SOCIETY FOR SCIENCE

Rules Wizard

SUMMARY

These documents require Adobe® Acrobat Reader, which is a free download from the Adobe® website.

The answers you gave to questions on the previous pages of the Rules Wizard indicate that you need to download the following forms in order to adhere to the International Rules:

These three forms are required for **all** participants:
- Checklist for Adult Sponsor (1)
- Student Checklist (1A) and Research Plan
- Approval Form (1B)

- Official Abstract Form (87 kb) -- Some fairs may require the use of the Regeneron ISEF Official Abstract Form; others may have their own required format. Please contact your regional fair for more information. **Note:** Regeneron ISEF finalists do **not** fill out this abstract form - they have to fill out their abstract on-line. Please read the instructions for completion thoroughly.

- Regulated Research Institutional/Industrial Setting Form (1C) (28 kb) -- This form must be completed by the scientist supervising the student research conducted in a regulated research institution (e.g., university lab, medical center, NIH, SSTP, etc.) or industrial setting. A Research Institution Approval form may need to be supplied by the research site (i.e. IRB/IACUC/IBC).

THESE FORMS ARE NOT TO BE ELECTRONICALLY TRANSFERRED TO Society for Science.   THE FORMS MUST BE COMPLETED BY THE APPROPRIATE INDIVIDUALS, SIGNED AND COPIES SUBMITTED TO your science fair for local, regional or state competition.

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Society for Science

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Checklist for Adult Sponsor (1)
This completed form is required for ALL projects.

To be completed by the Adult Sponsor in collaboration with the student researcher(s):

Student's Name(s): Liu Zihao, Ng Jean Tzi, Edric

Project Title: Data-Driven Method for Li-Ion Battery Health Monitoring

1. ☑ I have reviewed the ISEF Rules and Guidelines, including the science fair ethics statement.

2. ☑ I have reviewed the student's completed Student Checklist (1A) and Research Plan/Project Summary.

3. ☑ I have worked with the student and we have discussed the possible risks involved in the project.

4. ☐ The project involves one or more of the following and requires prior approval by an SRC, IRB, IACUC or IBC:
   - ☐ Humans
   - ☐ Vertebrate Animals
   - ☐ Potentially Hazardous Biological Agents
   - ☐ Microorganisms   ☐ rDNA   ☐ Tissues

5. ☑ Items to be completed for **ALL PROJECTS**
   - ☑ Adult Sponsor Checklist (1)
   - ☑ Student Checklist (1A)
   - ☑ Research Plan/Project Summary
   - ☑ Approval Form (1B)
   - ☑ Regulated Research Institutional/Industrial Setting Form (1C) (when applicable; after completed experiment)
   - ☐ Continuation/Research Progression Form (7) (when applicable)

Additional forms required if the project includes the use of one or more of the following (check all that apply):

☐ **Humans,** including student designed inventions/prototypes. (Requires prior approval by an Institutional Review Board (IRB); see full text of the rules.)
   - ☐ Human Participants Form (4) or appropriate Institutional IRB documentation
   - ☐ Sample of Informed Consent Form (when applicable and/or required by the IRB)
   - ☐ Qualified Scientist Form (2) (when applicable and/or required by the IRB)

☐ **Vertebrate Animals** (Requires prior approval, see full text of the rules.)
   - ☐ Vertebrate Animal Form (5A) - for projects conducted in a school/home/field research site (SRC prior approval required
   - ☐ Vertebrate Animal Form (5B) - for projects conducted at a Regulated Research Institution. (Institutional Animal Care and Use Committee (IACUC) approval required prior experimentation.)
   - ☐ Qualified Scientist Form (2) (Required for all vertebrate animal projects at a regulated research site or when applicable)

☐ **Potentially Hazardous Biological Agents** (Requires prior approval by SRC, IACUC or IBC, see full text of the rules.)
   - ☐ Potentially Hazardous Biological Agents Risk Assessment Form (6A)
   - ☐ Human and Vertebrate Animal Tissue Form (6B) - to be completed in addition to Form 6A when project involves the use of fresh or frozen tissue, primary cell cultures, blood, blood products and body fluids.
   - ☐ Qualified Scientist Form (2) (when applicable)
   - ☐ The following are exempt from prior review but require a Risk Assessment Form 3: projects involving protists, archae and similar microorganisms; projects using manure for composting, fuel production or other non-culturing experiments; projects using color change coliform water test kits, microbial fuel cells; and projects involving decomposing vertebrate organisms.

