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ABSTRACT

Each year, beginning in the early spring, Department of Defense Dependent Schools, Pacific Region conducts a Junior Science and Humanities Symposium program. The information for putting together such a program is contained in this document. Students are invited to conduct original research in the sciences, mathematics, the humanities, and computer applications that relate to research in those three fields. The research period ends in early spring of the next year. Following conclusion of the research period, students who complete research projects and the writing of research project papers spend a week presenting their research to other students, visiting locations where research is actively being conducted, participating in Japanese-American cultural events and a host of other activities. During the week, three top student researchers are chosen from the participants. Later in the spring, the winning students travel to the National Junior Science and Humanities Symposium in the United States where the first place researcher presents his or her research again. The student who presents his or her paper at the National Symposium competes with other students for an opportunity to make a presentation at the International Junior Science and Humanities Symposium, usually held in London, England, during the following summer. (MVL)

DEPARTMENT OF DEFENSE DEPENDENT SCHOOLS
PACIFIC REGION

JUNIOR SCIENCE AND HUMANITIES SYMPOSIUM

SCHOOL LEVEL MANAGEMENT INFORMATION BOOKLET FOR SY89-90

April 1989

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DOCUMENT PURPOSE

This document contains all of the information necessary to administer the annual Department of Defense Dependent Schools-Pacific Region Junior Science and Humanities Symposium at the school level. It is published yearly in April and intended for use by DoDDS-P high school principals, JSHS coordinators, sponsors and mentors in administering the local JSHS program. In addition, it should be used by students as they conduct their research and write about their projects.

PACIFIC JUNIOR SCIENCE AND HUMANITIES SYMPOSIUM OVERVIEW

SYMPOSIUM REGIONAL DIRECTOR: Regional Science Coordinator

SYMPOSIUM HOST: District Superintendent of Schools, Japan

ACTIVITY DESCRIPTION: The symposium is a 4 day meeting of high school students who have done experimental research in any of the sciences, mathematics, humanities or computer sciences. Formal and informal presentations are made of student research laboratories at the symposium site are visited and speakers discuss the importance of research to the future of Mankind. The importance of the humanities is also stressed.

LOCATION: Tsukuba Science City, Japan

TRANSPORTATION ARRANGEMENTS: Arrangements are made by the high school administrations and DSO Japan.

POPULATION INVOLVED:

1. TARGET PARTICIPANTS: Students from all DoDDS Pacific High Schools
2. NUMBER OF STUDENTS/TEACHERS: About 100
3. GRADE LEVELS: 9-12

DATES OF THE ACTIVITY: April 23-27, 1990

FUNDING RESPONSIBILITY:

1. FOR FACULTY: The symposium operates under a contract from the Academy of Applied Sciences/Army Research Office and all expenses are borne by Symposium. Transportation and substitute expenses are paid by DoDDS-Pacific.
2. FOR STUDENTS: All symposium expenses are borne by the Symposium. Transportation expenses are paid by DoDDS-Pacific.

APPLICANT SELECTION PROCESS: To be eligible for participation, each student must submit an application for participation by December 15 1989, and an acceptable completed research paper reporting on the experimental work done by the individual. One copy of the research paper must arrive in the Regional Office and one copy in DSO-Japan not later than February 15, 1990. Each student's mentor decides whether his or her student has complete the research project at a level sufficient to warrant participation.

PURPOSE OF THE ACTIVITY: To foster the skills of critical thinking, to develop an awareness of the process inquiry and the meaning of "knowledge," to expand career horizons, and to provide recognition for those who do, "a good piece of academic work."

PROGRAM DESCRIPTION

Each year, beginning in the spring, Department of Defense Dependent Schools, Pacific Region conducts a Junior Science and Humanities Symposium program. Students are invited to conduct original research in the sciences, mathematics, the humanities and computer applications that relate to research in those three fields. The research period ends in early spring of the next year. Following conclusion of the research period, students who complete research projects and the writing of research project papers spend a week presenting their research to other students, visiting locations where research is actively being conducted, participating in Japanese-American cultural events and a host of other activities. During the week, three top student researchers are chosen from the participants. Later in the spring, the winning students travel to the National Junior Science and Humanities Symposium in the United States where the first place researcher presents his or her research paper again; this time to student researchers from the entire United States. The student who presents his or her paper at the National Symposium competes with other students for an opportunity to make a presentation at the International Junior Science and Humanities Symposium, usually held in London, England during the following summer.

PROGRAM OBJECTIVES

The symposium objectives are to:

1. PROMOTE high school level research and experimentation in the humanities, the sciences, mathematics, and engineering.

2. RECOGNITION of the significance of research in human affairs, and the importance of humane and ethical principles in the application of research results.

3. IDENTIFY talented youth and their teachers, recognize their accomplishments and encourage their continued interest and participation in humanities, science, mathematics and engineering.

4. EXPAND the horizons of research oriented students by exposing them to opportunities in the academic, industrial, and governmental communities.

5. ENLARGE the number of future adults capable of conducting research.

PROGRAM THEMES

The following Symposium themes have been established for school years 87-88 through 94-95. It is not necessary that student researchers orient their research around the theme for the year. The theme of the year should be advertised by the school JSHS coordinator at the beginning of the program year (the spring of the previous school year) and at the beginning of the school year. Program themes may stimulate some students to join the program who might otherwise not conduct a research project.

School Year	Theme
1. 87-88	The World Ocean Our Last Frontier
2. 88-89	Space Challenge of the 21st Century
3. 89-90	Science and Humanities - The Eternal Quest
4. 90-91	The Integration of Science and Technology for Mankind
5. 91-92	Biotechnology - Designs for the Future
6. 92-93	Telecommunications - Conversation with the Stars
7. 93-94	The Cosmic Connection
8. 94-95	Project Civilization

PROGRAM AWARDS

1. <u>Students</u>:

a. Formal Presentations. Three top researchers are chosen from those individuals selected to make formal presentations.

(1) The three top presenters receive a trip to the National JSHS held in the continental U.S.

(2) The first place person receives a scholarship to the college of his or her choice. The value is usually $500.00

b. Poster Presentations. Three top presenters are chosen from each poster session. A book of some sort is usually given to each of these individuals.

2. <u>Mentors</u>: The mentor of the winning student in the formal presentation session is presented a grant to purchase equipment for his or her school. The grant is usually

$300.00. In cases where the mentor of a student is not a member of a school faculty, the grant shall go to the high school of the winning student and be spent for equipment in a subject area related to the area in which the winning student conducted his or her research.

PARTICIPANT ELIGIBILITY

Participation in the Junior Science and Humanities Symposium is open to all students attending Department of Defense Dependent Schools, Pacific Region High Schools (grades 9-12) who are interested in and subsequently complete an acceptable research project in the sciences, mathematics, humanities or computer applications that relate to research in those fields.

APPLICATION FEE

There is a $30.00 non-refundable application fee. The fee must accompany a students application for participation in the Junior Science and Humanities Symposium. The payment must be made by check (cash will not be accepted) payable to the Treasury of the United States.

SYMPOSIUM COORDINATORS

A JSHS Coordinator may be assigned by the school administrator (coordinators could be paid under the extra curricular activity program; a decision regarding such payment, however, is up to the school administrator). Coordinators, when assigned, can be but are not necessarily mentors or sponsors (see Symposium Mentors and Sponsors below). The coordinator insures that the school level JSHS program functions in accordance with the guidelines set forth in this publication; that is, the students of the various mentors meet the necessary time requirements, applications are submitted, application fees are paid, parental permission slips are on file at the school, student papers are submitted and action, when necessary, is taken to have travel orders cut. Coordinators may be from any discipline but preferably teach science, mathematics, computer and or humanities subjects. Coordinators also may help to locate mentors, who are non school people like scientists, medical personnel and university professors working in the local community and willing to guide a student through his or her research.

SYMPOSIUM MENTORS

Mentors are people who guide students through their research, helping them with the scientific method, literature searching, and writing their research papers. Mentors may be teachers, scientists, medical personnel, mathematicians, computer specialists and others working in the local community. Mentors may be coordinators and or sponsors.

SPONSORS

Sponsors are people who accompany students from their schools to the Pacific Region Junior Science And Humanities Symposium. They need not but may be coordinators and mentors.

PROJECT GUIDELINES

1. Scientific Method: The scientific method should be used in all research projects. The method generally consists of: (1) identification of a problem; (2) gathering all the pertinent data; (3) formulating an hypothesis; (4) performing experiments; (5) interpreting the results of the experiments; (6) drawing one or more conclusions regarding the hypothesis. Students often conduct library research projects, falsely thinking that such endeavors are a correct application of the scientific method. Generally, such is not the case. Proper use of the method will be stressed heavily during the evaluation process leading to selection of research projects for formal presentation at the Symposium.

