engineering proceedings

Proceeding Paper

Hybrid Courses Based on Basic Sciences and Green Technologies in Engineering Programs †

Huber Nieto-Chaupis

Faculty of Engineering, Universidad Autónoma del Perú, Panamericana Sur Km. 16.3, Villa el Salvador 15842, Peru; hubernietochaupis@gmail.com

† Presented at the 3rd IEEE International Conference on Electronic Communications, Internet of Things and Big Data Conference 2023, Taichung, Taiwan, 14–16 April 2023.

Abstract: An ineluctable topic has emerged and needs to be treated in engineering programs for green energies. Particularly in the programs of electrical and systems engineering, students can acquire the capabilities to envision the arrival of green standards to generate clean energy sources. In this article, the introduction of new forms of green energy is systematically presented through a basic experiment in electricity in which a potato is used to investigate the current and electric power. The experiences were conducted at the 2022-I at a private university in Lima City. The results demonstrated that the topic of biofuel in the framework of green energy can be studied in undergraduate courses. Indeed, prospective students of engineering can be oriented toward research in engineering for the implementation of new electrical systems that provide electricity with low budgets.

Keywords: engineering education; physics; devices and systems

Citation: Nieto-Chaupis, H. Hybrid Courses Based on Basic Sciences and Green Technologies in Engineering Programs. *Eng. Proc.* **2023**, *38*, 49. https://doi.org/10.3390/engproc2023038049

Academic Editors: Teen-Hang Meen, Hsin-Hung Lin and Cheng-Fu Yang

Published: 27 June 2023

1. Introduction

An appropriate time to show the promising green technologies to freshmen [1–3] would be the first semester. In particular, all programs in engineering have to be aggregated in the curricula. Important topics would be the following.

- Searching for green batteries
- Green energy for massive applications
- Software to manage green energies
- Use of ongoing technologies in the green scenario

Thus, the potential ways to teach these topics and the abilities of freshman students to think about them in the future are necessary. With the massive usage of smartphones, tablets, and laptops, the main question about the topic is what green technologies are used to replace conventional batteries [4,5].

The topics about green technologies can be relevant to various factors such as motivation, perspective, compromise in chosen programs, and research aspects. Thus, attention has been paid to the basic courses of physics [6,7], in which a simple scheme is presented for students to gain knowledge to create new circuits based on biological waste. From the well-known experiment to understand electric fields and Ohm's law, the implementation of biological compounds as a replacement for electrical circuits is presented.

The potential usage of waste as a source of energy is examined as a course of physics-II in the system engineering department iofn a private university located in the south pole of Lima City.

The course teaches the following topics.

- The theory of equipotential lines
- The experience of lines of electric fields
- The usage of wasted potatoes

- The demonstration of Ohm law
- Presentation of scenarios in which the waste replaces electrical batteries.

In the experience, students are required to have a solid background in math, particularly calculus, as Gauss law and vectorial analysis are demanded for a solid understanding of the experiment. This encompasses the idea that, in conjunction with theory, math and experiments must be learned together [8–10]. This is the foundation on which students embark to learn new green technology. Thus, the purpose of this study is to present the design of the course in which the topics of physics are taught and to provide capabilities to face the new technologies through basic sessions of experiments.

The paper is structured as follows. In the second section, the content of the session based on theory and experiment is described. In the third section, Ohm's law and a bio-circuit are explained using the peels of potatoes as a source of electric energy. Finally, the conclusion is drawn.

2. Session of Physics

In this section, the design of a session of physics (level 2) in the program of system engineering is presented. According to the content of the course, the topic corresponds to a concrete experience in the verification of equipotential lines. The theory is established on the concepts of vectors and Coulomb's law [11–13].