☐ **Hazardous Chemicals, Activities and Devices** (No SRC prior approval required, see full text of the rules.)
   - ☐ Risk Assessment Form (3)
   - ☐ Qualified Scientist Form (2) (required for projects involving DEA-controlled substances or when applicable)

☑ **Other**
   - ☑ Risk Assessment Form (3)

☑ **I attest to the information checked above and that I have read and agree to abide by the science fair ethics statement.**

Low Kay Siang
Adult Sponsor's Printed Name

(signature)
Signature

04/01/22
Date of Review (mm/dd/yy)

97228448
Phone

lowks @ hci.edu.sg
Email

Student Checklist (1A)

This form is required for ALL projects.

1. a. Student/Team Leader: _Liu Zihao_ Grade: _JC2_

    Email: _171555U@student.hci.edu.sg_ Phone: _80385774_

    b. Team Member: _Ng Jean Tzi, Edric_ c. Team Member: _____

2. Title of Project: _Data–Driven Method for Li-Ion Battery Health Monitoring_

    _____

3. School: _Hwa Chong Institution_ School Phone: _6468 3955_

    School Address: _661 Bukit Timah Road, Singapore, 269734_

    _____

4. Adult Sponsor: _Low Kay Siang_ Phone/Email: _lowks@hci.edu.sg_

5. Does this project need SRC/IRB/IACUC or other pre-approval? ☐ Yes (Tentative start date: _____) ☑ No

6. Is this a continuation/progression from a previous year? ☐ Yes ☑ No
    If Yes:
    a. Attach the previous year's ☐ Abstract **and** ☐ Research Plan/Project Summary
    b. Explain how this project is new and different from previous years on
        ☐ Continuation/Research Progression Form (7)

7. This year's experimentation/data collection:

    _04/04/22_ _01/01/23_
    Actual Start Date: (mm/dd/yy) End Date: (mm/dd/yy)

8. Where will you conduct your experimentation? (check all that apply)
    ☑ Research Institution ☐ School ☐ Field ☑ Home ☐ Other: _____

9. Source of Data:
    ☑ Collected self/mentor ☐ Other Describe/url: _____

10. List the name and address of all non-home and non-school work site(s), whether you worked there virtually or on-site:

    Name _School of Electrical and Electronic Engineering, NTU_

    Address: _50 Nanyang Avenue, Singapore, 639798_

    _____

    Phone/ _67911744_
    email

11. **Complete a Research Plan/Project Summary following the Research Plan/Project Summary instructions must accompany this form.**

12. **An abstract is required for all projects after experimentation.**

International Rules: Guidelines for Science and Engineering Fairs 2022–2023, **societyforscience.org/ISEF**

Research Plan/Project Summary Instructions

A complete Research Plan/Project Summary is required for ALL projects and must accompany Student Checklist (1A).

- All projects must have a Research Plan/Project Summary
  a. The Research Plan is to be written prior to experimentation following the instructions below to detail the rationale, research question(s), methodology, and risk assessment of the proposed research.
  b. If changes are made during the research, such changes can be added to the original research plan as an addendum, recognizing that some changes may require returning to the IRB or SRC for appropriate review and approvals. If no additional approvals are required, this addendum serves as a project summary to explain research that was conducted.
  c. If no changes are made from the original research plan, no project summary is required.
  d. Some studies, such as an engineering design or mathematics projects, will be less detailed in the initial project plan and will change through the course of research. If such changes occur, a project summary that explains what was done is required and can be appended to the original research plan.

