Formative Assessment while Pupils Study Circular Motion

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Pupils studied laws of Circular Motion (CM) by fixing a yarn with a freely hanging screw nut to bicycles spokes. At slow turn rates nut just hang down. A velocity above a certain level keeps the yarn strained. If the wheel rotates at a velocity that just keeps the yarn strained the centripetal force at the highest point of CM results from gravity only. Analysing data at several radii results an estimate of gravitational acceleration g. While performing this pupils were accompanied with formative assessment methods during and after the project to improve teacher's feedback. Contribution shows diverse students' results and teacher experiences.

INTRODUCTION

For several years at the KGS-Sehnde, located in Germany near Hanover, we (physics teacher group) guide the students of class 10 (age 15) through a physics project. Some past examples are: marble-run track, rubber band plane, catapult and circular motion of a bicycle wheel which we present here. Emphasis of the projects is always the report. Neither we can expect perfect experimental setup nor reports ready to be printed.

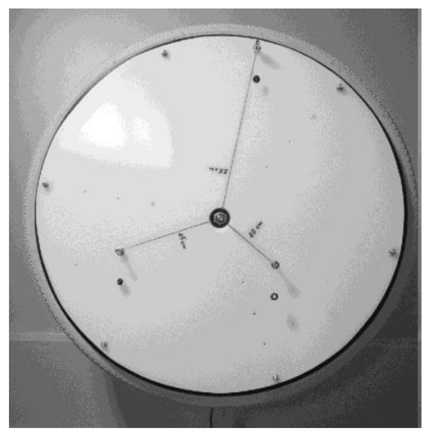


Figure1: Nuts hanging on a wheel

However because physical and mathematical skills of the students vary very much it is always a challenge for the teacher to assess the students adequately. The aims of the project are:

- inquire fundamental terms of circular motion
- understand the laws of circular motion
- remind and strength inquiry skills like data analysis using diagrams and concepts of linear regression and proportionality,
- find and study relevant literature on their own;
- Also some soft-skills are intended to be developed further, like:
- organising themselves in groups, plan meetings, work together efficiently,
- type writing using ten fingers
- usage of a word processor, and other pc-tools

THE PROJECT: SEVEN WEEKS OF WORK

The project started immediately after the summer holiday. The pupils got a verbal introduction and a introductory paper that clearly points out what is expected (*MATERIAL I*).

Working on the project ran beside normal school operations, but very little homework in physics. While pupils meet weekly for regular physics classes a part of the lesson is reserved for questions raising from the project.

Some years ago we discussed with the pupils weather or not to do a project and what about. The result was a long term discussion about the meaning of such a project and the fact that in other classes there is none (some teachers disagree about doing a project). The school director left the decision whether or not to do a project to the teacher.

If we would have left pupils working on their own until the report had to be handed in, it would be just summative assessment. But formative assessment (observations by the teacher; classroom discussions) caused to change the planed physics lessons according to pupils needs.

Table 1: Timetable of project circular motion (CM)

Week 2013	Planed Project Status	Example: Status Group A	Example: Status Group B	Impact to physics lessons
33	groups get together, discuss experimental setup	appointment for next weekend	New in class; no idea who to work with; too much to do;	Introduction of project work
34	buy all goods necessary.; build experimental setup	Bicycle unhandy; use disk instead, set up takes time	do not know who to ask	Force some pupils to get together
35	Do experiments; get data create a table of data	take pictures, experiments done and got some data	appointment planed for next week	Change curriculum: CM-fundamental terms
36	analyse data: diagrams, linear regression	How to do data analysis ???	Met with classmates; fix of nut is tricky but got some data; internet inquiry	Forces at highest point in CM.
37	write report: diagrams	Do analysis acc. to sample-sheet; relation to g? ask dad, lookup internet; start writing;	Need to hurry; do analysis of data	Example sheet for data analysis + example: (*MATERIAL II*)
38	Write report: physical explanations	No time: other examinations	Rush some diagrams; see report of others	Discussion: elong-ation not acceptable;
39	Critical reflection, list of cost	Write report, reflection, cost- and timetable, digital copy	Write report	How to handle bad data: be fair!

40	Hand over the report	Finish	Finish	collect reports; if so see film / experiment

Giving the pupils an aim i.e. writing a report there was a motor stimulating thoughts and plans. The questions that came up in physics lessons seemed just satisfactory for all of the pupils and answers were returned to be adequate, e.g.:

- when pupils asked for fundamental terms of circular motions the actual physic lesson was changed and we discussed examples like a drilling machine, washing machines, earth rotation and calculated or estimated time periods, frequencies, amplitudes, angular- and track velocity etc.
- generating a diagram v^2 over r was very unusual for pupils. Therefore we decided to do an example data analysis as a worksheet.