2. Use of Animals in Research: The use of animals in research projects is to be closely monitored by school officials at the local level. In this regard, the following guidance applies:

a. Unacceptable Projects. Projects leading to the needless killing of animals or where there is high probability that the research will lead to the death of an animal are not acceptable as Junior Science and Humanities Symposium research projects.

b. Disapproved Projects. Projects where there is a chance the research will lead to death of research animals should be evaluated by a board of science teachers or other science personal prior to their approval. The board will evaluate the proposal/s to ensure that all possible precautions to prevent death of the animal/s have been taken. If, after evaluation, the board feels there is still a high probability that death will occur regardless of the precautionary measures the project should not be approved.

c. Acceptable Projects. Projects where there is a slight chance that a research animal will die are acceptable but should be scrutinized closely by faculty mentors prior to their being approved. All possible precautions should be taken to prevent the loss of a research animal.

d. Acceptable Projects. Projects where research animals die for no apparent reason are acceptable.

3. Research Paper Organization: Guidance for the organization of student research papers is provided in Appendix F, Organization of Student Papers and Abstracts.

4. Additional Guidelines: Additional guidelines for the conduct of high school research is provided in Appendix G Guidelines for High School Students Conducting Research.

ABSTRACTS

1. General: An abstract shall be written for every paper which is submitted and shall accompany the paper when it is submitted. A form is included in Appendix A, Abstract Forms, for this purpose. Xerox copies of the form may be made to meet the needs of individual schools.

2. Length: The abstract should be of adequate length to describe the project but should not exceed 175 words.

3. Writing: The abstract must be single spaced and typed. Hand written abstracts will not be accepted.

4. Suggestions for Abstract Writing:

a. Answer Questions. Abstracts should answer the questions; Who; What; Where; When; Why; sometimes, How?

b. Tense. The past tense and third person should be used to describe completed research.

c. English Usage. Proper sentence structure and grammar must be used.

d Abbreviations. Do not use abbreviations.

e. Assumption. Assume readers will have a good technical vocabulary.

f. Specialized Vocabulary. Try to avoid the use of highly specialized words.

g. Results and Conclusions. State results and conclusions or findings in a clear, concise fashion.

5. Example Abstracts: Examples of abstracts are included in Appendix H, Example Abstracts.

6. Additional Information: Additional information about abstract writing is contained in Appendix G.

TYPING

1. Paper: The paper must be typed, double spaced. Papers that are not typed will not be accepted.

2. Abstract: When typing the abstract, the form provided in Appendix A is used; also see the "Abstract" section, above and Appendix G.

PAPER SUBMISSION

1. Time: Papers are submitted to arrive on or before the deadline date listed below in the Symposium Time-line.

2. Copies: Two copies of the paper shall be submitted as follows:

a. One copy to;

DISTRICT SUPERINTENDENT OF SCHOOLS, JAPAN
APO SAN FRANCISCO, CA 96328-0005
AUTOVON 225-3940/3941/3947

b. One copy to;

SCIENCE COORDINATOR
DODDS-PACIFIC/EDUCATION DIVISION
FUTENMA BOX 796
FPO SEATTLE, WA 98772-0005
AUTOVON 635-2365/2147/2151

JUDGING GUIDELINES

1. First Evaluation. All research papers submitted as part of the Junior Science and Humanities Symposium program are evaluated by a team of scientists and other research

oriented individuals to determine: (1) the quality of the investigator's research design; (2) the originality of the topic or approach; (3) the level of scientific understanding displayed in the paper; (4) the quality of the paper itself. Papers are chosen for formal presentation at the Symposium based upon the outcome of this evaluation. Appendix B contains a copy of the Research Paper Evaluation form used for this process. This evaluation leads to the selection of students who will make formal presentations at the symposium. All students not chosen to make formal presentations, make poster session presentations.

2. Second Evaluation. Students chosen to present their papers formally at the Symposium are evaluated a second time. This time, the quality oral presentations are judged to determine: (1) the quality of the research design; (2) the originality of the topic or approach; (3) the level of scientific understanding displayed by the presenter; (4) the quality of the presentation. Three people are normally selected, as a result of this process, to attend the National Junior Science and Humanities Symposium in the U.S. One of the students' is selected as the winner and presents his or her paper at the National Symposium. Appendix C contains a copy of the Oral Presentation Evaluation form used for this process.

ORAL PRESENTATIONS

1. Preparing For Oral Presentations: Students often become nervous when they must face an audience. As a result of being nervous, their presentations, which might have otherwise been well done, turn out poorly. Practice presentations in front of a video camera may help students overcome some of their fears, nervousness and the like. Once students have had their presentations taped, they: (1) view the tape to see actually what the audience saw when the presentation was made; (2) ask fellow students to view the tape with them and make suggestions regarding ways to improve the presentation; (3) have mentors, sponsors, coordinators and teachers view the tape and make suggestions for improvement. For the best possible results, this process should be repeated several times.

2. Visuals: During presentations, 2x2 slides and overhead projectors may be used. Visuals must be easily readable at the back of a large lecture hall. Visuals should numbered plainly so that if one needs to be shown again it can be easily located.

3. Timing: Formal presenters are allowed 15 minutes to make their presentations. Speakers must stop at the end of 15 minutes even though they have not completed their presentation. They will be given a three minute warning by the program moderator following 12 minutes of presentation. Following conclusion of a presentation, the presenter will be allowed 10 minutes to answer questions asked about the research project by the judges and the audience. During the question and answer period, the audience is free to ask questions only about the research project and the presenters suggestions for additional research in his or her field of investigation.

POSTER SESSIONS

1. General: Poster sessions are held during the Symposium.

2. Participants: All students not selected to make formal presentations are expected to make poster presentations.

3. Posters:

a. Size; Posters should be about one meter long and one meter wide.

b. Composition; Posters should summarize a research project, showing, in the most vivid way possible, the important aspects of the project. They should include:

(1) Project Title

(2) Author

(3) Methods

(4) Results

(5) Conclusions

Methods and results should be presented graphically with photographs and a minimum of text. The conclusion(s), being the most important part should be related to the experimental results. The amount of verbiage should be limited and written in clear, correct, standard English.

c. Color: Intelligent use of color can make the difference between a monotonous display and one that says, "For something interesting, come over here."

d. Crowding: Be careful not to crowd the poster with too much data. Consider providing interested individuals with a copy of your abstract rather than trying to force everything about your project on one poster.

e. Evaluation; Posters will be evaluated by sponsors. Judges will use sections the form included in Appendix D, Poster Session Evaluation Form. First, second and third place projects will be chosen as a result of this process, for each session.

4. Poster Session Length: There are three one hour sessions. Each student who is presenting a poster is assigned to one of the sessions and has the other two sessions free. During the session to which a person is assigned, he or she is expected to make mini-presentations to students and others interested in finding out more about his or her research.

SYMPOSIUM TIME-LINE

1. April 1, 1989	Students begin research projects.
2. December 15, 1989	Students submit: a. Applications for participation in JSHS to the Regional science coordinator. b. The $30.00 non-refundable application fee to the Regional science coordinator. c. One copy of "Parental Permission for School Activity" DSP Form 105 or equivalent to the JSHS coordinator.
3. February 15, 1990	Students submit: a. Abstract and one copy of their research paper to the Regional science coordinator. b. Abstract and one copy of their research paper to District Superintendent of Schools, Japan.
4. April 23-27, 1990	Regional JSHS at Tsukuba City, Japan

5. May 1990 National JSHS, U.S.

6. July 1990 International Youth Science Fortnight, London, England

APPLICATION FORM

A copy of the Junior Science and Humanities Symposium application form is included in Appendix E. Xerox copies of the form should be made to cover the needs of individual schools.

PARENTAL PERMISSION FORM

Parental permission must be obtained before a student can attend the Symposium. Permission is obtained by having parents complete, "Parental Permission for School Activity," DSP Form 105 or equivalent. Completed forms for attending students shall be retained by the administration of the students respective schools.

ACCEPTANCE TO ATTEND

Acceptance of a student to attend the symposium is based upon the quality of the work done by the particular applicant. The determination of whether or not a student's work, both research and final research report meets acceptable standards based upon the information published herein, is made at the student's school by his or her mentor. Once a research paper has been deemed acceptable by a mentor and forwarded to the Regional Office that student is accepted for attendance at the symposium.

ORDERS

1. <u>Sponsors</u>: Travel orders shall be issued for sponsors by school administrators in accordance with guidance set forth for Region approved events. Sponsor TDY orders will be issued with the following statement in block 16 of DOD Form 1610, "Traveler must depart NLT 21 April 1990 and return NLT 29 April 1990. Limited per diem of $3.50 per day is authorized from 1500 hours 23 April through 1200 hours 27 April 1990. Full per diem is authorized for the remainder of the TDY period." Use of commercial foreign air carrier. may be authorized by the DSO. Otherwise Military Airlift Command (MAC) shall be used. Where necessary, rail and bus transportation may be used. If additional funds are

required for Region approved events, a request for amendment to DSPA Form 7001 should be requested from the regional finance officer.

2. Students: Student travel orders will be issued similar to those used for student travel for athletic events.

TRAVEL

1. Yokota Arrival Times: Yokota MAC terminal tentative arrival times, flight numbers and arrival dates for those students and sponsors traveling via MAC to the regional JSHS should be forwarded as soon as possible by telephone to District Superintendent of Schools, Japan at AUTOVON 225-3940/3941/3947.

2. Meeting Arriving JSHS Attendees: A DoDDS representative will attempt to meet all incoming flights based upon information provided as directed in paragraph 1 of this section. If your flight is not met, call Takashi Suyama by telephone at 0425-45-4894 or 225-3940/3941/3947.