Students need to understand the sequence of equations.

$$\frac{\boldsymbol{F}}{q} = \boldsymbol{E} = \int d\boldsymbol{E} = \int \frac{dQ(\boldsymbol{r} - \boldsymbol{r}')}{|\boldsymbol{r} - \boldsymbol{r}'|^3} \tag{1}$$

where 4 π ε_0 = 1. With the definition of Coulomb's law, the electric fields can be derived. Through a mathematical procedure based on vectorial calculus, (1) is derived.

$$\boldsymbol{E} = -\nabla \left[\frac{Q}{|\boldsymbol{r} - \boldsymbol{r}'|} \right] \tag{2}$$

Students can recognize the term in brackets which constitutes the electric potential Φ, and has a direct relation with the Coulomb force, which is given by:

$$\boldsymbol{F} = q\boldsymbol{E} = -\nabla \left[\frac{qQ}{|\boldsymbol{r} - \boldsymbol{r}'|} \right]. \tag{3}$$

Direct communication with students specifies the necessity to implement the gradient operator "∇" in (2). It is expected that students pass up to the second course of calculus in which the gradient operator is linked to a geometrical view such as the tangent. Students are asked to simulate the system of two electrodes with opposite signs. Here, the use of an external package in the session combines the usage of math at the basic level [14–16]. In this way, the session employs Wolfram, which allows students to simulate two electrodes emitting lines of electric fields.

Figure 1 shows the 3D representation of three spatial variables. Students use the Gaussian functions and their product to the second-order polynomial. Two well-defined Gaussian functions are separated at a distance between the electrodes. Although it is not a direct mathematical manifestation of two electrodes, the use of mathematical packages allows the simulation of the spatial position of real electrodes.

Once the simulation of electrodes is completed, the next step is the use of Wolfram to reconstruct the lines of the electric field as well as the equipotential lines. The use of directives in physics with Wolfram is to determine the possible topology of lines. Thus, the command is conducted by students (Figure 2).

According to Figures 1 and 2, students can complement the assimilated theory to define the experimental arrangement through in-situ verification. Figure 3 shows the basic arrangement. A bucket, two electrodes, a voltmeter, and a power source to provide 10 V are required in the experiment to understand the field and equipotential lines. It is important to note that the instructor can modify the geometry of electrodes, such as circular, rectangle, and others. Thus, the emission of field lines shows the dependency of the geometry of the source.

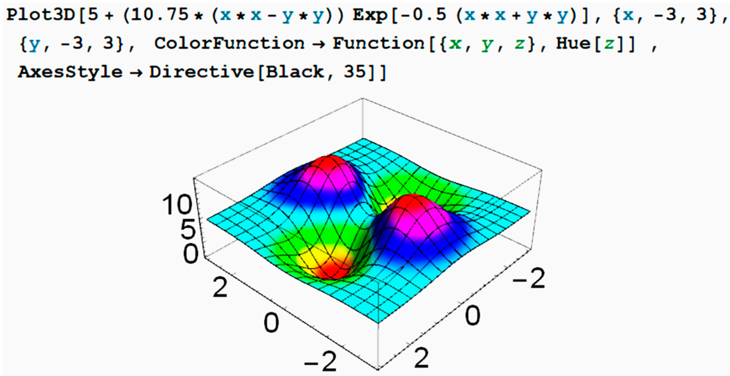

Figure 1. Simulation of two electrodes as a 3d surface of two Gaussian functions by using the package, Wolfram [17].

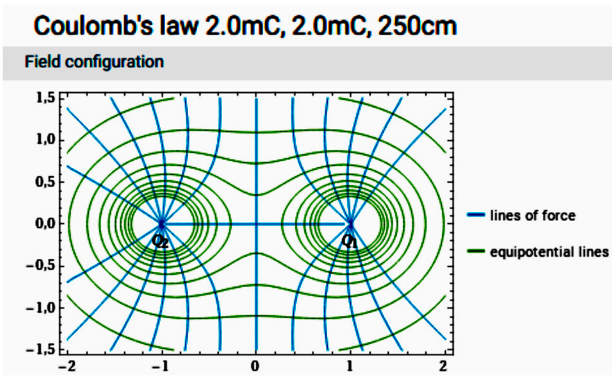

Figure 2. Simulation of Two Electrodes in a 2D Arrangement by Using Installed Commands in Wolfram. This is Conjunction with Figure 1.

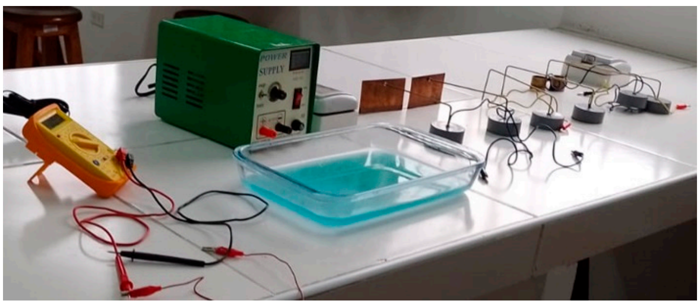

Figure 3. Experimental arrangement of laboratory corresponding to the observation of equipotential lines.