- The Research Plan/Project Summary should include the following:
  a. **RATIONALE:** Include a brief synopsis of the background that supports your research problem and explain why this research is important and if applicable, explain any societal impact of your research.
  b. **RESEARCH QUESTION(S), HYPOTHESIS(ES), ENGINEERING GOAL(S), EXPECTED OUTCOMES:** How is this based on the rationale described above?
  c. Describe the following in detail:
      - **Procedures:** Detail all procedures and experimental design including methods for data collection, and when applicable, the source of data used. Describe only your project. Do not include work done by mentor or others. If you will use published surveys, questionnaires or tests, describe how you obtained these, including required permission if applicable.
      - **Risk and Safety:** Identify any potential risks and safety precautions needed.
      - **Data Analysis:** Describe the procedures you will use to analyze the data/results.
  d. **BIBLIOGRAPHY:** List major references (e.g. science journal articles, books, internet sites) from your literature review. If you plan to use vertebrate animals, one of these references must be an animal care reference.

Items 1–4 below are subject-specific guidelines for additional items to be included in your research plan/project summary as applicable.

1. **Human participants research:**

   a. **Participants:** Describe age range, gender, racial/ethnic composition of participants. Identify vulnerable populations (minors, pregnant women, prisoners, mentally disabled or economically disadvantaged).
   b. **Recruitment:** Where will you find your participants? How will they be invited to participate?
   c. **Methods:** What will participants be asked to do? Will you use any surveys, questionnaires or tests? If yes and not your own, how did you obtain? Did it require permissions? If so, explain. What is the frequency and length of time involved for each subject?
   d. **Risk Assessment:** What are the risks or potential discomforts (physical, psychological, time involved, social, legal, etc.) to participants? How will you minimize risks? List any benefits to society or participants.
   e. **Protection of Privacy:** Will identifiable information (e.g., names, telephone numbers, birth dates, email addresses) be collected? Will data be confidential/anonymous? If anonymous, describe how the data will be collected. If not anonymous, what procedures are in place for safeguarding confidentiality? Where will data be stored? Who will have access to the data? What will you do with the data after the study?
   f. **Informed Consent Process:** Describe how you will inform participants about the purpose of the study, what they will be asked to do, that their participation is voluntary and they have the right to stop at any time.

2. **Vertebrate animal research:**

   a. Discuss potential ALTERNATIVES to vertebrate animal use and present justification for use of vertebrates.
   b. Explain potential impact or contribution of this research.
   c. Detail all procedures to be used, including methods used to minimize potential discomfort, distress, pain and injury to the animals and detailed chemical concentrations and drug dosages.
   d. Detail animal numbers, species, strain, sex, age, source, etc., include justification of the numbers planned.
   e. Describe housing and oversight of daily care.
   f. Discuss disposition of the animals at the end of the study.

- **Potentially hazardous biological agents research:**
  a. Give source of the organism and describe BSL assessment process and BSL determination.
  b. Detail safety precautions and discuss methods of disposal.

4. **Hazardous chemicals, activities & devices:**

   a. Describe Risk Assessment process, supervision, safety precautions and methods of disposal.
   b. Material Safety Data Sheets are not necessary to submit with paperwork.

Research Plan

1. Rationale

In line with its push towards sustainability and the lowering of carbon emissions outlined in the Singapore Green Plan 2030, Singapore has launched concerted efforts to transition its vehicle population to cleaner energy, aiming for Internal Combustion Engine (ICE) vehicles to be gradually phased out, and having all vehicles powered by clean energy by 2040. The biggest concern about the promotion of electric vehicles (EVs) is the Li-Ion battery, the key component of energy supply of EVs. Li-Ion batteries has been widely used today, including the EVs and power grid energy storage systems (ESS). It is crucial to have an accurate model for the estimation of state of health (SOH) of Li-Ion batteries for battery energy management and maintenance.

