	TEAM: Team 1	
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Smartphone-accelerations into physics situations	Italy	Francesco Fichera Sara Sciarra
EXPERIMENT:		

- ORIENTATION

We are going to measure the speed of the bicycle wheel. Therefore, we will change the gears. We will also calculate the angular velocity and track speed change of the bicycle wheel. We will do this experiment by attaching a smartphone to a bicycle wheel. With the app we will measure the angular velocity and the acceleration. We will calculate the Track speed.

- **Research question:**

When you change the gears of the bike, how does it affect the speed of the wheel?

Sub-questions:

What happens with the angular velocity and track speed, when you change the gears of the bike?

- **Hypothesis**

The angular velocity will be smaller when you turn the gear up (so when the chain is on a bigger sprocket). The track speed will also be smaller when you turn the gear up, because the speed will reduce. This is because your rear wheel then does less revs each time you pedal on the bike.

The angular velocity will be bigger when you turn the gear down (when the chain is on a smaller sprocket). The track speed will also be bigger when you turn the gear up

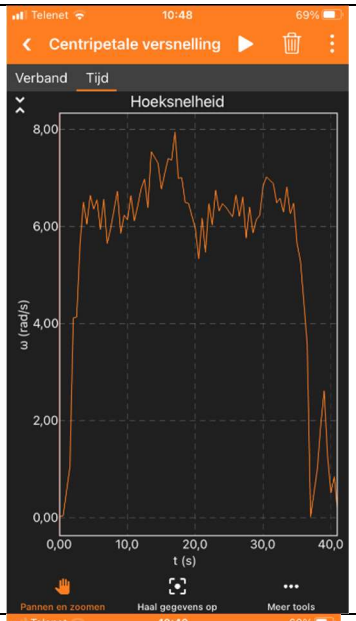
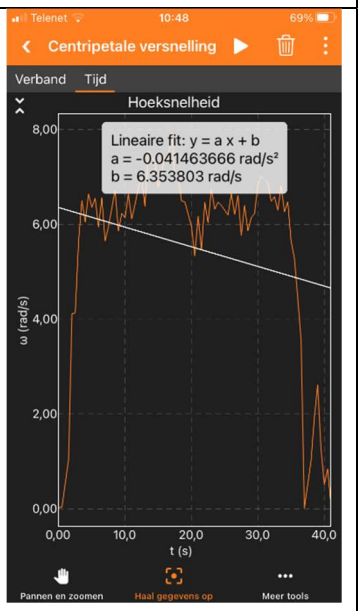
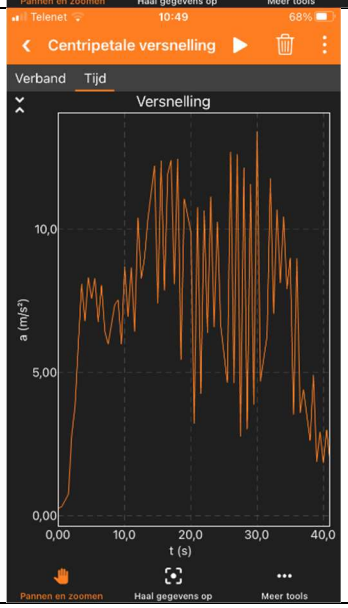
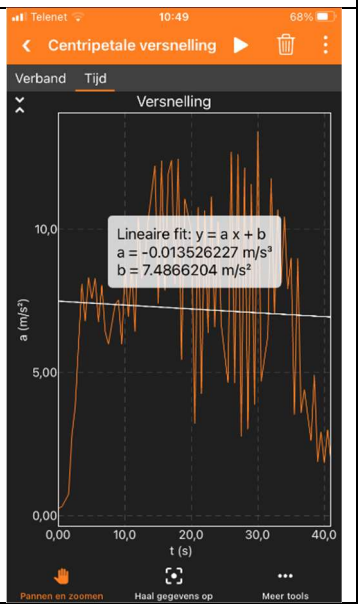
because the speed will increase. That's because your rear wheel revs more each time you pedal on the bike's pedals.