While using Wolfram for a theoretical simulation of involved physics, students witness the physics of Coulomb's law and the gradient operator, which constitutes an educational objective in the program.

3. Usage of Potato Peels

In South America, the consumption of potatoes is general, so there are lots of peels. Thus, the idea is to reuse the peel as biological materials for producing electricity [18–20].

Therefore, the peel in the experiment of equipotential lines is used to measure the main electrical parameters and test the potential capability in a real circuit. From (3), the electric field is defined as

$$\boldsymbol{dE} = \frac{dQ}{|R|^2}. \quad (4)$$

From $\rho = dQ/dV$,

$$\boldsymbol{dE} = \frac{\rho dV}{|R|^2}. \quad (5)$$

By keeping a spherical symmetry,

$$\frac{1}{4\pi}\boldsymbol{dE} = \frac{\rho(R,\alpha)dRR^2}{|R|^2}. \quad (6)$$

Then, the electric field can be written as:

$$\boldsymbol{E} = \frac{1}{4\pi}\int \boldsymbol{dE} = \int \frac{\rho(R,\alpha)R^2dR}{|R|^2}. \quad (7)$$

$\rho(R,\alpha)$ is a volumetric charge density depending on the radius, and α is a parameter characterizing the density of electric charge.

The measurement of electricity before and after adding the peel to water is performed to see if the peel is forming an electric field and is changing the electrical configuration.

Figure 4 shows that in presence of a charged compound, the lines of the field are distorted, this suggests the deformation of equipotential lines [21]. Thus, such a phenomenon triggers the deformation of equipotential lines with the peel of potatoes. Figure 5 shows the experiment with 150 g of the peel. The peel is introduced in 0.3 L of water. With a power source of 10 V, the equipotential lines are dramatically changed yielding 5.54 and 4.96 V. The electric field is affected as

$$\boldsymbol{E} = \lambda\ell + \int \frac{\rho(R,\alpha)R^2dR}{|R|^2} \quad (8)$$

where "λ" is the linear charge density and l is the length of the metallic bar in the bucket. A mathematical form for $\rho(R,\alpha)$ is a nonlinear function. Electric charges can be found in the proteins of potatoes. This is the reason why the deformation of field lines is presented in Figure 4. The arrow indicates the place of the peel of the potato emitting asymmetric field lines without following any pattern. From the above, students understand that the peel of the potato exhibits electrical properties.

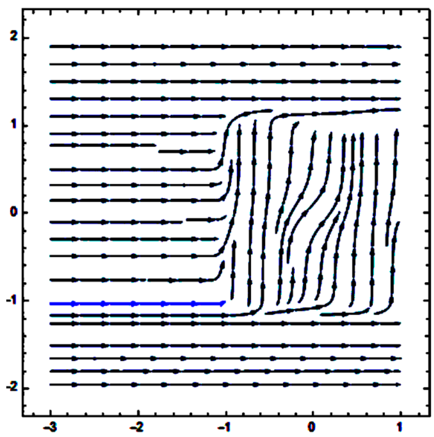

Figure 4. Use of command stream points in Wolfram to simulate the incorporation of peel of potato into bucket. The arrow indicates the position of peel deforming the lines of field.

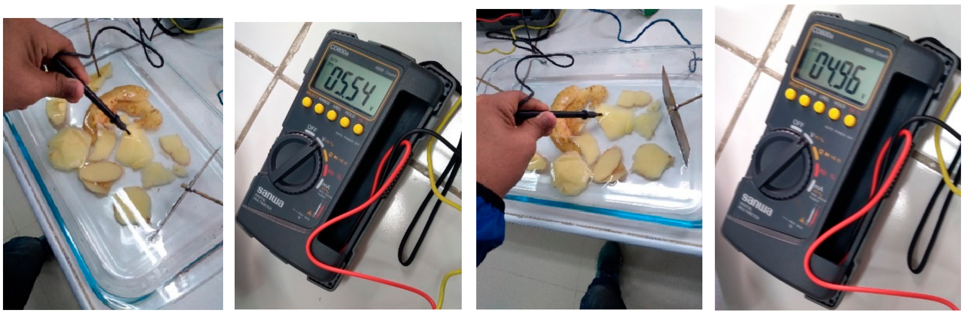

Figure 5. Inclusion of Peel Potato with Water in A Bucket. The Electrodes Are a Pointer. The Power Source is 10 V.