However, in future projects some formative assessment methods like a written status reports collected from all groups on a regular basis might help to get an even better insight of work within the groups. In order to discuss with all pupils such a status report could be selected by the teacher or randomly and anonymised.

EVALUATION OF THE REPORT

Figure 2 shows an example result of the pupils experiments. A linear regression to r-v^2 data had a slope of 10,7m/s² (R^2=0,85) fairly near g=9,81m/s².

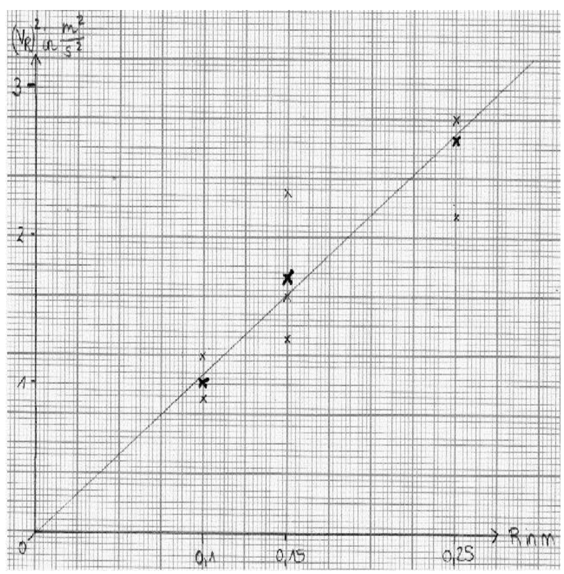


Figure 2: example result: slope approximates g

Reports were returned to the pupils with feedback according to categories like experimental setup, data analysis using diagrams and computer algebra system (CAS), explanation of physical laws, but also more formal issues like clarity of language and completeness of work.

In order to get to a fair evaluation each group got points to be shared between group members. Given marks did not differ more than three points between group members.

CONCLUSION

Major benefits of the project are:

- getting familiar with inquiry skills in practice;
- motivation that stimulates physics lessons;
- having a common goal;
- improving pupil to teacher relation;

It might be seen critical that marks within groups did not differ for more than three points. Therefore weak pupils somehow hide behind competent classmates leaving all the work for the experts. Also the influence of others like parents and relatives cannot be diverted from the work pupils did themselves. However, we felt that the project should encourage the pupils to cooperate rather than being observed and evaluated individually. And if pupils accepted help it means that there were questions and there was discussion which again is beneficial for learning about circular motion.

For most pupils the project took nearly 20 hours – a weekly average of about 3 hours. Cost were below 15€ in most cases which we think both is acceptable.

FUTURE WORK

The experiment of a hanging nut mounted on a rotating disc might be useful in standard physics lessons. But it cannot be expected that pupils develop the experimental setup on their own. Also it seems sophisticated to estimate g from that approach. Therefore we intend to support the pupils by:

- Giving pupils a description of experimental setup;
- Giving pupils a worksheet that supports data collection, analysis using CAS and diagrams;
- Hints for ambitious pupils, e.g. to think about forces at the highest point when rotation is just fast enough to stress the yarn;
- Introducing regular status reports to be done from all groups and feedback accordingly
- Peer assessment, i.e. group partnerships as a sensitive controlling instrument meant to identify problems in time; teacher involved if needed;
- Present a timescale with milestones that might help the pupils to organise themselves.

MATERIAL I

Physics class 2013 August 2013

KGS Sehnde

Circular-Motion

Tratitionally we start our physics class with a project. Until now pupils did mouse-trap-cars, submarines, rockets, bridges, ships, rubber-band-planes, catapult, marble-tracks and water-rockets.

1. Your Task

Compare the forces that appear at a vertical circular motion with gravity.
Fix a M6-nut at the front wheel of a bicycle, leaving 5cm free space for the nut to swing. Observe the nut at the highest point i) moving the wheel slowly (nut always hanging down) and ii) moving the wheel rapidly (nut will remain outwards). Measure for at least the three radii (distance centre of wheel – screw) R=10cm, 15cm and 25cm the lowest turn rates, i.e. frequencies, at which the screw just remains outwards. Improve the quality of the measurement by taking an average over at least three measurements. For calculation of the turn rates use the speedometer of the bicycle. Note the displayed numbers of the instrument and do all calculation afterwards.