3. Yokota Departure: Buses will depart for Tsukuba City from the Yokota Officer's Club parking lot at 1200, 23 April 1989.

FOOD

1. Student Responsibility: Students are responsible for all food costs incurred following their departure from home and prior to the evening meal, 23 April 1990 and following the noon meal on 27 April 1990 and the time they arrive home again.

2. Symposium Meals: Food is provided free to all participants during the Symposium period.

LODGING

1. Early Arrival at Yokota Air Base: Sponsors and students arriving at Yokota Air Base prior to 23 April 1990 will be provided lodging at Yokota High School or some similar location. Travelers should bring:

a. Sleeping bags.

b. Towels.

c. Shower shoes.

d. Bathrobe.

2. <u>Late Departure From Yokota Air Base</u>: Sponsors and students departing Yokota Air Base on 01 and 02 April 1989 will be provided lodging at Yokota High School or some similar location.

3. <u>Students, Sponsors And The BOQ</u>: Sponsors and their students wishing to make BOQ reservations before departure for Tsukuba City and following return from Tsukuba may do so. The cost of such lodging, however, will be the responsibility of the traveler. Takashi Suyama must be notified at AUTOVON 225-3940/3941/3947, two weeks prior to your arrival, if BOQ reservations are made for the group from your school.

TRAVEL CLAIMS

All sponsors must file a travel claim, DOD Form 1351 within five working days following the completion of travel.

TENTATIVE SYMPOSIUM SCHEDULE

<u>April 23, 1990 (Monday)</u>

1200	Depart Yokota Air Base
1600	Arrive Tsukuba Training Center, Check In
1700	Sponsors Meeting
1800	Banquet at University Hall
2300	Lights Out

<u>April 24, 1990 (Tuesday)</u>

0715	Breakfast
0830	Depart for Tsukuba Training Center
0845	Poster Session One
0945	Poster Session Two
1045	Poster Session Three
1145	Depart for Lunch
1300	Depart for Field Trip
1700	Sponsors Meeting
1800	Dinner
2300	Lights Out

<u>April 25, 1990 (Wednesday)</u>

0715	Breakfast

0845	Depart for Tsukuba Training Center
0900	Student Presentations
1145	Depart for Lunch
1245	Depart for Field Trip
1630	Depart for Mr. Inaba's House and Cultural Cultural Exchange Program
2300	Lights Out

April 26, 1990 (Thursday)

0715	Breakfast
0815	Sponsors Meeting
0845	Depart for Tsukuba Training Center
0900	Student Presentations
1000	Key-Note Speaker
1030	Student Presentations
1145	Depart for Lunch
1245	Depart for Field Trip
1800	Dinner
1930	Possible Student Party
2300	Lights Out

April 27, 1990 (Friday)

0715	Breakfast
0830	Sponsors Meeting
0845	Depart for Tsukuba Training Center
0900	Closing Ceremony
1130	Lunch
1300	Depart for Yokota Air Base

THINGS TO KNOW ABOUT TSUKUBA CITY AND THE TRAINING CENTER

1. Money: It is difficult to change dollars to yen! You should plan accordingly, bringing as much yen as you think you will need.

2. Towels: The training center does not provide towels with the rooms. You must bring your own.

3. Dress:

   a. Students;

      (1) Dress-up the first night for the banquet.

      (2) Dress-up during formal presentations.

      (3) Dress-up during poster presentations.

(4) Bring casual and cool weather clothing, its not too late for snow in this part of Japan.

b. Sponsors;

(1) Be prepared to introduce your students to the audience for formal presentations.

(2) Casual and cool weather clothing.

4. Rooms: Each sponsor anc student has an individual room; sponsors usually stay in the same area on the same floors as their students.

5. Food: Food at the Training center is Japanese style. There are local establishments where other types of food may be purchased. Such purchase, however, is at the individuals own expense.

APPENDIX A

ABSTRACT FORMS

NAME:
HOME ADDRESS:
SCHOOL:
SPONSOR/TEACHER:
TITLE:

ABSTRACT FORM FOR NATIONAL JSHS STUDENT PARTICIPANTS

Everyone who attends the National JSHS receives a book that includes 1 to 1 photographic reproductions of the abstracts typed within the above borders. There is no editing of the submitted abstract; therefore, one should make sure there are no careless mistakes such as typographical errors or misspelled words and that the abstract is clearly and concisely written.

A good abstract can be written by proper condensation of a full length, carefully structured research paper. The abstract should accurately convey the essential nature of the research conducted and the most significant conclusions reached. In the context of the National JSHS, a further purpose of the abstract is to attract the interest and curiosity of the non-specialist reader and thus to encourage exchange, discussion and elaboration between various authors and between authors and readers.

INSTRUCTIONS: Employ a typewriter using type of a standard style (such as IBM Prestige Elite 72, 12 letters/inch). Use the spacing and capitalization style shown by examples on the reverse side of this sheet. If any diagramming is necessary, do it in black ink. If a machine with special characters is not available, black ink should be employed. The typing must be single-spaced. The abstract should be of adequate length but not exceed 175 words. Only the material contained within the border lines will be photographed.

DO NOT SUBMIT A PHOTOCOPY OF THIS FORM TO THE NATIONAL JSHS OFFICE. ABSTRACTS MUST BE SUBMITTED ON THIS FORM WITH THE BLUE BORDER.

APPENDIX B

RESEARCH PAPER EVALUATION FORM

Junior Science and Humanities Symposium

Name of Student: ______________________________

Title of Presentation: ______________________________

____

RESEARCH PAPER EVALUATION

POINTS		CRITERIA
______	40	I. Quality of Research Design
	______	a. Statement and delineation of problem
	______	b. Identification of variables
	______	c. Recognition of limitations of measurements
	______	d. Adequacy of data (amount)
	______	e. Statistical analysis appropriate to *high school*
______	20	II. Originality of Topic or Approach
	______	a. Suitable subject for high school research
	______	b. Personal work vs. professional help
	______	c. Originality vs. laboratory manual report
______	25	III. Scientific Understanding Displayed
	______	a. Emphasis on significant vs. trivial
	______	b. Objectivity
	______	c. Scientific vs. value judgments
	______	d. Recognition of the limitations of the study
	______	e. Conclusion based on data.
______	15	IV. Quality of the Paper Itself
	______	a. Title page
	______	b. Table of contents
	______	c. Summary or abstract
	______	d. Introduction
	______	e. Discussion
	______	f. Conclusions/recommendations
	______	g. Acknowledgements
	______	h. References (Note: Many schools do not have extensive libraries)
	______	i. Display of data
	______	j. General clarity of expression
______	Total Points	

Comments:

____

Signature of Evaluator Date

DoDDS-Pacific Region in cooperation with U.S. Army Research Office

APPENDIX C

ORAL PRESENTATION EVALUATION FORM

Junior Science and Humanities Symposium

Name of Student: ____________________

Title of Presentation: ____________________

____

ORAL PRESENTATION EVALUATION

POINTS		CRITERIA
______	25	I. Quality of Research Design
	______	a. Statement and delineation of problem
	______	b. Identification of variables
	______	c. Recognition of limitations of measurements
	______	d. Adequacy of data (amount)
	______	e. Statistical analysis appropriate to *high school*
______	10	II. Originality of Topic or Approach
	______	a. Suitable subject for high school research
	______	b. Personal work vs. professional help
	______	c. Originality vs. laboratory manual report
______	35	III. Scientific Understanding Displayed
	______	a. Emphasis on significant vs. trivial
	______	b. Objectivity
	______	c. Scientific vs. value judgments
	______	d. Recognition of the limitations of the study
	______	e. Conclusion based on data.
______	30	IV. Quality of the Presentation
	______	a. Introduction
	______	b. Discussion
	______	c. Conclusions/recommendations
	______	d. Acknowledgements
	______	e. References (Note: Many schools do not have extensive libraries.)
	______	f. Display of data
	______	g. General clarity of expression
______	Total Points	

Comments:

____________________ ____________________

Signature of Evaluator Date

DoDDS-Pacific Region in cooperation with U.S. Army Research Office

APPENDIX D

POSTER SESSION EVALUATION FORM

JUNIOR SCIENCE AND HUMANITIES SYMPOSIUM

Name of Student: ______________________________

Research Project Title: ______________________________

____

POSTER SESSION EVALUATION

Note! All items in the criteria column are evaluated both on the students poster and on his or her informal presentation to fellow students and others.

POINTS			CRITERIA
________	___45___	I.	Quality of Research Design
	________	a.	Is the problem well stated and delimited?
	________	b.	Are variables identified?
	________	c.	Is there a recognition that measurements are limited?
	________	d.	Is the data sufficient enough to support decisions that were made?
	________	e.	Is the statistical analysis appropriate to the experience of the student researcher?
________	___25___	II.	Originality of Topic or Approach
	________	a.	Was the research topic suitable for HS research?
	________	b.	Is there evidence that the majority of the work was accomplished by the student?
________	___30___	III.	Scientific Understanding Displayed
		a.	Did the student emphasize significant details?
	________	b.	Was the student objective?
	________	c.	Were limitations of the study recognized?
	________	d.	Were conclusions based upon data?