4. Ohm Law and Proposal for Green Energy Circuit

Once the peel of the potato is recognized by students as an inherent bio-electrical component, in the next session, the introduction of circuit laws such as Ohm's law is explained. Students are encouraged to pay attention to the theoretical and experimental points of Ohm's law. For this, the difference in electrical potential is discussed (see Figure 5), and resistance is introduced. The tool turns out to be useful for observing Ohm's law [22]. Figure 6 shows two resistors, R_2 and R_3, in parallel and in series to R_1. Theoretically, Ohm's law is expressed as

$$V = \frac{R_2 R_3}{R_2 + R_3} I, \tag{9}$$

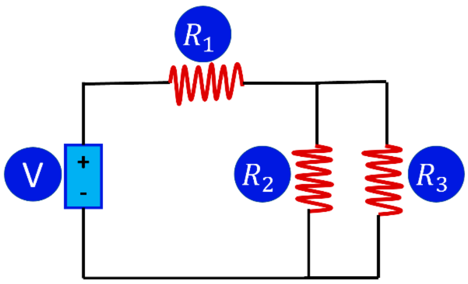

Figure 6. Basic circuit with 2 resistors in parallel being in series with one near to power source. The peel of the potato is expected to be R_3.

While factorizing "R_2",

$$V = \frac{R_2 R_3}{R_2\left(1 + \frac{R_3}{R_2}\right)} I = \frac{R_3}{\left(1 + \frac{R_3}{R_2}\right)} I. \tag{10}$$

The denominator has the below form if $\left(\frac{R_3}{R_2}\right)^q \approx 0$ for $q \geq 2$ then

$$Exp\left(\frac{R_3}{R_2}\right) \approx 1 + \left(\frac{R_3}{R_2}\right) + \frac{1}{2!}\left(\frac{R_3}{R_2}\right)^2 + \frac{1}{3!}\left(\frac{R_3}{R_2}\right)^3 + \cdots \tag{11}$$

Therefore, (10) is written as

$$V = Exp\left(-\frac{R_3}{R_2}\right) I R_3. \tag{12}$$

Equation (12) behaves like a Weibull distribution from the fact that these probability distribution functions can be written as $f(x) = x^{k+1} e^{-x^k}$. Thus, the replacement of "R_3" by peel potato is interesting for students who verify that biological compounds can serve as biodevices. The peel of the potato can also be an "extra" power source in water, as shown in Figure 6.

In Figure 7 the equivalent electrical circuits done with PASCO is displayed. When "R_3" becomes a power source, an advanced theory of circuits is applied. The instructor suggests demonstrating the theorem of Thevenin and experimenting. When "R_3" is a power source, the Thevenin voltage and current are determined, then "R_2" is removed. Thus, when "R_3" = V_B the biological power source is applied with Kirchhoff's law as follows:

$$I = \frac{R_2 + R_3}{R_2 R_3}(V_B - V). \tag{13}$$

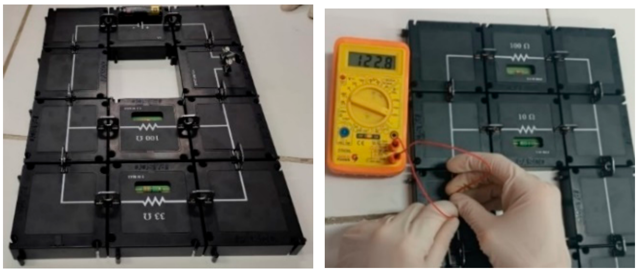

Figure 7. Experimental Design with PASCO of Figure 6. The Resistance R3 had Two Values: 33 Ohm and 100 Ohm.