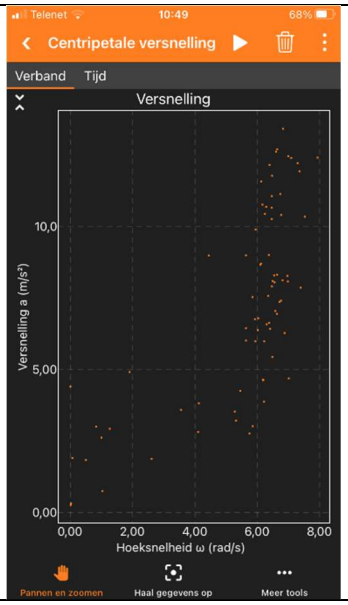
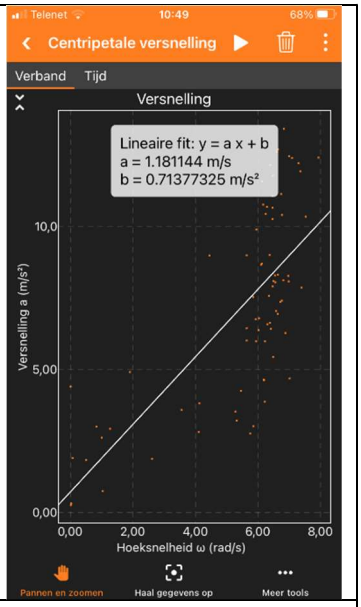
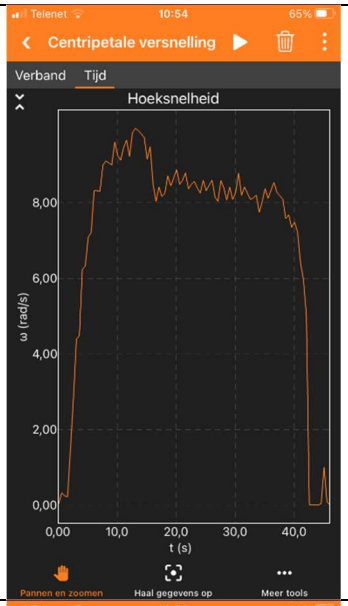
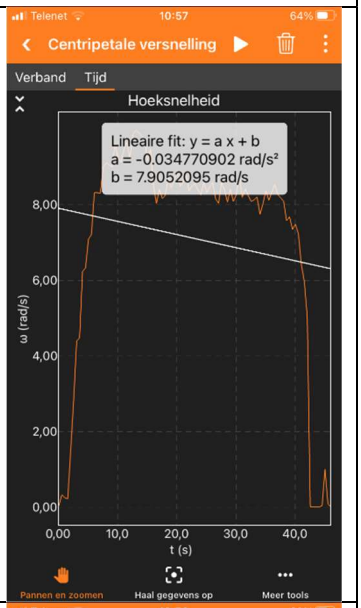
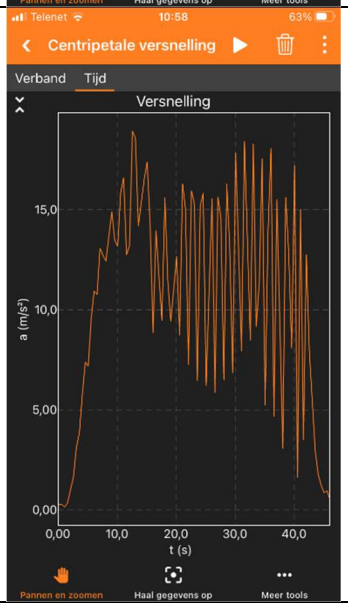
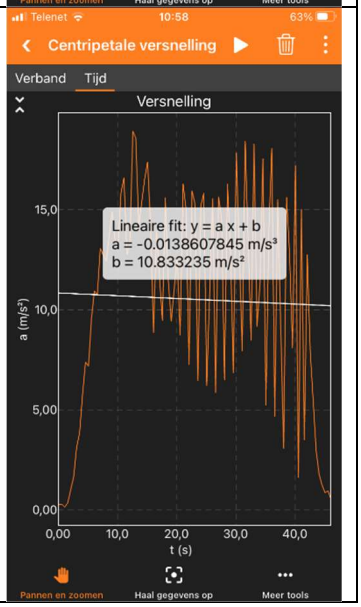
- PREPARATION
  - **Material**:
    - Bicycle with gears
    - phyphox app
    - Smartphone
    - Tape
    - Ruler (to measure the radius of the wheel)
  - . **Method:**
    - Turn the bike upside down (don’t actually ride the bike, but just turn the pedals. This is much safer for your phone)
    - Measure the radius of the wheel
    - Attach the smartphone to the back wheel with tape
    - Turn on the app phyphox (the experiment on the app that we will use is Centrifugal acceleration (Mechanics))
    - Make the weel spin by pushing the pedals
    - Using Phyphox:
      - 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 around in circles for 15s.
    - Watch the results of this experiment on the phyphox app and export the data
    - Repeat the experiment 3 times