Name of the Evaluator ______________________________

APPENDIX E

STUDENT APPLICATION FORM

STUDENT APPLICATION FOR THE

PACIFIC REGION JUNIOR SCIENCE AND HUMANITIES SYMPOSIUM

DIRECTIONS

A. Provide a complete answer in each blank.

B. Forward with a check in the amount of $30.00, payable to the Treasury of the U.S.

1. Name & Student Identification Number: ____________________

____

2. Sex: ________ ________________________________

3. School Name: ________________________________

4. Home Mailing Address: ____________________________

____

5. Home Telephone Number: ____________________________

6. Mentor's Signature: ______________________________

7. Principal/Asst. Principal Signature: __________________

____

8. Mail To: Science Coordinator
DoDDS-Pacific/Education Division
Futenma Box 796
FPO Seattle 98772-0005

APPENDIX F

ORGANIZATION OF STUDENT PAPERS

ORGANIZATION OF STUDENT RESEARCH PAPERS

Research papers should contain at least the following sections, in that order:

1. Title.

2. Abstract.

3. Introduction (reasons for doing the project).

4. Methods (a description of the way the project was conducted - the reader should be able to duplicate your research base upon what has been said in this section; the makes and models of specialized equipment should be included here).

5, Findings (your findings are described here; the section often includes a summary of observations, Tables, Figures and Photographs)

6. Discussion (this section is a technical discussion which often begins with a restatement of the problem you investigated followed by a discussion of your findings and a comparison of your findings with what is known about the problem based upon information in various literature sources).

7. Conclusions (what conclusions can be drawn about the problem you researched based upon your findings?).

8. Recommendations For Further Research (here, statements are made, based upon your findings, about the types of additional study, which when conducted, will allow us to better understand the problem you investigated_.

9. Literature Cited (list the literature you cite in your writing).

10. Appendicies (included here are data tables, lists of symbols used, a glossary etc, as appropriate to your project. Common apparatus such as test tubes should not be listed here).

APPENDIX G

GUIDELINES FOR CONDUCTING RESEARCH

Contents

List of Figures

CHAPTER 1:

Your Research Project

1.1 *Message to the Student.*

So you have decided to undertake a bit of research in science! Congratulations from the scientific community! This manual has been prepared to help you plan and carry out a project in an effective and efficient manner. It will not tell you what to do or precisely how to do it. Rather, it will make available to you some techniques devised by scientists to maximize meaningful results from their efforts. It will be up to you to plan your work and to choose and employ techniques that will be most effective in your research. In every way, it is to be your project.

It is through investigative efforts like the one you are beginning that mankind has expanded its knowledge. The cumulative effects of asking and answering questions and p[illegible]ng on the answers account considerably for the nature of our modern life style. The process known as "research" is closely tied in with the term "progress," and the products of research play a large part in what we call our culture.

The work you are about to do is important. Dignity and pride are associated with the expansion of knowledge. A legitimate, honest question deserves an answer even if its significance is not immediately apparent. Often the worth of a research result is not perceived until years after completion of the project. You need not be concerned with the amount of significance of the results of your project, but with the quality of its planning, logic, and accuracy.

We wish to help you avoid floundering around and moving in directions not likely to lead toward accomplishment of your objectives. Therefore, you will first be provided in this manual with a general discussion of the research process. This will be followed by some tips on experimental design and on planning in general. One of our first objectives will be to get you to view your task as a whole, so you will be able to evaluate your state of progress as the project moves toward completion. Some specific techniques of research will then be discussed, to enable you to select ones that can be applied to your situation.

It is assumed that you have had at least a first course in algebra and one or more introductory courses in science. That should be adequate preparation for you to read and understand most of the material in this manual. Parts of Chapters 5 and 6 are mathematical, and you may not be sufficiently prepared to understand them completely on first reading. If that should be the case, do not let it stop you from reading the rest of the manual and being guided by it, counting on the fact that your understanding of analysis and statistical measures will improve from subsequent study.

As a first step, a professional researcher searches the published literature to see whether a study he proposes to undertake has already been made and the outcome adequately reported. You should of course make an effort along that line. However, since you are not likely to have access to all of the literature on your topic, if it should turn out that you arrive at conclusions already established through earlier work, that is not necessarily bad. Your present effort is largely aimed at "how to do it."

There is a classic true story of a physics professor who, while watching the light of fireflies one summer night, was excited by the thought, what is its spectrum? So he hired some boys to catch fireflies and spent some time rigging up apparatus, and then he had another thought: has this study already been made? To his embarrassment, a few minutes' search of the literature revealed that it had long since been performed.

1.2 *Cause and Effect: A Model to Pursue.*

If you already have a research problem in mind, it probably is one that requires discovering or demonstrating a cause-and-effect relationship. You may be interested in finding how one event causes another to occur. You may be seeking to understand how a change in the concentration of a certain ion causes a change in some animal or plant population. You may be interested in knowing how some environmental factor such as temperature, rainfall, or sunlight affects leaf size, stem length, or thickness of bark. You may wish to discover or quantify the rate at which sand grains creep down a slope or a river gnaws at its bank.

In any case, your project will surely involve you in the keeping of records. A scientist is more than an observer; he makes records of his observations. He then analyzes his recorded information, seeking to uncover the existence of relationships, which in turn may lead him to a better understanding or a solution of the problem. Relationships sometimes are revealed simply by a series of statements of observed facts or columns of numbers. Probably more often, relationships are revealed by graphing one set of numbers against another set of numbers. Still more information often is obtained by employing some type of mathematical model or statistical analysis. Thus, through record keeping and various forms of analysis of his records a researcher solves problems and also is able to communicate findings to others in a meaningful way. In this manual you will be exposed to graphing techniques and to certain types of statistical analysis. We hope to show you ways in which these techniques might be used in solving your particular research problem, in reporting your findings, and in gaining acceptance of your conclusions.

1.3 *Mechanisms of Research.*

You will be presented in Chapter 2 with an example of a formalized research procedure. From earlier studies you may recognize it as an outline of the "scientific method." Please understand that it is only a generalized framework to help you conceive and sequence the steps of your project. A research plan often takes a shape not described by this generalized research model. Frequently a research procedure is not constructed through the formulation of a hypothesis to be proved or disproved, but through the recognition of the existence of a problem or the absence of some needed information. Quite often a scientist sets out to investigate a problem in his area of specialization, working with the knowledge that what is now known is not adequate. This is termed exploratory or *basic* research. Research aimed at putting into practical use some previously learned basic knowledge is called *applied* research.

It will not be necessary to design your procedure so that it exactly fits any formalized model. Professor Bridgman of Harvard University once described the research process as "going at nature with no holds barred." Our aim is to help you avoid spending time devising techniques already worked out by others.

CHAPTER 2:

Research and How it Works.

2.1 *The Research Process.*

The researcher starts with a problem or a phenomenon that needs to be investigated. He endeavors to develop a sequence of actions that he believes will increase his knowledge and understanding. It may consist, for example, of a series of situations in which he is able to alter a variable and to observe what happens. The most knowledge-producing situation is one in which alteration of a variable results in changes in only one of the possible other variables.

Such a controlled situation is an *experiment*. Experiments generate events, happenings, known in the technical sense as *facts*. A fact, to a scientist, is an event described in the manner of its occurrence. For example, if a dense object held at arm's length is released, it falls to the ground. This is an observed *fact*, which in this case takes place with the observer having had no part in the activity other than release of the object. From many falling-object experiments he may sense, without making any measurements, that the object's speed constantly increases. However he may obtain numerical *data* by devising equipment that yields the values of displacement attained at equally-spaced moments of time. Then by graphical analysis he determines in what *manner* the speed increases. At a later time he may learn how to account for this particular motion from knowledge of gravitation and the laws of motion. In this experiment the controlling variable, time, increases independently after the moment of release, and the controlled or dependent variables are downward displacement and speed. Complete analysis reveals that true free-fall motion depends only upon gravitational field intensity and not at all upon the mass of the falling object. Exploratory research of this type has revealed many facets of the operations of nature.

Some research projects start with the formulation of a *hypothesis*. This is a statement, an assumption or a supposition, that under a described set of circumstances, a described result will take place. A hypothesis may describe the ways in which different variables will or should affect a particular phenomenon. It may be an educated guess as to the nature of a relationship. The advantage of formulating a hypothesis is that it tends to focus the investigator's energy in a single direction, so that his effort may be devoted toward either acceptance or rejection of his hypothesis. If his work leads to rejection, he may then formulate a new hypothesis and work on it.

Under some circumstances the scientist will proceed on the assumption of a *null* hypothesis, which states that *no* relationship exists between certain variables.

After the scientist's experiments and tests have been completed and he has formulated his conclusions, he publishes his research and/or reads "papers" at scientific symposia or conventions of scientists. A "contributed" paper is one on his own work, volunteered to be published in a journal or given orally. An "invited" paper is one that has been asked for. It frequently combines and surveys all of the work done in a particular field.