The student can check out the linearity between the Thevenin's current and the difference in voltage "$V_B - V$". Any difference between the current from (13) and the derived equation from (11) is written as:

$$I = \frac{V}{R_3} Exp\left(\frac{R_3}{R_2}\right), \tag{14}$$

Mass and humidity are relevant parameters. When "R_3" is replaced by the peel of the potato, a current is obtained depending on the potato-like resistor exhibiting a two-zone behavior when I(R_3) is plotted. Thus, the student can try other forms with the waste of fruits, spoiled food, or another biological compound for searching new green technologies. Finally, in Table 1, the outcomes of the whole experience are listed. It is noteworthy that variables have shown to keep a direct relationship to student satisfaction, being this very import to avoid desertion. Thus, communications among students were optimal, task and workshop were done in home. However, it is not clear if students after lab have had the chance to improve the gained knowledge. In addition, the lab is clearly a healthy space to demonstrate sociability among students. Future work, shall be analyzed the issue of impact of physics laboratory onto the formation of engineers, as well as the period after the finishing the grade of bachelor of engineering.

Table 1. Outcomes of Experience.

Variable	Impact	In Campus	Outside Campus
Communication	Middle	Yes	Yes
Workshop	Middle	Yes	No
Review of literature	High	Yes	Probable
Sociability	High	High	High

5. Conclusions

In this study, experiences on the use of the peel of the potato as a potential candidate for a green device in electrical circuits are obtained with the theoretical foundation about the role of the biological resistor. This can be introduced in the second course of physics to motivate students to understand the construction of electrical circuits with the prospective use of biomaterials [23–25].