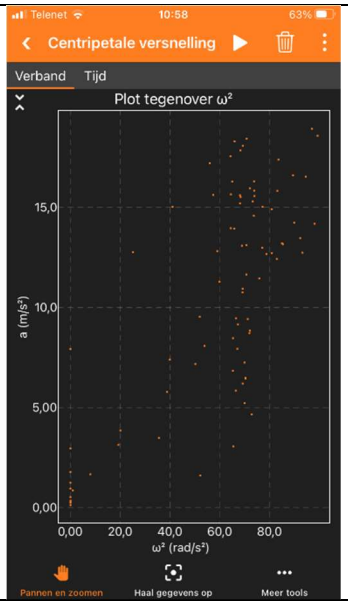
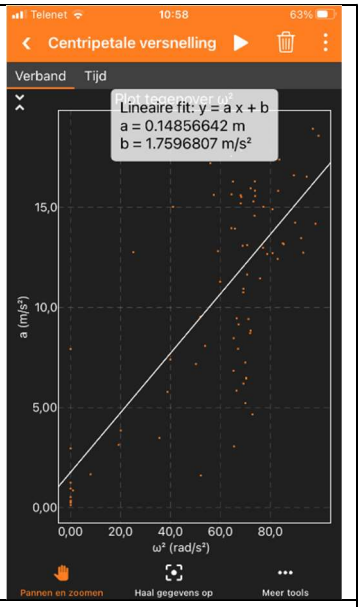
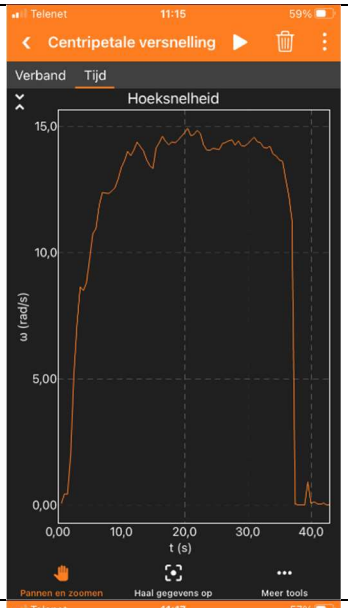
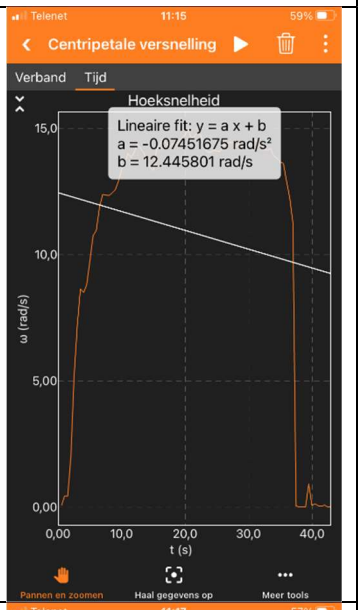
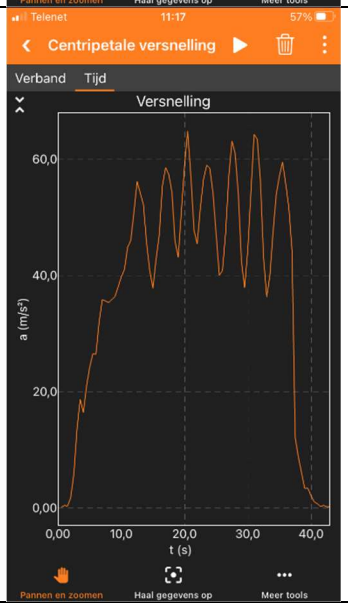
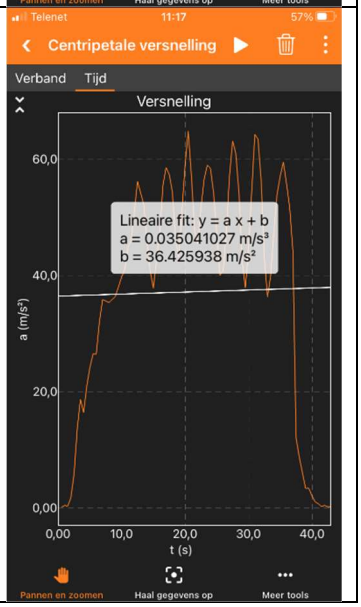
2nd part of the experiment:

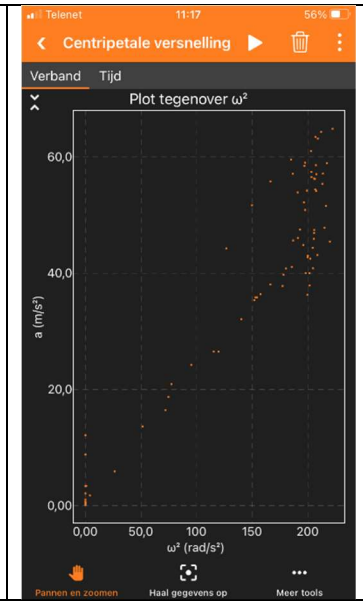
- Change the gears
- Repeat the previous steps
- Also do this experiment 3 times
- Change the gears one last time, so you have 3 different gear settings in total
- Repeat the previous steps
- Also do this experiment 3 times

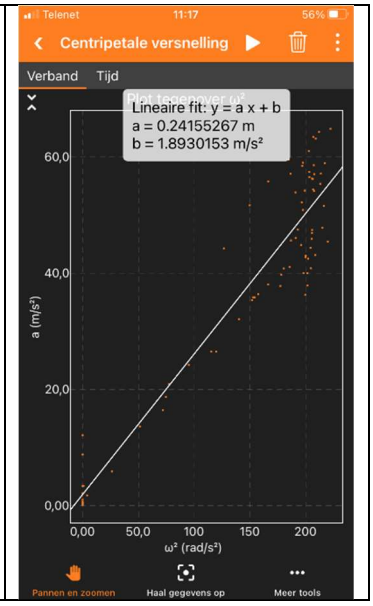
- DATA ANALYSIS and DISCUSSION
  - **Observations and Measurements**:

The first gear		
The angular velocity:		
centripetal acceleration:		

		
The third gear:		
Angular velocity:		
Centripetal acceleration		

		
The sixth gear:		
Angular velocity:		
Centripetal acceleration:		





First gear:

Angular velocity:

t(s)	ω(rad/s)
0,0696605	0,020545063
0,569147	0,032793172
1,56811825	1,039428727
2,06760425	4,109629128
2,567090542	4,128473482
3,066576542	5,640902596
3,5660615	6,500617045
4,0655475	6,038711038
4,5650325	6,640057763
5,0645185	6,352922331
5,56400325	6,548010618
6,06348925	5,931651587
6,56297875	6,562410887
7,06246475	5,641297561
7,5619475	5,946802738
8,560920167	6,723035567
9,060407167	5,848511119
9,559894625	6,229421783
10,05938063	6,129617983
10,5588685	6,636262251
11,0583555	6,106797944
11,5578405	6,420496357
12,0573275	6,771722126
12,55681463	6,973895861
13,05630063	6,37518844
13,55578667	7,538134836
14,55475854	7,300568678
15,05424454	6,764645237
15,55373125	7,095950016
16,05321725	7,396874963
16,55270563	7,361043067

