GeoGebra Supporting Materials for Introductory University Courses

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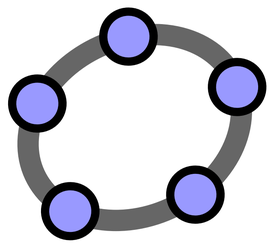
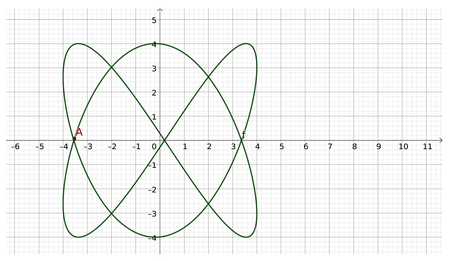
Motivation: why GeoGebra?

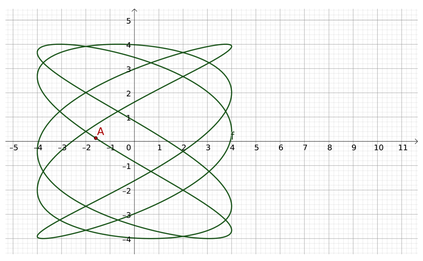
- **GeoGebra** (a portmanteau of geometry and algebra) is an interactive geometry, algebra, statistics and calculus application, intended for learning and teaching mathematics and science from primary school to university level.
- **GeoGebra** is **freely** available on multiple platforms, with apps for desktops (Windows, macOS and Linux), tablets (Android, iPad and Windows) and web.
- Website: https://www.geogebra.org.
- **Easy sharing** of the models on-line.
- **Easy integration** into LMS materials (e.g. Moodle).
- Wide international community $\Longrightarrow$ rich reservoir of shared materials (e. g. [3–4, 6–8]).
- Provides numerical solving of algebraic equations, ODE's, simple animations.
- Leads to the more geometrical interpretation of some problems.