Funding: The Universidad Autónoma del Perú has funded totally the present research.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Schoenung, A.J.M. Teaching green topics to chemical engineers: Innovation in the process design curriculum. In Proceedings of the 2009 IEEE International Symposium on Sustainable Systems and Technology, Tempe, AZ, USA, 18–20 May 2009; pp. 1–2.
2. Duerden, S.; Doak, B.; Garland, J.; Green, M.; Roedel, R.; Williams, P.; McCarter, J. Scaling up Arizona State University's first-year integrated program in engineering: Problems and solutions. Proceedings of Frontiers in Education 1997 27th Annual Conference. Teaching and Learning in an Era of Change, Pittsburgh, PA, USA, 5–8 November 1997; Volume 3, pp. 1442–1449.
3. Hesketh, R.P.; Hollar, K.A.; Dericks, B.J. Incorporating green engineering in the chemical engineering curriculum. In Proceedings of the SMC'03 Conference Proceedings. 2003 IEEE International Conference on Systems, Man and Cybernetics. Conference Theme—System Security and Assurance (Cat. No.03CH37483), Washington, DC, USA, 8 October 2003; Volume 2, pp. 1745–1752.
4. Manas, K.; Gupta, J.; Singh, B. Green Energy Based Multipurpose EVs Charging Station with Flexible DC Charging Functionality for Residential/Commercial Building Applications. In Proceedings of the 2022 IEEE Global Conference on Computing, Power and Communication Technologies (GlobConPT), New Delhi, India, 23–25 September 2022; pp. 1–6.
5. Arsalis, A.; Papanastasiou, P.; Georghiou, G.E. Integration of a Green Hydrogen Subsystem in a Photovoltaic-Battery Nanogrid System. In Proceedings of the 2022 2nd International Conference on Energy Transition in the Mediterranean Area (SyNERGY MED), Thessaloniki, Greece, 17–19 October 2022; pp. 1–5.
6. Kattayat, S.; Josey, S. Implementation of digital platform in teaching physics concepts applied to engineering education and student's performance: An exploratory study. In Proceedings of the 2018 Advances in Science and Engineering Technology International Conferences (ASET), Dubai, Sharjah, Abu Dhabi, United Arab Emirates, 6 February–5 April 2018; pp. 1–5.
7. Srinivasa, A.; Bassichis, W.H. Work in Progress: The Role of Physics in an Engineering Education. In Proceedings of the Frontiers in Education: 36th Annual Conference, San Diego, CA, USA, 27–31 October 2006; pp. 27–28.
8. Tan, S.; Xu, C.; Huo, J.; Wang, X. The remote education assistant system for the virtual physics experiment teaching system. In Proceedings of the 2009 4th International Conference on Computer Science & Education, Nanning, China, 25–28 July 2009; pp. 1451–1454.
9. SenthilKumar, R. Work in Progress: Use of Interactive Simulations in the Active Learning Model in Physics Education for Engineering Students at a College in Oman. In Proceedings of the 2019 IEEE Global Engineering Education Conference (EDUCON), Dubai, United Arab Emirates, 8–11 April 2019; pp. 1359–1362.
10. Larkin-Hein, T. The write touch in physics and engineering education. In Proceedings of the 31st Annual Frontiers in Education Conference. Impact on Engineering and Science Education. Conference Proceedings (Cat. No.01CH37193), Reno, NV, USA, 10–13 October 2001; Volume 3, pp. S3F–S31.
11. Serway, R.A. *Physics for Scientists & Engineers with Modern Physics*; Saunders College Pub.: Philadelphia, PA, USA, 2005.
12. Physics, U. *Vol-1 Sanny, Loyola Marymount University Samuel Ling*; Truman State University: Kirksville, MO, USA, 2016.
13. Griffiths, D.J. (Ed.) *Introduction to Electrodynamics*; Prentice Hall: Hoboken, NJ, USA, 1999.
14. Klug, M.; Hausberger, P. Motivaton of students for further education in simulation by an applied example in a related other course in engineering education—A case study. In Proceedings of the 2009 Winter Simulation Conference (WSC), Austin, TX, USA, 13–16 December 2009; pp. 248–255.
15. Todorova, S. Using Simulation as an Experiential Learning Tool for Enhancing Students Learning in Environmental Engineering. In Proceedings of the 2019 IEEE Global Engineering Education Conference (EDUCON), Dubai, United Arab Emirates, 8–11 April 2019; pp. 1384–1385.
16. Van Til, R.; Banachowski, M.; Wagner, C.; Sengupta, S.; Hillberg, P. Using a discrete event simulation program in an engineering probability and statistics course. In Proceedings of the 2009 39th IEEE Frontiers in Education Conference, San Antonio, TX, USA, 18–21 October 2009; pp. 1–5.
17. Available online: https://www.wolframalpha.com/input?i=Coulomb%27s+law+2.0mC%2C+2.0mC%2C+250cm&lang=es (accessed on 1 April 2023).
18. Núñez-Delgado, A.; Dominguez, J.R.; Zhou, Y.; Race, M. New trends on green energy and environmental technologies, with special focus on biomass valorization, water and waste recycling: Editorial of the special issue. *J. Environ. Manag.* **2022**, *316*, 115209. [CrossRef] [PubMed]
19. Wang, Z.; Chen, H.; Xia, R.; Han, F.; Ji, Y.; Cai, W. Energy, exergy and economy (3E) investigation of a SOFC-GT-ORC waste heat recovery system for green power ships. *Therm. Sci. Eng. Prog.* **2022**, *32*, 101342. [CrossRef]

20. Dafiqurrohman, H.; Safitri, K.A.; Setyawan, M.I.B.; Surjosatyo, A.; Aziz, M. Gasification of rice wastes toward green and sustainable energy production: A review. *J. Clean. Prod.* **2022**, *366*, 132926. [CrossRef]
21. Elmoursi, A.A.; Castle, G.S.P. Mapping of field lines and equipotential contours in electric field problems using the charge-simulation technique. *J. Electrost.* **1987**, *19*, 221–234. [CrossRef]
22. Available online: https://www.pasco.com/resources/lab-experiments.
23. Nieto-Chaupis, H. Experiences on the quality of education assessment in a network engineering program in Lima city. In Proceedings of the 2017 IEEE URUCON, Montevideo, Uruguay, 23–25 October 2017; pp. 1–4.
24. Rubiano, S.M.M.; López-Cruz, O.; Soto, E.G. Teaching computer programming: Practices, difficulties and opportunities. In Proceedings of the 2015 IEEE Frontiers in Education Conference (FIE), El Paso, TX, USA, 21–24 October 2015; pp. 1–9. [CrossRef]
25. Palacios, C.A.; Reyes-Suárez, J.A.; Bearzotti, L.A.; Leiva, V.; Marchant, C. Knowledge Discovery for Higher Education Student Retention Based on Data Mining: Machine Learning Algorithms and Case Study in Chile. *Entropy* **2021**, *23*, 485. [CrossRef] [PubMed]