Eventually, if his findings (and perhaps those of others also) stand up under scrutiny and are reproducible, the result may be the emergence of a new scientific *law*. Often described in the form of a mathematical relationship, a law is an observed regularity between the variables involved in a particular phenomenon. A scientific law should not be assumed to be the final word on its subject. Its acceptance may not last for all time, and its accuracy may depend upon how closely the variables in it are measured. An example is the ideal gas law, $PV = nRT$, which predicts the behavior of a sample of an *ideal* gas under various pressures and temperatures. This law accurately describes the behavior of some *real* gases at normal laboratory conditions, but not accurately at extremes of temperature and pressure.

The ideal gas law identifies the variables and describes the relationship among them, but does not explain why a particular variable produces the described effects on the others. The explanation occurs at a higher intellectual level in an all-encompassing statement called a *theory*. A theory serves to explain a number of events that are classified by the laws pertaining to that particular type of phenomenon. The ideal gas law is one of a number of gas laws which make up a broad theory that explains the nature of the gaseous state, the kinetic-molecular theory of gases.

2.2 *Formalized Research Model.*

The research investigator starts with an observed phenomenon that is not understood or a topic that needs to be studied and develops ideas that lead to controlled experiments. Experiments lead to facts, which he observes and records, resulting in data. He then employs one or more methods of analysis of the data, leading to a tentative solution, which is one use of the term *hypothesis*. This solution may be found unacceptable or in need of being tested for reproducibility. In either case he goes back to more experimentation. He may finally accept the hypothesis as a solution to the original question and announce it as a conclusion.

This research model or flow pattern would seem to indicate that research activity tends to breed more research activity, which indeed often is true. Your task in designing the parts and steps of your project is to approach the problem in such a way that your actions progress from the phenomenon to be investigated to its explanation in an orderly and efficient fashion. It is crucially important not to overlook a factor that affects the final result. Erratic final values that seem to have no explanation can be indicative of the presence of such an overlooked or unrecognized factor.

2.3 *Comparative Studies: A Different Approach.*

You may have become interested in exploring a type of situation in which controlled experiments are not an appropriate means of discovering a cause-and-effect relationship. You may need to examine a situation in which it is impossible or impractical to control the variables. Such a problem occurs when one needs to examine the behavior of people or events that are very complex in scope or nature. For example, suppose it has been found that in a section of a farming community, certain farmers have experienced losses of their crops due to some unknown cause. Clearly it would be much too difficult a task to control and vary all possible factors that might lead to a crop failure. Therefore, to identify the cause of the problem it is necessary to employ some method other than the experimental one.

One method takes the form of the experimental approach in reverse. This method is based upon measurement of the effect normally considered to be the dependent variable while search is made for the cause. The logic employed involves searching for one factor that is common to all of the cases of failure. Then it is possible to construct a hypothesis that this common circumstance is, in fact, the probable cause of the phenomenon or is related to it.

Let us apply this line of reasoning to the situation of the crop failure in a farming community. Suppose investigation of the farming methods employed indicated that a wide range of techniques were used. However, all of the farmers who had experienced crop failure had purchased a fertilizer from the same dealer, and in every instance where crop failure had occurred, fertilizer from the same shipment had been distributed in the fields. This would lead to the hypothesis that this fertilizer may have been the cause of the loss of the crop. To test the hypothesis, the investigator would seek to show that no crop failure occurred where fertilizer from another source had been used. If this were found to be the case, the evidence would be very strong for saying that the cause of the crop failures was tied in with the fertilizer from this particular shipment. It could also lead to further research including analysis of the fertilizer shipment in question.

In the above described example there was a perfect coordination between cause and effect. This example was used to illustrate the principle of logic involved in establishing cause-and-effect relationships. In practice such a clear-cut relationship seldom presents itself. Instead, the researcher is confronted with trends and tendencies and erratic examples of relationships between events. It is therefore necessary for him to have a way to determine, by a measurement process, the extent or degree of a tendency. Luckily such measures do exist. It is possible to calculate statistical measures which numerically state the likelihood of the existence of more than a coincidental relationship between two events. We will return to the calculation of these statistical measures in a later section.

CHAPTER 3:

Planning Your Research Project.

3.1 *The Importance of Planning.*

To achieve the kind of result you desire you will have to do some planning. The great accomplishments of mankind, ranging from the building of the pyramids to the placing of a man on the moon, have all required much more than solution of the engineering problems involved. They have required very complex plans to bring about the proper sequence of events needed to carry out the project. Your first research project may indeed appear to you to have the magnitude of building a pyramid when you begin, and possibly you may be even more aware of its magnitude when you have finished!

It is necessary for you to anticipate a sequence of events that may lead you to your final goal and to start with it even though there is some probability that developments may dictate some change in the sequence as you move ahead. A mistake to avoid is operating without looking forward to the probable subsequent steps. Indeed, you should not make use of parts of this manual without reading through all of it first. Otherwise you may find yourself dealing with hindsight and needing to go back and rework parts of your project.

3.2 *Activity Planning.*

The development of an activity plan for your project should be considered. A logical approach is to identify all the steps that you think should lead you from the beginning of your work to its completion and to review the resources required to carry out these steps. Some planning options might include *outlining*, *listing* of events in sequence,

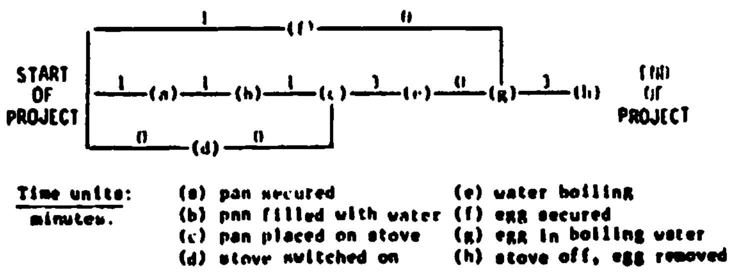


Figure 1. Planning Scheme for Boiling an Egg.

and *designing* of data tables or charts. At this point it may be useful for you to look at some techniques that can be borrowed from existing systems of planning.

You might consider a planning technique employed by management officials in large corporations to bring about a complex chain of events.[1] As an example, Figure 1 outlines the steps required to boil an egg. The lines in the diagram represent activities that lead toward completed goals. The number above each line is the number of time units allocated to that activity. The letters enclosed in parentheses identify the completed goals. The time units are minutes in this particular example. This planning scheme (perhaps rather generously) allows one minute each to locating a pan, filling it with water, and placing it on the stove. Sometime during those three minutes the stove is switched on. Three minutes later the water has come to a boil and the egg is dropped in. In another three minutes the egg is soft boiled and the stove is switched off. The overall time for carrying out the project is indicated by the pathway with the greatest total of time units. While the development of some plan for your project will be essential, it may not be necessary to formalize your plan to the extent shown in this illustration.

It is likely that your project will undergo changes as it proceeds. Unexpected developments probably will cause you to alter some methods of operation. You may as well anticipate unexpected problems. Thus you will approach the project with a realistic mental attitude. It has been said, "No matter how much you plan, something will always go wrong somewhere." An advantage of having a plan is that it allows you to know how far along you are at any time, and the perspective it gives will help curb any frustrations that may develop.

[1]Anthony L. Iannone. *Management Program Planning and Control with PERT, MOST, and LOB* (Englewood Cliffs, N.J.: Prentice Hall, Inc., 1967), pp. 7–35.

CHAPTER 4:

Getting Help

4.1 *Asking for Help.*

It is not uncommon for professional researchers to seek advice from others. The enterprising researcher will foster good working relationships with many types of professionals. He usually has to confront so many complex problems involving engineering, mathematical computations, library searchers, and field work that it is unreasonable to expect him to have expertise in all of these areas. People not directly engaged in research can often provide valuable assistance and equipment. Therefore, a wise researcher recognizes when his project will be benefited by outside help and knows how to go about obtaining it.

4.2 *How To Ask.*

If you already know people who can help you, do not hesitate to ask for their advice. If you must seek help and formal communication is required, some suggested guidelines are:

1. Don't ask for help until you have exhausted your own resources.
2. Spend enough time thinking and reading so that you can ask specific questions. A letter that in effect says "please send me everything you have" tends to make its recipient feel unable to help.
3. Inform your consultant of your background and school level so that he can gear his response to your degree of preparation.
4. Ask early (perhaps for an appointment) and give your consultant time to reply at his convenience. A desperate last minute request may not bring an answer.
5. Ask to borrow equipment only if you have an established relation-

ship with the person or institution being contacted.
6. A letter of thanks is always appreciated.[2]

4.3 *Whom To Ask.*

If you are unsure about whom to ask or where to write for advice, some suggested procedures include:

Describing your situation to a teacher.

Making contact with the appropriate science department of a nearby college, university, or industrial organization.

Determining whether your state has a scientific organization or academy of science that provides such help and communicating with it.

Visiting nearby museums that feature scientific exhibits.

4.4 *Giving Credit For Help Received.*

If, after completing your project, you present a "paper" describing it and your findings, give credit where credit is due. You may be called upon to state how you became aware of the topic. There is no need to be reluctant about stating the amount of help you may have received, for as stated earlier in Section 4.1, it is quite common for professionals to employ the advice and help of people who are specialists in various fields.