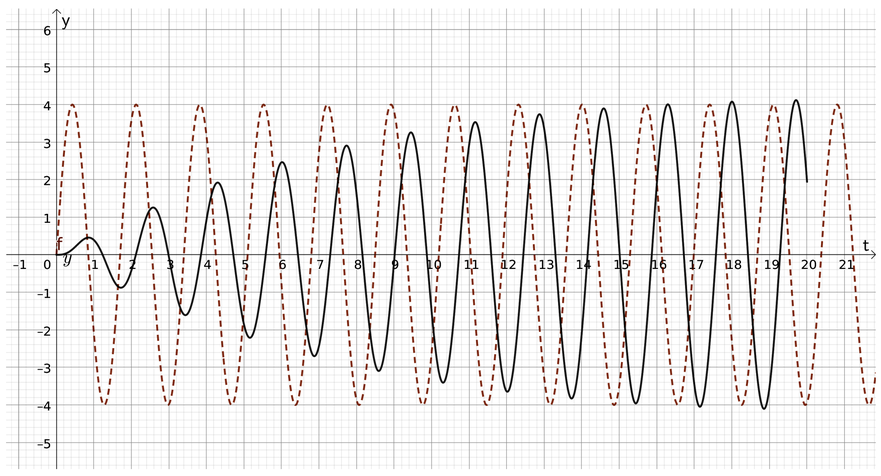
Physics courses for future chemists

- Lissajous curves

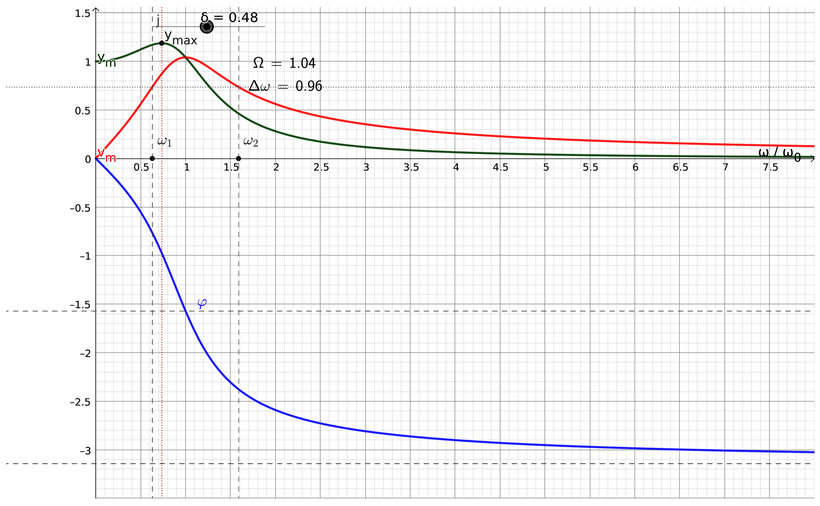




- Forced oscillations

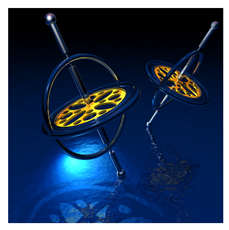


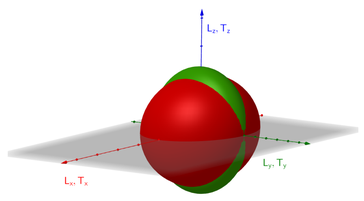
- Resonance curve



Classical mechanics

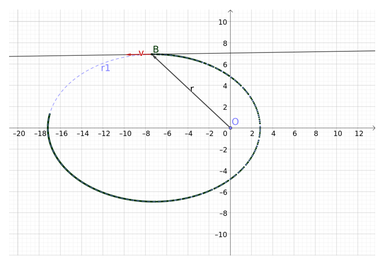
- Free non-symmetric gyroscope as an example of conservation of kinetic energy and angular momentum (a problem from [1])





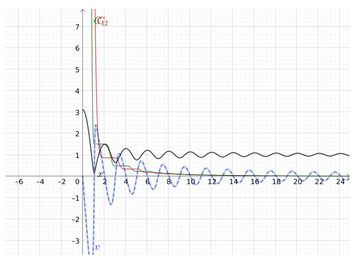
- Kepler's equation with numerical solution:

$$\Psi - \varepsilon \sin \Psi - \sqrt{\frac{GM}{a^3}}\, t = 0$$



- Buquoy's variable mass problem formulated by J. F. A. Buquoy (1781–1851):

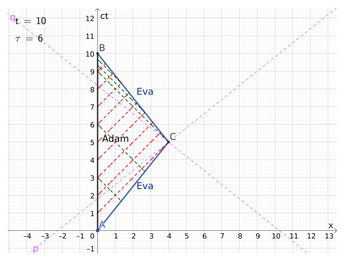
$$\ddot{y} = g\left(\frac{y_c}{y} - 1\right) - \frac{1 + \operatorname{sign}(\dot{y})}{2}\frac{\dot{y}^2}{y}, \quad y_c = \frac{F}{\eta g}, \quad g = 9.81\,\mathrm{m\,s^{-2}}$$

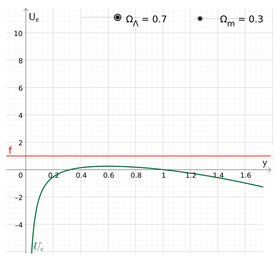


Special relativity and intro to cosmology

- Special relativity is a rather abstract topic $\Longrightarrow$ useful illustrate relativistic effects visually [2,5]
- Twin paradox and effective potential for Friedmann universe expansion equation

$$\dot{y}^2 = H_0^{\,2}\left[1 - \left(\Omega_{m0} + \Omega_{\Lambda 0} - \frac{\Omega_{m0}}{y} - \Omega_{\Lambda 0} y^2\right)\right], \qquad y = \frac{a}{a_0}$$





Conclusion

- ✔ GeoGebra models are a suitable supplement to solutions to some problems within university courses, bringing a firmer understanding of discussed solutions.
- ✔ Some students often use this tool at secondary schools and use this tool for preparing graphs, even for bachelor's thesis.

References

[1] Chorlton F 1963 Textbook of Dynamics (London: D. van Nostrand Company Ltd.).

[2] Kersting M and Blair D 2021 *Teaching Einsteinian Physics in Schools* (London New York: Routledge).

[3] Rodríguez Y, Santana A and Mendoza L M 2013 Physics education through computational tools: the case of geometrical and physical optics *Phys. Educ.* **48** 621.

[4] Solvang L and Haglund J 2021 How can GeoGebra support physics education in upper-secondary school—a review *Phys. Educ.* **56** 055011.

[5] Takeuchi T 2010 *An Illustrated Guide to Relativity* (Cambridge University Press).

[6] Teichrew A and Erb R 2020 How augmented reality enhances typical classroom experiments: examples from mechanics, electricity and optics *Phys. Educ.* **55** 065029.

[7] Tomić M K, Aberšek B and Pesek I GeoGebra as a spatial skills training tool among science, technology engineering and mathematics students *Computer Applications in Engineering Education* **27** 1506–1517.

[8] Walsh T 2017 Creating interactive physics simulations using the power of GeoGebra *The Physics Teacher* **55** 316–7.

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