	TEAM: TEAM 5	
	Belgium	Ine Van Neste Yänka Delecluyse Lotte De Coster
Smartphone-accelerations into physics situations	Italy	Bianca Casalani Elena Atzeni
EXPERIMENT: Centrifugal acceleration		

1. ORIENTATION

Our experiment is that we will put a phone on a rotary device and let it spin, you will have to put the phone on different spaces on the rotary device. We want to measure how the velocity and the acceleration changes and if the angular velocity or the centrifugal acceleration changes. Because we had to do this experiment at school, we decided to use an office chair.

- **Research question:**

  How does the velocity and the acceleration change when we measure from different distances from the center of the rotary device (=change radius)?

- **Hypothesis**

  When you put your phone on different places on the rotary device, your radius will change. We think that the centrifugal acceleration will be smaller if the radius increases and that the velocity will become bigger when the radius increases. This is derived from the following formula: ac = v^2/r. The centrifugal acceleration is inversely proportional to the radius and the velocity is directly proportional to the radius. The angular velocity will not change, because it is independent of the position on the wheel.

2. PREPARATION

- **Material**:

  -Phone, with the app Phyphox

  -rotary device

  -person who spins the rotary device

  -tape

  -a ruler

- **Method:**

- Place the phone on the rotary device
- And tape it on the device
- Let the rotary device spin and use the app ‘Phypox’ (https://phyphox.org/experiment/centrifugal-acceleration/, this is the link to the experiment)
- press on the three points in the right upper corner and press on timed measurement.
- Delayed start 5s and duration experiment 10s.
- Press on start button and start spinning the rotary device for 15s.
- When you are ready press again on the three points and export the data to excel.
- Place the phone on another place on the rotary device.
- Spin again and measure again (explained above)
- Repeat this for a few times

3. DATA ANALYSIS and DISCUSSION

- **Observations and Measurements**:

  Measurements 10 cm from the center

  Measurement 1:

Time (s)	Angular velocity (rad/s)	Acceleration (m/s^2)
1,020752654	4,264296956	3,947252192
1,520752654	4,377655418	5,080700708
2,020752654	4,120097537	1,810609842
2,520752654	4,313479582	3,656021007
3,020752654	4,561620998	5,13057487
3,520752654	4,419415203	2,586854461
4,020752654	4,348748813	3,221537674
4,520752654	4,865587571	5,595029723
5,020752654	4,736505868	3,422755832
5,520752654	4,950541653	4,828306979
6,020752654	4,843336765	5,040056025
6,520752654	4,342634333	1,976423145
7,020752654	4,583905465	5,061615342
7,520752654	4,685100881	4,878537329
8,020752654	4,706644872	2,568262998
8,520752654	5,115848864	6,611368954
9,020752654	4,464062397	3,080292012
9,520752654	4,786721236	4,179070572

Measurement 2:

Time (s)	Angular velocity (rad/s)	Acceleration (m/s^2)
0,775894273	5,082910194	2,055367295
1,525894273	5,429400265	4,408107463
2,025894273	5,31150901	5,63775585
3,025894273	5,507206674	2,619148329
3,525894273	4,813835246	7,027732289
4,025894273	5,5839193	3,031284708
4,525894273	5,030512446	6,383838907
5,025894273	4,503642964	5,208274178
5,525894273	5,385232483	2,89946732
6,025894273	4,820467767	6,444914804
6,525894273	5,744025418	2,707717713
7,025894273	5,242852287	6,524482437
7,525894273	5,165457913	4,5355535
8,025894273	5,373503177	4,738263059
8,525894273	4,711013913	5,641991879
9,025894273	5,678804014	2,342869104
9,525894273	4,745768347	6,052475991

Measurement 3:

Time (s)	Angular velocity (rad/s)	Acceleration (m/s^2)
0,539929655	3,240644053	3,054598516
1,289929655	5,561600456	10,96075762
1,789929655	4,935250075	9,304288109
2,289929655	5,21769934	7,883767433
3,039929655	5,418687684	5,187204875
3,539929655	5,008812129	11,81549946
4,039929655	5,495468678	7,44869795
4,539929655	5,529581292	11,31291413
5,039929655	5,81195468	10,83644053
5,539929655	5,614626624	9,508319884
6,039929655	5,404188106	11,85966662
6,539929655	5,475301111	6,106773107
7,039929655	5,474978158	13,14936962
7,539929655	5,716325172	6,009632759
8,039929655	5,527329612	12,8643915
8,539929655	5,811864857	8,317593895
9,039929655	5,507333644	11,40095951
9,539929655	5,706324053	10,66102396

Measurements in the center:

Measurement 1:

Experiment

Time (s)	Angular velocity (rad/s)	Acceleration (m/s^2)
0,775754193	5,240178112	1,581785764
1,275754193	5,91822539	6,399991103
2,025754193	5,442222841	5,812894934
2,525754193	5,690687771	5,382732008
3,025754193	5,66772433	4,679946622
3,525754193	5,336288483	6,211805887
4,025754193	6,064418243	3,299211745
4,525754193	5,522236491	6,833721611
5,025754193	6,218843534	2,868677414
5,525754193	5,487973941	6,813340516
6,025754193	5,886065428	2,650849586
6,525754193	5,376316604	6,349328965
7,025754193	5,763295566	4,270076347
7,525754193	5,735411143	5,899456091
8,025754193	5,923650979	5,570704491
8,525754193	5,917771151	5,137618616
9,025754193	5,601321107	6,024985942
9,525754193	6,097709008	4,131205052

Measurement 2:

Time (s)	Angular velocity (rad/s)	Acceleration (m/s^2)
0,769813462	5,125901379	0,995140064
1,269813462	5,435052072	5,250582895
2,019813462	4,395168054	2,967533833
2,519813462	5,154373258	5,529411864
3,019813462	4,991145804	1,213660761
3,519813462	5,573497803	5,861907714
4,019813462	5,030048065	2,688928105
4,519813462	5,237109229	3,861968422
5,019813462	5,603998	5,327459407
5,519813462	4,918559793	1,703585913
6,019813462	5,258657277	5,52079874
6,519813462	4,917571988	2,134267401
7,019813462	5,119014862	3,86572723
7,519813462	5,643201377	4,861606224
8,019813462	5,28443764	2,597084387
8,519813462	5,803692947	6,02366434
9,019813462	4,861602857	1,166012171
9,519813462	5,148548182	5,020557041

Measurement 3:

Time (s)	Angular velocity (rad/s)	Acceleration (m/s^2)
0,529173469	3,567895634	1,26400476
1,029173469	5,822229595	6,744791613
1,779173469	5,985667261	3,093584848
2,529173469	5,88399767	4,239907713
3,029173469	6,067496628	5,842670019
3,529173469	6,300494671	5,285338901
4,029173469	6,175164674	5,955143491
4,529173469	5,94573823	5,163731741
5,029173469	6,025433797	5,172816698
5,529173469	6,008329553	5,757910848
6,029173469	5,598585805	3,699998488
6,529173469	5,694695015	6,272795219
7,029173469	6,08515759	3,205308631
7,529173469	6,169452994	7,12937346
8,029173469	6,010654556	2,904847638
8,529173469	6,111274348	7,137021939
9,029173469	5,677978995	2,023621771
9,529173469	5,868154327	6,968167048

Experiment

Measurements 5 cm from the center:

Measurement 1:

Time (s)	Angular velocity (rad/s)	Acceleration (m/s^2)
0,775101001	5,327178278	3,681920634
1,275101001	5,516120349	9,102478368
1,775101001	5,565934031	3,470082059
2,275101001	5,782013171	8,993172457
2,775101001	6,276222951	6,265501044
3,525101001	5,667534588	6,421111743
4,025101001	5,864500036	7,294265029
4,525101001	5,910894579	8,159635461
5,025101001	5,866042588	6,078662599
5,525101001	5,759903793	8,765309168
6,025101001	5,835570845	4,520459004
6,525101001	6,026324571	10,02695646
7,025101001	6,173462693	4,766274557
7,525101001	6,0541546	10,14603356
8,025101001	5,536310357	2,801567613
8,525101001	5,88141571	9,952286148
9,025101001	5,793200477	3,994968198
9,525101001	6,011574463	9,781783069

Measurement 2:

Time (s)	Angular velocity (rad/s)	Acceleration (m/s^2)
0,524074507	4,533920428	2,166689395
1,274074507	5,736194444	8,785635176
1,774074507	5,596543887	5,584873474
2,274074507	5,982860072	7,723920628
3,024074507	5,608326565	6,227037728
3,524074507	6,187543156	9,260521131
4,024074507	5,458218838	4,601037902
4,524074507	6,324658617	10,46269757
5,024074507	5,087152732	2,779379822
5,524074507	5,792367803	10,0235673
6,024074507	5,646890931	2,91642836
6,524074507	5,160008052	8,317909695
7,024074507	5,466487149	5,777270746
7,524074507	5,131288268	6,04057513
8,024074507	5,61359442	8,778438272
8,524074507	5,627479966	4,38832123
9,024074507	5,928466357	10,08046836
9,524074507	5,780374726	3,707653406

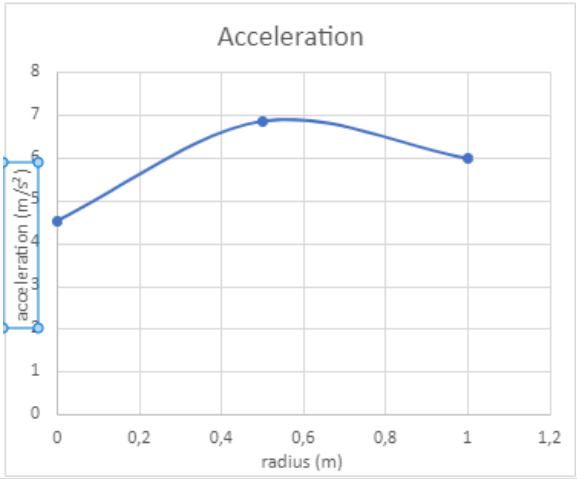
Measurement 3:

