869	9.708784103	0.016759872	0.004352585																									
1.817240	0.220273286	0.059858869	9.680521757	-0.011971474	0.001934456																									
2.019144	0.251398861	0.068433972	9.672870636	-0.019153595	-0.001933888																									
2.221048	0.234638929	0.043096945	9.739910126	0.047885895	0.007737863																									
2.422952	0.234638929	0.062251143	9.706190381	0.014365196	0.006395111																									
2.624856	0.238474777	0.071820246	9.748488923	0.057462395	0.02024548																									
2.826760	0.232446555	0.076616794	9.636956215	-0.050068016	0.011123108																									
3.028664	0.205907628	0.02537024	9.677659035	-0.014365196	0.002221712																									
3.230568	0.229850382	0.016759872	9.703990705	0.011971474	0.010639652																									
3.432472	0.258816688	0.071820246	9.64413929	-0.047884941	0.001019521																									
3.634376	0.241821751	0.07422252	9.663292885	0.028731346	-0.00478347																									
3.836280	0.196230532	0.071820246	9.703990705	0.011971474	-0.002365529																									
4.038184	0.191541985	0.079011068	9.668081284	-0.023942947	-0.007201384																									
4.240088	0.244216025	0.071820246	9.672870636	-0.019153595	-0.011069934																									
4.441992	0.241821751	0.059858869	9.683292885	-0.028731346	-0.01687363																									
4.643896	0.241821751	0.047885895	9.69681263	0.004788399	-0.015905896																									
4.845800	0.244216025	0.052674048	9.694418907	0.002294676	-0.015422231																									
5.047704	0.239427477	0.083799616	9.694418907	0.002294676	-0.014398568																									
5.249608	0.208019602	0.081652966	9.677659035	-0.014365196	-0.017539982																									
5.451512	0.122108012	0.009577099	9.675264359	-0.16759872	-0.021225086																									
5.653416	0.246610299	0.059858869	9.672870636	-0.019153595	-0.020937156																									
5.855320	0.280130148	0.064645417	9.668081284	-0.023942947	-0.020929611																									
6.057224	0.2753416	0.05027977	9.668081284	-0.023942947	-0.034765492																									

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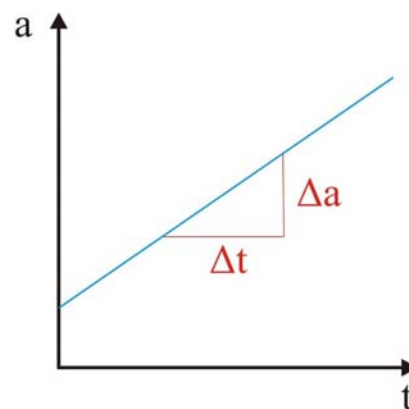
Aufzugsexperiment

Beschleunigung: $a(t)$ \longrightarrow Sensordaten

Geschwindigkeit: $v(t) = \int a(t)dt$

Position (Höhe): $z(t) = \int v(t)dt$

Ruck: $j(t) = \frac{da(t)}{dt}$



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Aufzugsexperiment

Beschleunigung: $a(t)$ \longrightarrow Sensordaten

Geschwindigkeit: $v(t) = \int a(t) dt$

Position (Höhe): $z(t) = \int v(t) dt$

Ruck: $j(t) = \frac{da(t)}{dt}$ \longrightarrow $j_i = \frac{a_i - a_{i-1}}{t_i - t_{i-1}}$