Some of the research investigations attempted and completed by high school students are quite modest in nature, founded upon the researcher's own curiosity and carried out with relatively simple equipment. On the other hand, some students have carried out projects that employed advanced designs suggested by a teacher or a scientist or engineer in the community. Perhaps the researcher was also aided by the use of sophisticated and expensive apparatus, either borrowed for use in the home, field, or school, or employed on the premises of a nearby institution. All levels of sophistication have their place in research and none should be regarded as being any more or less creditable than any other.

[2]Charlene K. Swilling, ed., *Handbook of the North Carolina Student Academy of Science* (Raleigh, N.C.: N. C. Department of Agriculture, 1964), pp. 8-9.

CHAPTER 5.:

Data Analysis

5.1 *Construction of Tables of Data.*

While an experiment is in progress a scientist records events and numerical values, and this record becomes a body of information called *data*. He then analyzes this information and through the analysis reaches conclusions based upon the relationships observed between the factors in his experiments that varied or were variable.

It is desirable for the data tables to be clear and unambiguous. The simplest data table consists of three columns and a number of lines. The first column frequently will be headed "Trial Number," and that column indicates the events or steps that took place. The next two columns give information about two variable quantities. Each column is headed with the name of the variable quantity and the name of the unit of measure appropriate to the numbers in that column. The first column indicates values of the independent variable, arbitrarily determined and set by the researcher. The second column lists values of the dependent variable, obtained by count or read from the scale of an instrument.

Figure 2 is an example of a simple data table. It records an experiment in which a fixed amount of a gas is made warmer in ten unequal steps of temperature. The gas is allowed to assume a new volume, at each step, such that the pressure is unchanged. The data table shows that as the temperature is increased, a progressive increase in volume is required to prevent an increase in pressure.

The words above the data table constitute a descriptive title, more technically known as a *caption*. Note that the words in the title are in agreement with the following guidelines recommended for composing a title or caption:

1. Start by naming the dependent variable.
2. Conclude with the name of the independent variable.
3. Use words that identify what the relationship is.
4. Do not include units of measure.

There are occasions when a table of data consists of many columns and rows. Figure 3 may be taken as an example. This table is used in an experiment dealing with Ohm's law. Five resistors are listed by rated value and tolerance in manufacture. Columns 4, 5, and 6 are used to record the number of cells employed in examination of each resistor and the numerical values of resultant observed current and voltage; both of these are dependent variables. The final three columns are for calculated values and these are separated from the first six columns by a heavy line.[3]

Having studied these sample data tables to get ideas for logical formats, you should use your creative talents in designing tables for your experiments. Your tables of original data comprise an important part of your project, and the skill you show in constructing the tables will be a measure of the quality of your research.

Volume of a Sample of a Gas at Constant Pressure, as a Function of Temperature.

Trial Number	Temperature K	Volume cm^3
1	295	110.0
2	297	111.0
3	300	111.8
4	305	113.7
5	307	114.6
6	310	115.8
7	315	117.6
8	325	121.0
9	350	130.6
10	372	138.7

Figure 2. Example of a Simple Data Table.

[3]Sherwood Githens, Jr., and Bernard D. Toan, *Teachers Manual for Quantitative Physical Science*, 2 vols. (Durham, N.C.: Moore Publishing Company, 1976), 1: 225-27.

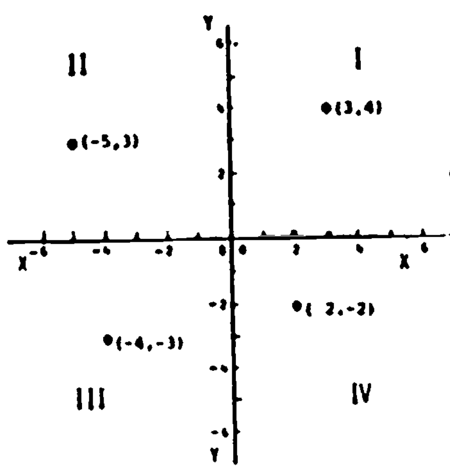
Resistance of Wire-Wound Resistors at Room Temperature
Measured by Voltmeter and Ammeter and Ohm's Law

1 Resistor #	2 Rated value R ohms	3 Tolerance %	4 No. of cells used -	5 Current I amps	6 Potential difference V volts	7 Calculated resistance R ohms	8 Difference between rated and measured resistances ohms	9 %
1	5.6	5	1	0.233	1.33	5.7	+ 0.1	+ 1.8
2	7.5	5	1	0.178	1.33	7.5	0	0
3	20	5	2	0.142	2.99	21.1	+ 1.1	+ 5
4	56	5	3	0.082	4.57	55.8	− 0.2	− 0.3
5	91	5	3	0.050	4.61	92.3	+ 1.3	+ 1.4

Figure 3. Example of a Many-Columned Data Table.

5.2 *Graph-making Techniques.*

An analytical tool used very often in research is the graph. Through its position and shape, a graph line reveals pictorially the nature of the relationship that exists between two variable quantities. The graph is in a sense a picture that helps you gain more information from the numbers recorded in your data tables. It usually communicates more effectively than the numbers. The conventions of graph making are



Quadrant No.	Independent Variable:X	Dependent Variable:Y
I	positive	positive
II	negative	positive
III	negative	negative
IV	positive	negative

Figure 4. Graphical Conventions and Quadrants.

demonstrated in Figure 4. A horizontal line called an axis has a scale that rises in value to the right. The vertical axis has a scale that increases in value from bottom to top (becomes less negative and more positive upwards.) In this illustration of graphing technique the zero of each scale has been positioned at the point where the axes intersect. Axes thus scaled divide the surface into four parts called quadrants. Conventionally these are numbered I, II, III, and IV, as shown. Almost always the numbers on the horizontal axis stand for values of the independent variable, which in the general case is designated by the letter x. Those on the vertical axis represent values of the dependent variable, y. Every point in the graph surface simultaneously corresponds to two numbers, read by projection against the two scaled lines. A small table in Figure 4 shows the signs of the values of the points in each quadrant. The

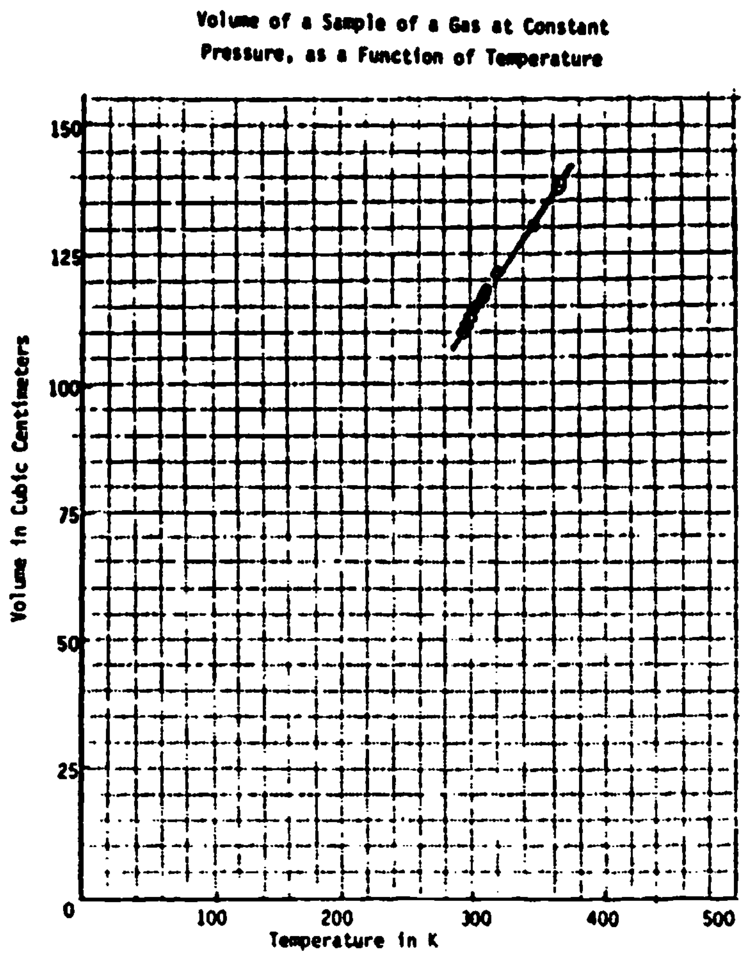


Figure 5. The data of Fig. 2 graphed with the zeros of both scales located at the intersection of axes.

form (x, y) is employed for labelling the points: the x value is shown first, followed by a comma.

Figure 5 is a graph of the data of Figure 2 plotted in quadrant I with the 0,0 point located at the intersection of the axes. Notice that the ten points are crowded together, so that establishing the graph line is difficult. It is not clear whether the line is straight or slightly curved, or if extended would or would not pass through the 0,0 point. However, a perspective is gained on the overall range of the experimental measurements. This graph indicates a need for further experimentation at lower temperatures.