2. Report:

For your project we expect you to write a report, 8 pages maximum, including:
- table of contents
- a digital picture of your experimental setup (important it proves you worked on your own!!)
- a drawing of your experimental setup including values of all length
- description of what you did
- your measurements (raw data) as a table
- two diagrams of your data that show the laws of circular motion, i.g.: 1.) $r - v^2$ and 2.) $1/r - \omega^2$ as x- and y- axes.
- Explain the major physical phenomena, at least balance of forces at the highest point.
- Explain the relation of $g=9{,}81 m/s^2$ to that diagrams above and how g could be determined from those diagrams. Discuss the result.
- list the cost you had and the time you invested for the project (at least an estimations).
- discuss the project critically including conclusions and aspects to improve.
- List literature used
- City, Date and signature of the authors.

The evaluation of your report will also take correctness of language, written style, formal aspects and correct citations into account.
The report is not supposed to be a diary or a builders tuition!

3. Working Conditions: Cooperate in small groups of 2-3 pupils that you arrange yourself.

4. Hand-in:

Each group has to hand in a printed and a digital version of the report. Both will be returned after evaluation. The digital version will be archived at school.
Handing in has to happen in the last physics lesson before autumn holidays. A later hand in will not be accepted. In case nothing was handed in evaluation will be lame.
If you wish to show your experiment at school, let the teacher know in advance. This will improve your evaluation.

5. Evaluation:

Most important for the evaluation of the project is the report. The project contributes to your verbal evaluation of the first half year.

Good luck, your Physics teacher Dr. Wunder

Figure 3: Project Introduction

MATERIAL II

Analysis of circular motion at bicycle wheel

Fundamental Terms:

Circumference $U = 2 \cdot \pi \cdot R = \pi \cdot D$ (1)

Time-Period: T (Time per round)

Track velocity at radius R: $v_B = \frac{U}{T} = \frac{2\pi R}{T}$ (2)

Example: Wheel with diameter D=28Zoll=0,71m => U=2,234m

If the bike goes v=20km/h=5,55m/s one round of the wheel takes

because of (2): $T = \frac{U}{v_B} = \frac{2{,}234\,m}{5{,}56\,m/s} = 0{,}40\,s$

A position with radius r=0,1m has the track-velocity:

$$v_r = \frac{2\pi r}{T} = \frac{2\pi 0{,}1\,m}{0{,}40\,s} = 1{,}57\,\frac{m}{s}$$

In order to calculate the track velocity v_r from v_B of the bike one gets:

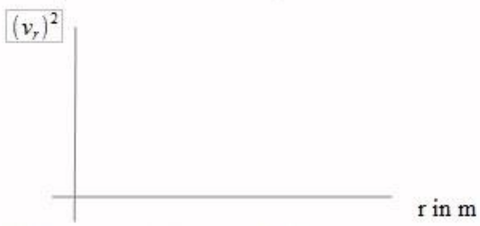
$$\underline{v_r} = \frac{2\pi r}{T} = \frac{2\pi r}{U/v_B} = \frac{2\pi r}{2\pi R} v_B = \frac{r}{\underline{R}} v_B$$ (Attention: convert km/h in m/s !) (3)

Procedure:

1. Fix the yarn so that the freely down hanging screw-nut is a radius of e.g.: r=0,1m.
2. Turn the wheel and observe the nut at the highest point. If the yarn is no longer straight note the velocity that the speedometer shows. This is v_B .
3. From v_B compute v_r using formula (3).
4. Repeat all measurements at least three times and calculate the average. Do that at different radii.
5. Data analysis using spreadsheet and Diagram:

	r	v_B	$v_r = \frac{r}{R} v_B$	$(v_r)^2$	
Example not typical!	0,1m	5,56m/s	1,56m/s	2,44m²/s²	
	0,1m	5,45m/s	1,53m/s	2,35m²/s²	
	0,1m	5,72m/s	1,61m/s	2,59m²/s²	
				2,46 (m/s)²	Average

Diagram:



Draw a straight line trough data points (linear regression) and estimate the slope of that line. Compare that slope with physical constants you are familiar with.

Hint: the diagram above has its meaning for your measurements, not the example in the table above.

Figure 4: Data Analysis

References

Colburn, A. (1997): How to Make Lab Activities More Open Ended, CSTA Journal, Fall 1997, p. 4-6 http:\\www.exploratorium.edu/ifi/resources/workshops/lab_activities.html

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