This project aims to develop a data-driven method to real-time monitoring the health of the Li-Ion batteries. Artificial intelligence (AI) algorithms will be developed through neural network using machine learning (ML), to learn from a battery health data set, train a health monitoring model, and then be used for real-time SOH monitoring of the batteries.

To monitor the health of the Li-Ion batteries, both battery data and the estimation model is required. This project will focus on the ML model for the estimation of SOH, provided the accurate data of the battery is collected in the lab.

In this project, we will produce an algorithm to predict the SOH of a battery given the datasets from the battery. In the SOH estimation model, the health indicator (HI) will be extracted first from the raw dataset. After correction and normalisation of the HI data, we will apply the ML model on these data and evaluate the SOH of the battery given. The project involves programming in MATLAB and Python along with the preliminaries in AI and ML.

Our project will mostly focus on the algorithm of estimation, whose accuracy is highly dependent on the quantity and quality of raw data that we used for training and evaluation in our model. Insufficient amount of data may not give us an inclusive result, while data that are not accurate enough may lead to an uncomprehensive and coherent result.

2. Engineering Goals and Expected Outcomes

This project aims to develop a data-driven method in forms of machine learning model to monitor the health of the Li-ion batteries, using the data collected from the battery in real time.

3. Procedures

a) Study all the literatures that are relevant to our project and do preliminary research for the measurement of state of health (SOH) of the battery.

b) Learn programming in MATLAB and Python, and the basic knowledge in artificial intelligence and machine learning. Practise building the basic neural network using Python.

c) Pre-process the data collected and extract the useful information from the datasets.

d) Apply different common deep learning network to build the preliminary architecture of the model.

e) Carry out experiments to try out the effects of different machine learning algorithm on the sample data.

f) Compare and evaluate the accuracy of different models in predicting the health of the battery.

g) Improve the model by optimising loss function and hyperparameters. Use back propagation for the training of hyperparameters.

h) Apply the data-driven model for the estimation of the health of the Li-ion batteries.

4. Risk and Safety

a) Spread of Covid-19: The appropriate Safe Management Measures as recommended by the government of Singapore were adhered to in the course of undertaking this project – masks were worn, meetings were conducted online whenever possible, a safe distance of at least one metre apart was maintained between individuals while physically conducting experiments in the lab.

b) Long screen time for the data computation: Students should take a break and look away at least every 30 minutes. They should pay attention to the posture throughout the day, whether sitting or standing, to reduce some of the strains of screen time.

5. Data Analysis

Given the sample data set from the previous research, we will carry out experiments to try out the effects of different machine learning algorithm on the sample data to find out the better algorithm in representing and generalising the SOH of the batteries. Three algorithms have been tried out in our preliminary research: Recurrent Neural Network (RNN), Long-Short Term Memory (LSTM), and Gated Recurrent Unit (GRU). All the three produce results in the estimation of the SOH of the batteries.

We will then quantitatively evaluate the accuracy of each algorithm by using the optimum loss function, to find the best model in the estimation of the SOH of the batteries. Back propagation is then used to train the values of the hyperparameters in the best model so that the model is improved.

In the end, we will use the final model to predict the SOH of the batteries given an unknown battery with relevant datasets. We will also evaluate the limitation and suggest further improvement on our model.

6. Bibliography

D. Liu, J. Zhou, H. Liao, Y. Peng and X. Peng, "A Health Indicator Extraction and Optimization Framework for Lithium-Ion Battery Degradation Modeling and Prognostics," in IEEE Transactions on Systems, Man, and Cybernetics: Systems, vol. 45, no. 6, pp. 915-928, June 2015, doi: 10.1109/TSMC.2015.2389757.

W. Liu and Y. Xu, "A Comprehensive Review of Health Indicators of Li-ion Battery for Online State of Health Estimation," 2019 IEEE 3rd Conference on Energy Internet and Energy System Integration (EI2), 2019, pp. 1203-1208, doi: 10.1109/EI247390.2019.9062037.