17,05219062	7,941706659
17,55167188	6,985633169
18,05115688	7,00050901
18,55064117	6,49078808
19,05012517	6,469480377
20,04909475	5,953493354
20,54858188	5,324753014
21,04806488	6,172045088
21,54754525	5,461619332
22,04702825	6,466421566
22,54651213	6,023730665
23,04599513	6,746741019
23,54547788	6,311720823
24,04496088	6,466649823
24,54444292	6,392240452
25,54340679	6,192683623
26,04288779	6,645057488
26,54237363	6,198134699
27,04185462	6,607986644
27,54133188	5,756010822
28,04081288	6,399803653
28,54029229	5,858884506
29,03977329	6,135813569
29,53925363	6,226139033
30,03873363	6,837120471

Centripetal acceleration

t(s)	a(m/s²)
0,0696605	0,265471585
0,569147	0,310334005
1,56811825	0,748939076
2,06760425	2,810918811
2,567090542	3,810899357
3,066576542	6,012848109
3,5660615	8,092206294
4,0655475	6,791864371
4,5650325	8,318106552
5,0645185	7,574115364
5,56400325	8,290437872
6,06348925	6,759679934
6,56297875	8,048267215
7,06246475	6,440510381
7,5619475	5,984957834
8,560920167	7,364540111
9,060407167	7,531955284
9,559894625	5,985645689
10,05938063	8,69881287
10,5588685	6,947792544
11,0583555	8,664428868
11,5578405	6,422227742
12,0573275	10,40194446

12,55681463	8,269433992
13,05630063	9,001969697
13,55578667	10,34286552
14,55475854	12,22016113
15,05424454	7,405355212
15,55373125	12,39189604
16,05321725	7,864151118
16,55270563	11,92678363
17,05219062	12,41108445
17,55167188	8,08121178
18,05115688	12,45381815
18,55064117	5,435485546
19,05012517	11,06189097
20,04909475	9,896465237
20,54858188	3,211294247
21,04806488	10,76682994
21,54754525	4,247074622
22,04702825	10,64755072
22,54651213	6,373363516
23,04599513	11,13672278
23,54547788	6,58194402
24,04496088	10,25803088
24,54444292	6,629377642
25,54340679	4,638031264
26,04288779	12,70398565
26,54237363	4,627825208
27,04185462	12,61983456
27,54133188	2,761626324
28,04081288	12,15094149
28,54029229	3,013073482
29,03977329	11,57662509
29,53925363	3,86953568
30,03873363	13,41719195

Third gear:

Angular velocity:

t(s)	ω(rad/s)
0,121710625	0,038130447
0,621206625	0,326629127
1,120699625	0,243505436
1,620187667	0,223941013
2,619174792	2,832620613
3,118666792	4,390814944
3,618158125	4,480158355
4,117650125	6,233998391
4,617141875	6,322638463
5,116633875	7,085786693
5,61612575	7,207938758
6,11561675	8,316661244
6,61510875	8,314021083
7,11459975	8,30212246

7,614090875	8,993345467
8,113581875	9,105223466
9,112563125	8,993869554
9,61205275	9,607518879
10,11154375	9,23927231
10,61103412	9,117288559
11,11052413	9,456530745
11,61001413	9,655568115
12,10950413	9,217401271
12,608994	9,852098512
13,108483	9,964950846
13,6079725	9,903779356
14,60695092	9,725918316
15,10644092	9,143173947
15,605931	9,481162963
16,10542	8,486437712
16,60490754	8,027174896
17,10439654	8,413668309
17,60388367	8,156714397
18,10337267	8,252155243
18,60286138	8,711041527
19,10234938	8,440120116
20,10132442	8,872584753
20,60081117	8,481783517
21,10029817	8,590574031
21,59978604	8,78431429
22,09927304	8,361263931
22,59875988	8,490055975
23,09824687	8,558278406
23,59773663	8,386267634
24,09722363	8,251860294
24,59670613	8,593312128
25,09619212	8,316888285
26,09516275	8,596146548
26,59464775	8,151065272
27,09413375	8,030804001
27,59361854	8,585466325
28,09310354	8,389077857
28,59259137	8,062843371
29,09207638	8,413070287
29,59155642	8,080253086
30,09104042	8,264260431