Figure 6 is a graph of the same data using expanded scales that do not start with zero at the intersection of the axes. The relationshp is now seen to be linear, and graphical determination of the value of its slope is made easier. Figure 7 is Figure 5 re-drawn using knowledge

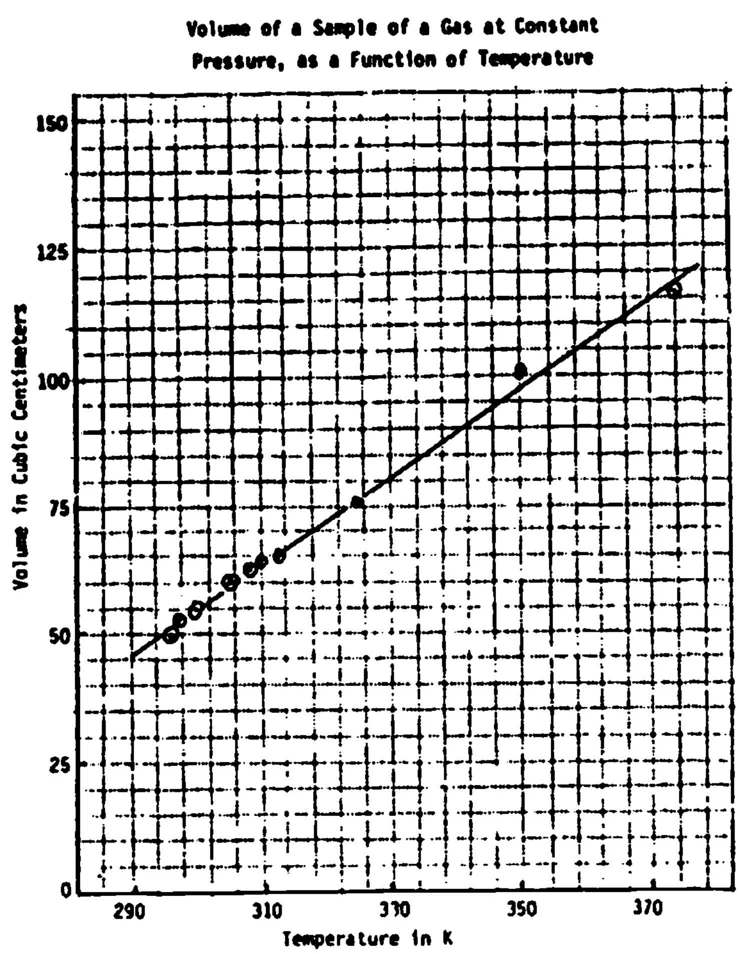


Figure 6. The data of Fig. 2 graphed employing expanded scale.

gained from Figure 6: that the relationship is linear, and an "educated guess" that when the line is extended it passes through the 0,0 point. This process of extension is called ***extrapolation***.

Each axis is labelled with the name of the quantity it describes, followed by the name of the unit employed. Graphs are titled in the same form as are data tables: "dependent variable . . . as a function of independent variable." The conventions that have been described are widely followed and you will find it useful to employ them so that your work will be easily understood by other researchers.

Usually your data will not call for showing all four quadrants. In fact, it is likely that your values will all be positive and thus fall within the first quadrant. Often you will get a more meaningful graph line by showing only a portion of the first quadrant, with your scales not including the 0,0 point. Your scales may begin and end at any value,

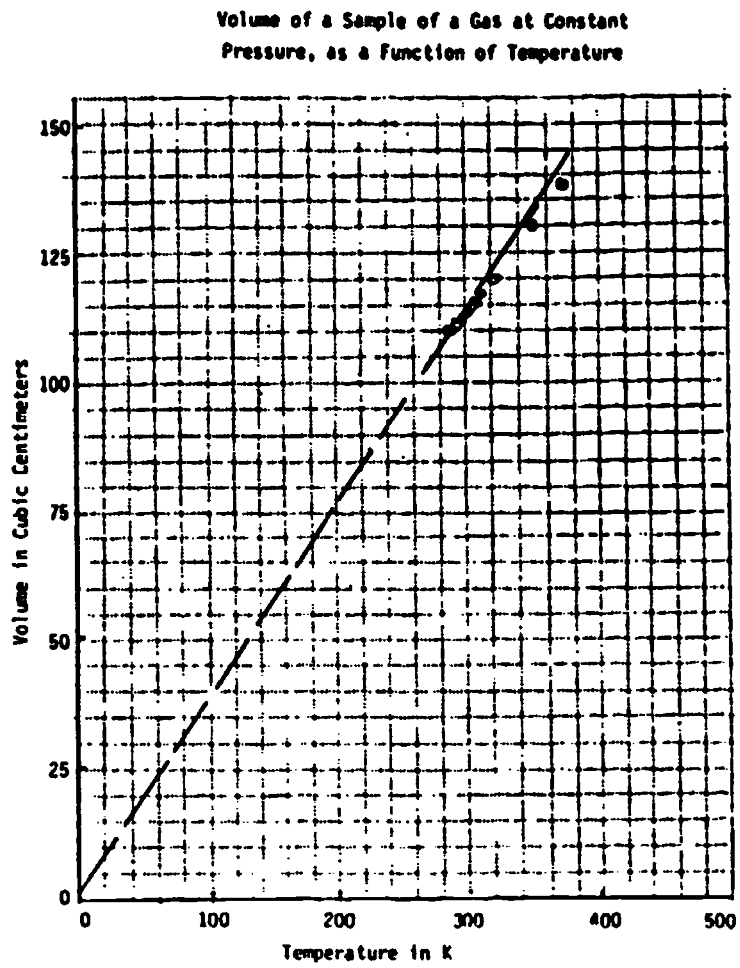


Figure 7. Figure 5 re-drawn using knowledge gained from Figure 6.

so long as they cover the ranges of value in your data tables and thus include all of the information from your experiments.

Finally, a *smooth* curve should be drawn. It should fit the points as closely as possible, with about as many points lying on one side as on the other. It is good practice, as seen clearly in Figure 6, to encircle each plotted point, and not to have the graph line pass through any circle, but to break the line at the circles thus avoiding obliteration of the points. If the relationshp is found to be linear, draw the line absolutely straight with the aid of a straight-edge. Use a French curve if it is seen to be curved. You want the line to show the relationship and not the experimental deviations from it.

Graphs are most easily plotted and values are most easily read if the major scale graduations are marked in uniform steps using whole numbers, with several unnumbered graduations between each scale number. Usually it is undesirable for the small divisions to represent an odd number of sub-units, such as 3, 7, 9. Decimal-type subdivisions are best.

Clearly, useful information can be obtained from graphs. When the time comes for you as a researcher to obtain information from your experiments, keep an open mind and be inquisitive. Do not hesitate to try various types of graphs in order to gain the best perspective of your project.

5.3 *Curve Fitting.*

Suppose you have designed and conducted an experiment, recorded data, and plotted points on a graph area. It is possible that the points may be randomly distributed and do not fall into a pattern or a line. In that case the experiment you performed shows no cause-and-effect relationship between the two variables you examined. In fact there may be none, and you may need to rethink part or all of your experimental design.

On the other hand, if a line form does take shape, indicating the presence of a cause-and-effect relationship, you will want to obtain a further refinement of your data by identifying the nature of the relationship and if possible, stating it in the form of an equation. A skilled researcher can often recognize the nature of a relationship from a quick glance at the position and shape of the graph line.

The diagrams in Figure 8 show some often-encountered relationships expressed in graphical form. The nature of each relationship is described below in words and in equation form. An examination of these shapes

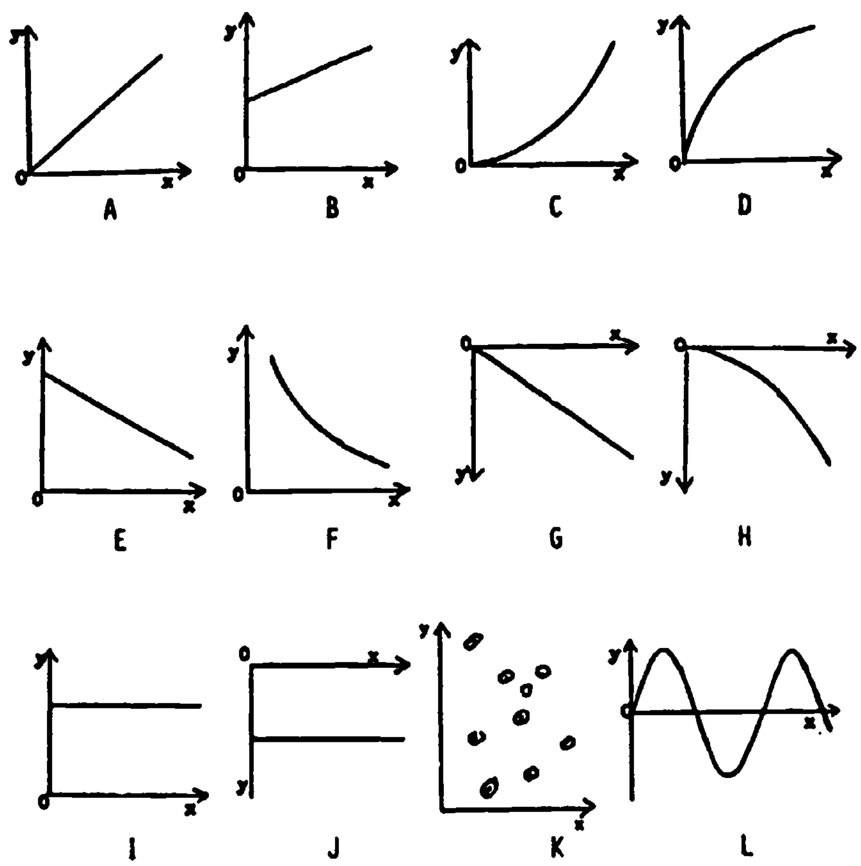


Figure 8. Graph lines that represent various relationships.

and their descriptions should give assistance in deriving an equation that summarizes the product of your research. This process is called *curve fitting*. In the equations below, x and y are variables and a, b, k, m, and A are constants.