W. Liu and Y. Xu, "Data-Driven Online Health Estimation of Li-Ion Batteries Using A Novel Energy-Based Health Indicator," in IEEE Transactions on Energy Conversion, vol. 35, no. 3, pp. 1715-1718, Sept. 2020, doi: 10.1109/TEC.2020.2995112.

Approval Form (1B)
A completed form is required for each student, including all team members.

---

1. To Be Completed by Student and Parent
  a. **Student Acknowledgment:**
  - I understand the risks and possible dangers to me of the proposed research plan.
  - I have read the ISEF Rules and Guidelines and will adhere to all International Rules when conducting this research.
  - I have read and will abide by the science fair ethics statement.

Student researchers are expected to maintain the highest standards of honesty and integrity. Scientific fraud and misconduct are not condoned at any level of research or competition. Such practices include but are not limited to plagiarism, forgery, use or presentation of other researcher's work as one's own, and fabrication of data. Fraudulent projects will fail to qualify for competition in affiliated fairs and ISEF.

Liu Zihao	_signature_	_04/01/22_
Student's Printed Name	Signature	Date Acknowledged (mm/dd/yy)
		(Must be prior to experimentation.)

  b. **Parent/Guardian Approval:** I have read and understand the risks and possible dangers involved in the **Research Plan/Project Summary**. I consent to my child participating in this research.

Liu Gang	_signature_	_04/01/22_
Parent/Guardian's Printed Name	Signature	Date Acknowledged (mm/dd/yy)
		(Must be prior to experimentation.)

---

2. To be completed by the local or affiliated Fair SRC
(Required for projects requiring prior SRC/IRB APPROVAL. Sign 2a or 2b as appropriate.)

a. **Required for projects that need prior SRC/IRB approval BEFORE experimentation** (humans, vertebrates or potentially hazardous biological agents).

The SRC/IRB has carefully studied this project's **Research Plan/Project Summary** and all the required forms are included. My signature indicates approval of the **Research Plan/Project Summary** before the student begins experimentation.

_____
SRC/IRB Chair's Printed Name

_____   _____
Signature   Date of Approval (mm/dd/yy)
                                 (Must be prior to experimentation.)

OR

b. **Required for research conducted at all Regulated Research Institutions with no prior fair SRC/IRB approval**.
This project was conducted at a regulated research institution (**not home or high school, etc.**), was reviewed and approved by the proper institutional board before experimentation and complies with the ISEF Rules. **Attach (1C) and any required institutional approvals (e.g. IACUC, IRB).**

_____
SRC Chair's Printed Name

_____   _____
Signature   Date of Signature (mm/dd/yy)
                                 (May be after experimentation)

---

3. Final ISEF Affiliated Fair SRC Approval (Required for ALL Projects)

SRC Approval After Experimentation and Before Competition at Regional/State/National Fair
I certify that this project adheres to the approved **Research Plan/Project Summary** and complies with all ISEF Rules.

_____	_____	_____
Regional SRC Chair's Printed Name	Signature	Date of Approval (mm/dd/yy)
_____	_____	_____
State/National SRC Chair's Printed Name *(where applicable)*	Signature	Date of Approval (mm/dd/yy)

Approval Form (1B)
A completed form is required for each student, including all team members.

1. To Be Completed by Student and Parent
a. Student Acknowledgment:
- I understand the risks and possible dangers to me of the proposed research plan.
- I have read the ISEF Rules and Guidelines and will adhere to all International Rules when conducting this research.
- I have read and will abide by the science fair ethics statement.

Student researchers are expected to maintain the highest standards of honesty and integrity. Scientific fraud and misconduct are not condoned at any level of research or competition. Such practices include but are not limited to plagiarism, forgery, use or presentation of other researcher's work as one's own, and fabrication of data. Fraudulent projects will fail to qualify for competition in affiliated fairs and ISEF.

Ng Jean Tzi, Edric | | 04/01/22
Student's Printed Name | Signature | Date Acknowledged (mm/dd/yy)
| | (Must be prior to experimentation.)

b. Parent/Guardian Approval: I have read and understand the risks and possible dangers involved in the **Research Plan/Project Summary**. I consent to my child participating in this research.