Centripetal acceleration:

t(s)	a(m/s²)
0,121710625	0,254181195
0,621206625	0,26810075
1,120699625	0,12915174
1,620187667	0,349334356
2,619174792	1,657587811
3,118666792	3,136096604

3,618158125	3,839086221
4,117650125	5,767648762
4,617141875	7,382304028
5,116633875	7,164689907
5,61612575	9,534789097
6,11561675	10,93150998
6,61510875	10,75534624
7,11459975	13,07940641
7,614090875	12,70650317
8,113581875	12,41498191
9,112563125	14,90505254
9,61205275	13,45713263
10,11154375	13,16071473
10,61103412	15,82292191
11,11052413	16,59699692
11,61001413	12,72949278
12,10950413	13,19881081
12,608994	18,92075359
13,108483	18,57574701
13,6079725	14,17501464
14,60695092	16,52951356
15,10644092	17,38534501
15,605931	14,2275524
16,10542	8,841102606
16,60490754	13,95246679
17,10439654	11,63893104
17,60388367	9,452296168
18,10337267	15,5983794
18,60286138	11,44498807
19,10234938	9,412888804
20,10132442	12,66442945
20,60081117	8,717423734
21,10029817	16,29261477
21,59978604	15,02199351
22,09927304	7,240014514
22,59875988	15,95215787
23,09824687	15,29384907
23,59773663	6,44302096
24,09722363	15,19281514
24,59670613	15,82516434
25,09619212	6,186441626
26,09516275	15,56195615
26,59464775	5,84389097
27,09413375	15,64354373
27,59361854	14,57636641
28,09310354	6,465067034
28,59259137	16,27685632
29,09207638	13,10597437
29,59155642	6,827288748
30,09104042	17,83666366

Sixth gear:

Angular velocity:

t(s)	ω(rad/s)
0,504568583	0,050910236
1,004043583	0,439694227
1,503519958	0,42841776
2,002994958	2,012951677
2,502470125	5,154318044
3,001944125	7,171467775
3,50141925	8,645184979
4,00089325	8,486606122
4,500367583	8,809366694
4,999841583	9,761382209
5,499315875	10,74704055
5,998789875	10,94918439
6,498263583	11,85637433
6,997736583	12,37423391
7,996685083	12,33443481
8,496157833	12,43555701
8,995631833	12,56182976
9,4951045	12,90361895
9,9945775	13,35660985
10,49405513	13,63047696
10,99352812	14,00887342
11,49299833	13,82934136
11,99247133	14,06964815
12,49194463	14,37175935
13,49089096	14,02234276
13,99036396	13,67552015
14,48983708	13,44351891
14,98931008	13,32411289
15,48878483	14,13837697
15,98825783	14,34740113
16,48773096	14,6021383
16,98720396	14,40320621
17,48667596	14,26222454
17,98614896	14,38340184
18,48562146	14,34222569
18,98509446	14,45243897
19,98403963	14,74126286
20,48351221	14,91721835
20,98298421	14,62142903
21,48245758	14,67433957
21,98192958	14,83715928
22,48140246	14,71054806
22,98087446	14,26707124
23,48034725	14,06298547
23,97981925	14,04491412
24,479292	14,12108782
25,47823596	14,07792977
25,97770796	14,31334125
26,47717958	14,35309588
26,97665158	14,42082188

27,47612396	14,4623189
27,97559496	14,25110969
28,47506633	14,41535742
28,97453733	14,2260723
29,47400975	14,2076832
29,97348075	14,30714606
30,97242171	14,5674144