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Time (s)	Acceleration x (m/s²)	Acceleration y (m/s²)	Acceleration z (m/s²)	Ruck (m/s³)
0.201952	0.225061834	0.057462939	9.675264359	
0.403904	0.246010299	0.086193899	9.705070562	
0.605856	0.229850382	0.071828246	9.706390381	
0.807808	0.234638929	0.069433972	9.677659036	
1.00976	0.229850382	0.064454517	9.69681263	
1.211806	0.234638929	0.071828246	9.677659036	
1.413802	0.229850382	0.07422252	9.69681263	
1.615776	0.215484738	0.059856869	9.700784103	
1.817751	0.220273286	0.059856869	9.680527817	
2.019725	0.251798861	0.069433972	9.672870636	
2.2217	0.234638929	0.043096945	9.739910126	
2.423678	0.234638929	0.062251143	9.706390381	
2.625652	0.239427477	0.071828246	9.749486923	
2.827628	0.232244655	0.076616794	9.630956215	
3.029602	0.205067628	0.020337024	9.677659036	
3.231577	0.229850382	0.016759925	9.703995705	
3.432478	0.258081668	0.071828246	9.64413929	
3.634442	0.241821751	0.07422252	9.68292885	
3.836427	0.196330532	0.071828246	9.703995705	
4.038401	0.191541985	0.079011068	9.668081284	
4.240376	0.244216025	0.071828246	9.672870636	
4.442354	0.241821751	0.059856869	9.68292885	
4.644329	0.241821751	0.047885496	9.69681263	
4.846304	0.244216025	0.052674048	9.694418907	
5.048278	0.259427477	0.083799616	9.684188007	
5.250253	0.208301902	0.098165266	9.677659036	
5.45223	0.122108012	0.009577099	9.675264359	
5.654211	0.246010299	0.059856869	9.672870636	
5.856185	0.280130148	0.064454517	9.668081284	
6.05816	0.2753416	0.05027977	9.668081284	

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Aufzugsexperiment

Höhenmessung mit Drucksensor

Internationale Höhenformel in Standardatmosphäre

Temperatur: $15^{\circ}\text{C} = 288,15\text{K}$

Luftdruck: $1013,25\text{ hPa}$

Temperaturgradient: $0,0065\frac{\text{K}}{\text{m}}$

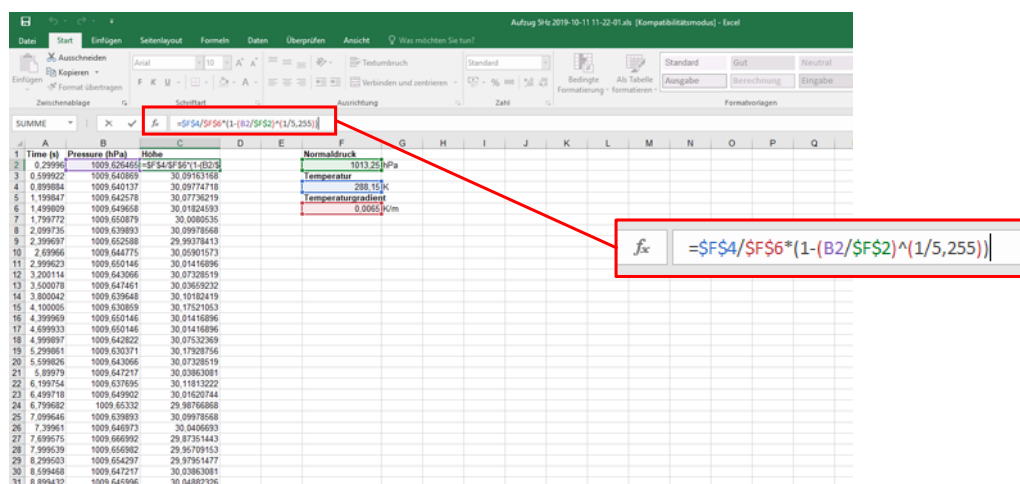
$$p(h) = 1013,25\text{hPa} \cdot \left(1 - \frac{0,0065\frac{\text{K}}{\text{m}} \cdot h}{288,15\text{K}}\right)^{5,255}$$

$$\rightarrow h = \frac{288,15\text{K}}{0,0065\frac{\text{K}}{\text{m}}} \cdot \left(1 - \left(\frac{p(h)}{1013,25\text{hPa}}\right)^{\frac{1}{5,255}}\right)$$

https://de.wikipedia.org/wiki/Barometrische_Höhenformel

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