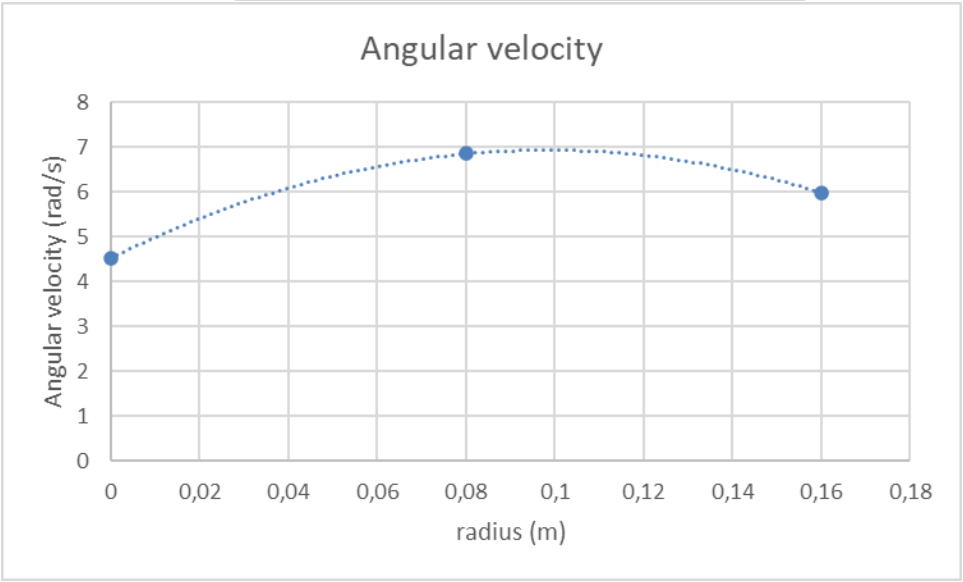
Time (s)	Angular velocity (rad/s)	Acceleration (m/s^2)
0,515855617	4,692307214	2,199040215
1,515855617	6,03417232	6,285726893
2,015855617	5,305953417	7,277605047
2,515855617	6,074392654	8,241996982
3,015855617	5,453559757	6,044271227
3,515855617	5,869425279	9,550127547
4,015855617	6,153633521	5,948379057
4,515855617	6,043432166	10,07592852
5,015855617	6,225883742	5,531976668
5,515855617	6,035816405	10,24252074
6,015855617	5,975944296	4,410095854
6,515855617	5,537976891	9,692616369
7,015855617	6,143047212	4,257715194
7,515855617	5,944132472	10,18837241
8,015855617	6,554680878	5,472886973
8,515855617	5,486316494	9,462433975
9,015855617	5,765974265	4,738824752
9,515855617	5,533025734	8,578345962

Experiment

Discussion:

Measurement: 16 cm from center	**Average Angular velocity: 5.041821422**	**Radius: 0.16m**
	Average acceleration: 5.985553684	
Measurement from the Center	**Average angular velocity: 5,833244519**	**Radius: 0.00m**
	Average acceleration: 4.525356741	
Measurement 8 cm from center	**Average angular velocity: 5,747044615**	**Radius 0.08m**
	Average acceleration: 6.852662164	





Inversely proportional relationship

Directly proportional relationship

Experiment

The angular velocity is constant if the rotation speed is constant. This we conclude out of the formula : $\omega = \frac{\varphi}{t}$

In the graphic we should see a straight line. In our graphic we see a deviation, because the speed of rotation probably was not constant. Plus or minus we can see that the angular velocity is around 5,45 rad/s.

The centrifugal acceleration increases with the square of the angular velocity. V Fox even shows a square plot to verify.

- Acceleration is 0, when the rotation speed is constant. There is deviation in the turning speed, which causes that our acceleration is 4.53 rad/s² in the centre. We comparted our measurements with the following formula $\alpha = \frac{d\omega}{dt}$ We have acceleration when we start with the turning, until the moment we have a constant rotation speed. The chair gives us a wrong outcome, because it was hard to keep the velocity constant. The rotation point of the chair wasn't very smooth, so sometimes we had to put more force to make the rotation happen, this can explain the high difference between the accelerations. We tried to decrease and increase the velocity, but it is hard to compare because there was never a constant velocity. The measurements show a lot of extreme values, such as 1,3 and 10,1.

  =>The further away that we put our phone from the center the bigger the change in velocity and acceleration. In our graphs we see that wen we put the phone further away the velocity will decrease

4. REFLECTION

Conclusion: Acceleration is the rate of change of velocity with time. Any change in the velocity of an object results in an acceleration: increasing speed, decreasing speed, or changing direction (called centripetal acceleration). That's because acceleration depends on the change in velocity and velocity is a vector quantity — one with both magnitude and direction. It's possible that our measurement results aren't totally right, because of the different in speeds we had when we were spinning the chair. It is impossible to always turn the chair with the same amount of speed.

- **Comparison** of the results of the different countries

- **Reflection:**

5. REFERENCES

Experiment