Centripetal acceleration:

t(s)	a(m/s²)
0,504568583	0,116521966
1,004043583	0,400346885
1,503519958	0,314178366
2,002994958	1,752076429
2,502470125	5,866072362
3,001944125	13,60187243
3,50141925	18,72248271
4,00089325	16,39136427
4,500367583	20,8849167
4,999841583	24,19241387
5,499315875	26,49534404
5,998789875	26,47344327
6,498263583	32,06758371
6,997736583	35,82088828
7,996685083	35,33724524
8,496157833	35,82699664
8,995631833	36,33823113
9,4951045	38,02478411
9,9945775	39,72028857
10,49405513	41,02499263
10,99352812	44,81748888
11,49299833	46,03434879
11,99247133	50,85852605
12,49194463	56,16510216
13,49089096	52,15722021
13,99036396	45,60240936
14,48983708	40,80231433
14,98931008	37,79388699
15,48878483	42,73699283
15,98825783	46,90935724
16,48773096	55,3639914
16,98720396	58,52562798
17,48667596	57,40944163
17,98614896	54,37704115
18,48562146	45,88934447
18,98509446	43,07918672
19,98403963	58,89314
20,48351221	64,81739879
20,98298421	57,12180219
21,48245758	47,78447534
21,98192958	45,38855772

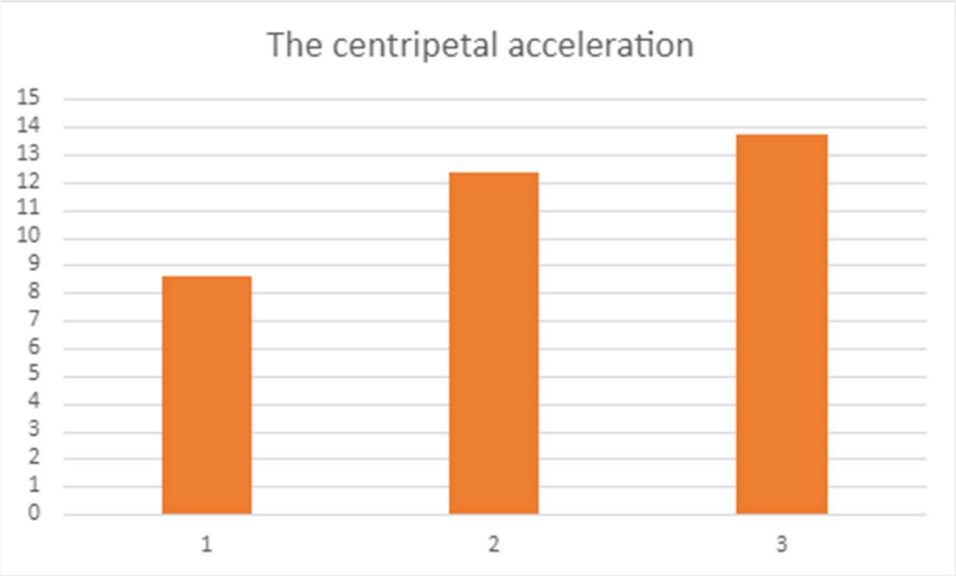
22,48140246	51,56982204
22,98087446	56,49976074
23,48034725	58,96717524
23,97981925	58,41581802
24,479292	54,17552173
25,47823596	40,01268274
25,97770796	40,80887001
26,47717958	47,39672694
26,97665158	57,00706781
27,47612396	63,14807645
27,97559496	60,99035248
28,47506633	54,12883083
28,97453733	42,4593784
29,47400975	37,84422399
29,97348075	44,31124828
30,97242171	64,27581252

Other measurements: the diameter of the wheel we used was 0,68m. + see the table we made under here ↓

Discussion: Our hypothesis on centripetal acceleration was right. The centripetal acceleration will be faster when the gear is higher. This makes sense because when the chain is on a larger sprocket, the wheel will spin faster when you give it a spin. The wheel makes more revs when you turn your bike's pedals. The acceleration is smaller when you turn the gear down. Our hypothesis on angular velocity was wrong. The angular velocity is bigger when you turn the gear up (when the chain is on a bigger sprocket) because the speed will increase, and smaller when you turn the gear down.