Tuam Fenq Ling | | 04/01/22
Parent/Guardian's Printed Name | Signature | Date Acknowledged (mm/dd/yy)
| | (Must be prior to experimentation.)

2. To be completed by the local or affiliated Fair SRC
(Required for projects requiring prior SRC/IRB APPROVAL. Sign 2a or 2b as appropriate.)

a. Required for projects that need prior SRC/IRB approval BEFORE experimentation (humans, vertebrates or potentially hazardous biological agents).

The SRC/IRB has carefully studied this project's **Research Plan/Project Summary** and all the required forms are included. My signature indicates approval of the **Research Plan/Project Summary** before the student begins experimentation.

_____
SRC/IRB Chair's Printed Name

_____   _____
Signature   Date of Approval (mm/dd/yy)
                                        (Must be prior to experimentation.)

OR

b. Required for research conducted at all Regulated Research Institutions with no prior fair SRC/IRB approval.
This project was conducted at a regulated research institution (**not home or high school, etc.**), was reviewed and approved by the proper institutional board before experimentation and complies with the ISEF Rules. **Attach (1C) and any required institutional approvals (e.g. IACUC, IRB).**

_____
SRC Chair's Printed Name

_____   _____
Signature   Date of Signature (mm/dd/yy)
                                        (May be after experimentation)

3. Final ISEF Affiliated Fair SRC Approval (Required for ALL Projects)

SRC Approval After Experimentation and Before Competition at Regional/State/National Fair
I certify that this project adheres to the approved **Research Plan/Project Summary** and complies with all ISEF Rules.

_____   _____   _____
Regional SRC Chair's Printed Name | Signature | Date of Approval (mm/dd/yy)

_____   _____   _____
State/National SRC Chair's Printed Name | Signature | Date of Approval (mm/dd/yy)
(where applicable)

Risk Assessment Form (3)

Must be completed before experimentation. Required for projects involving hazardous chemicals, activities or devices and may be needed by other projects.

Student's Name(s) ___Liu Zihao, Ng Jean Tzi Edric___

Title of Project ___Data-Driven Method for Li-Ion Battery Health Monitoring___

To be completed by the Student Researcher(s) in collaboration with Designated Supervisor/Qualified Scientist: (All questions must be answered; additional page(s) may be attached.)

1. Identify and assess the risks and hazards involved in this project.

   1. Spread of Covid-19
   2. Long screen time for the data computation

2. a) List all hazardous chemicals, activities or devices to be used; b) identify and list all microorganisms to be used that are exempt from pre-approval (see Potentially Hazardous Biological Agent rules).

   N.A.

3. Describe the safety precautions and procedures that will be used to reduce the risks.

   N.A.

4. Describe the disposal procedures that will be used (when applicable).
   1. The appropriate Safe Management Measures as recommended by the government of Singapore were adhered to in the course of undertaking this project – masks were worn, meetings were conducted online whenever possible, a safe distance of at least one metre apart was maintained between individuals while physically conducting experiments in the lab.
   2. Students should take a break and look away at least every 30 minutes. They should pay attention to the posture throughout the day, whether sitting or standing, to reduce some of the strains of screen time.

5. List the source(s) of safety information.

   N.A.

To be completed and signed by the Designated Supervisor (or Qualified Scientist, when applicable):
I agree with the risk assessment and safety precautions and procedures described above. I certify that I have reviewed the Research Plan and the International Rules, including the science fair ethics statement and will provide direct supervision.

___Xu Yan___
Designated Supervisor's Printed Name

___[signature]___
Signature

___04/01/22___
Date of Review (mm/dd/yy)

___Associate professor in School of Electrical and Electronic Engineering, NTU, Singapore___
Experience/Training as relates to the student's area of research

___Associate professor, NTU Singapore___
Position/Institution

___xuyan @ ntu.edu.sg___
Phone or email contact information

International Rules: Guidelines for Science and Engineering Fairs 2022–2023, **societyforscience.org/ISEF**