Table 1: The centripetal acceleration

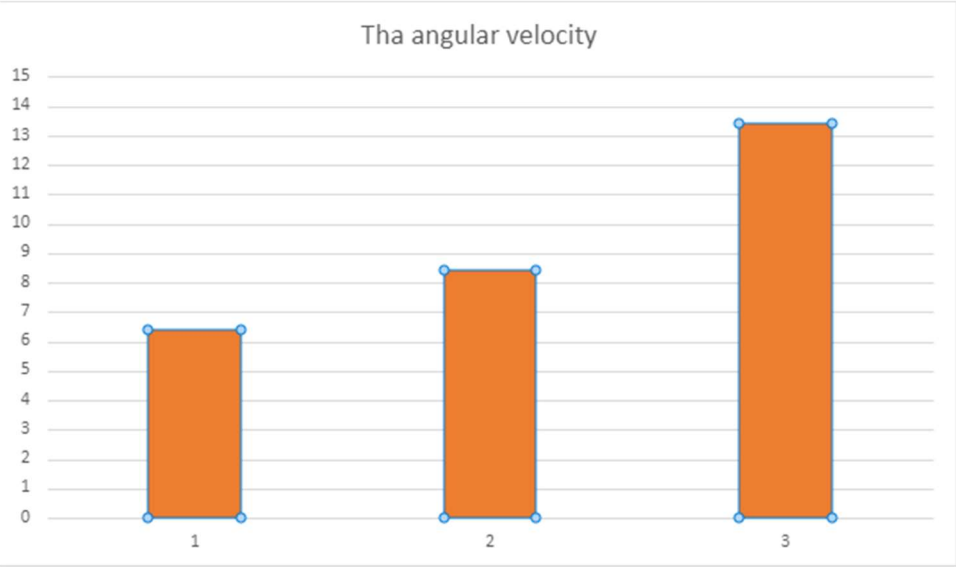
	Acceleration		
t (s)	First gear	Third gear	Sixth gear
5,00	7,57	7,16	10,74
10,0	8,69	13,1	13,6
15,0	7,41	17,4	14,34
20,0	9,89	12,7	14,9
25,0	4,63	6,19	14,0
30,0	13,41	17,8	14,6
The average speed	8,60	12,39	13,70



Graphic 1: The average speed of each gear during the experiment. The number on stands for the first gear, two for the third gear and 3 for the sixth gear.

Table 2: The angular velocity:

	ω (rad/s)		
t (s)	First gear	Third gear	Sixth gear
5,00	6,35	7,09	9,76
10,0	6,13	9,24	13,90
15,0	6,76	9,14	13,32
20,0	5,95	8,48	14,74
25,0	6,40	8,31	14,08
30,0	6,84	8,26	14,57
The average angular velocity	6,41	8,42	13,40



Graphic 2: The angular velocity of each gear during the experiment. The number on stands for the first gear, two for the third gear and 3 for the sixth gear.

- REFLECTION
  - **Conclusion**: The centripetal acceleration will change when the gear is higher. It will be faster. How higher your gear how faster the centripetal acceleration will be and the other way around. Namely, the lower the gear, the slower the centripetal acceleration will be. If you turn the gear up, the angular velocity will be bigger and if you turn it down, it will be smaller.

  - **Comparison** of the results of the different countries
  - **Reflection:** The results may not be very accurate, because it was hard to spin the wheel with a constant speed. Taping our phone on to the wheel also didn't go as smoothly as we planned. Maybe we should have counted how many gear screws our bike had, to have a better conclusion, but we still had an interesting experiment. Our hypothesis for the angular velocity was wrong, so we actually learned something. Next time we will also make sure to be better prepared for example by counting the gear screw as mentioned earlier. The teamwork in general went smoothly, because we have done lots of projects together and we complement each other well.

- REFERENCES

https://www.youtube.com/watch?v=lMnNBVB80xI