(a) The line passes through 0,0 and the slope is constant and positive. A *direct proportion* is indicated. The ratio y/x is constant. A test for direct proportionality is that if one variable is doubled or tripled, the other one doubles or triples. Equation: $y = mx$.

(b) The line does not pass through 0,0; y increases linearly as x increases. There is no proportionality; y is positive when $x = 0$ and the slope is constant and positive. Equation: $y = mx + b$.

(c) y increases as x increases; the slope is positive and increases as x increases. If y/x^2 is constant, the curve is *parabolic* and the equation $y = ax^2$ is *quadratic*.

(d) y increases as x increases; the slope is positive and decreases as x increases. If y^2/x is constant, the curve is parabolic and $y^2 = ax$.

(e) y decreases linearly as x increases. The slope is negative and constant; $y = mx + b$, in which m is negative.

(f) y decreases as x increases; the slope is negative and decreases as x increases. If the product xy is constant, an *inverse proportion* is indicated: $y = \frac{1}{x}$ and $x = \frac{1}{y}$.

(g) y is always negative, and its absolute value is directly proportional to x. The slope is constant and negative; $y = mx$, in which m is negative.

(h) y is negative and becomes more negative, and the slope is negative and becomes more negative, as x increases.

(i) y is constant and positive. The slope is 0, and y is not related to x.

(j) y is constant and negative. The slope is 0, and y is not related to x.

(k) Random distribution; no line form. y is not related to x, or x is not the only variable that determines y.

(l) y alternately positive and negative, slope also alternat... positive and negative, in a cyclic pattern. If $y = A \sin x$, this curve shape is called a *sinusoid*.

It is hoped that these examples will stimulate your thinking processes and result in your being able to express experimental results in equation form when that is appropriate. With time and practice a researcher gradually develops a feel for the equations that represent many graph forms. If you wish to probe deeper into this topic, consult a textbook on analytical geometry. Incidentally, note that Figure 7 corresponds to curve A. indicating a direct proportion between volume and temperature at constant pressure.

CHAPTER 6:

Statistical Measures

6.1 *When Statistics Can Help.*

For some types of research investigations the forms of graphical analysis described in Chapter 5 are insufficient or not applicable, and analysis of a statistical nature is more appropriate. Generally, statistical measures are used when the primary information is so voluminous that one must resort to sampling and analyzing a sample rather than the whole. Statistical analysis is also used to compare two or more sets of primary information with respect to a certain variable. It is very likely, for example, that research on the crop failure problem of Section 2.3 would employ statistical analysis of the survival of individual plants in the various farm crops of that community.

6.2 *Sampling.*

Suppose that one wishes to measure the amounts of various materials dissolved in a lake or river. Obviously it would be impossible to conduct measurements on an entire lake of water. In such a situation one obtains a large number of randomly collected small bottles of the water, analyzes them chemically and statistically, and reaches conclusions based on the assumption that the water in the bottles taken as a whole was a sample that adequately represents the entire body of water. It follows that a researcher must be knowledgeable of sampling techniques that will lead to a truly representative sample. To that end, one needs to know the meanings of the words "population," "individual," and "sample" as they are employed here.

The term *population* denotes all of a group of *individuals* (persons, objects, items) from which a *sample* (a selected number of individuals) is taken for statistical analysis. For instance, if the various features of the leaves of tobacco in a field are to be examined, the population consists of every leaf in that field. The researcher will probably measure no more than a few hundred individual leaves from different plants as a representative sample, and will statistically analyze the data thus obtained. The research conclusions will be assumed to apply to the entire crop in that field.

When undertaking the process of sampling, the researcher faces certain responsibilities and considerations. These include:

1. Identifying the population—Before taking the sample it will be necessary to define precisely the limits of the total population from which the sample will be drawn.
2. Obtaining a sample of adequate size—Although no formula exists to prescribe the size of the sample for an experiment, it should be clear that a larger sample would better represent the entire population. The researcher must ultimately decide on a sample that is reasonably large but still manageable for the experiment.
3. Obtaining a representative sample.

To ensure a representative sample, the researcher must decide on a method of sample choice that is logical for his particular investigation. One method is to choose entries in a random fashion. If a list of all individuals in the total population can be obtained, a random sampling interval, such as every fifth entry, can be applied to the list. Caution must be used to insure that no hidden bias is built into the population list. If the total population can be subdivided into intervals of continuous units such as time, distance, or area, a random sample of these intervals can be chosen by lot. Meaningful experimentation must give rise to reproducible conclusions. Therefore the researcher should furnish information about his methods of sampling.[4]

6.3 *Graphic Distribution of a Population.*

As an example, consider the following description of the nature of a hypothetical random sample of peanuts grown in a particular field during one season. The variable studied was the mass of a single peanut, and the reseacher's task was to describe the way nature distributed the property of mass in the field of peanuts. A problem of this type lends itself well to statistical measures; it is not practical to measure

[4]Leobold B. VanDalen, *Understanding Educational Research: An Introduction* (New York: McGraw-Hill Book Company, 1973), pp. 318-24.

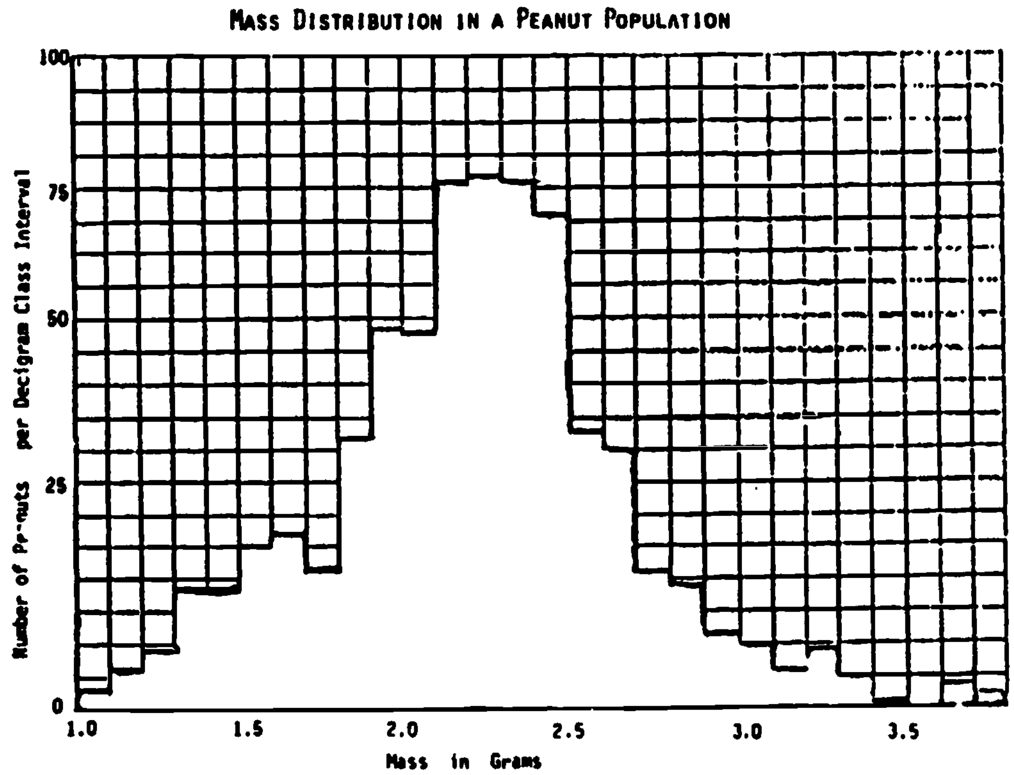


Figure 9. Histogram showing the mass distribution in a sample consisting of 777 peanuts.

each peanut in one truckload, much less in an entire field of peanuts.

The researcher first made a type of graph called a *histogram*, Figure 9. ... he decided upon a class-interval size of one-tenth of a gram and counted how many of 777 peanuts fell into each decigram class interval. He labelled the x-axis "mass in grams," *divided* it into ... and *scaled* it in grams. The y-axis was used to indicate the ... peanuts falling into each class. The histogram was then drawn as a series of side-by-side solid columns.

When a large n... of small class intervals is used, it is possible to plot points and ...w a smooth-line "distribution curve" as shown in Figure 10. Usually the properties of a natural product will be distributed in this manner, clustering around a central point and tailing off in either direction, perhaps not completely symmetrically. Both of these types of graphs serve as pictorial descriptions of observed distributions. If these are not sufficient, it may be desirable to describe the population using statistical parameters. The smoothed-out histogram of Figure 10 should not be confused with a later-discussed frequency distribution curve that is mathematically computed using statistical parameters.

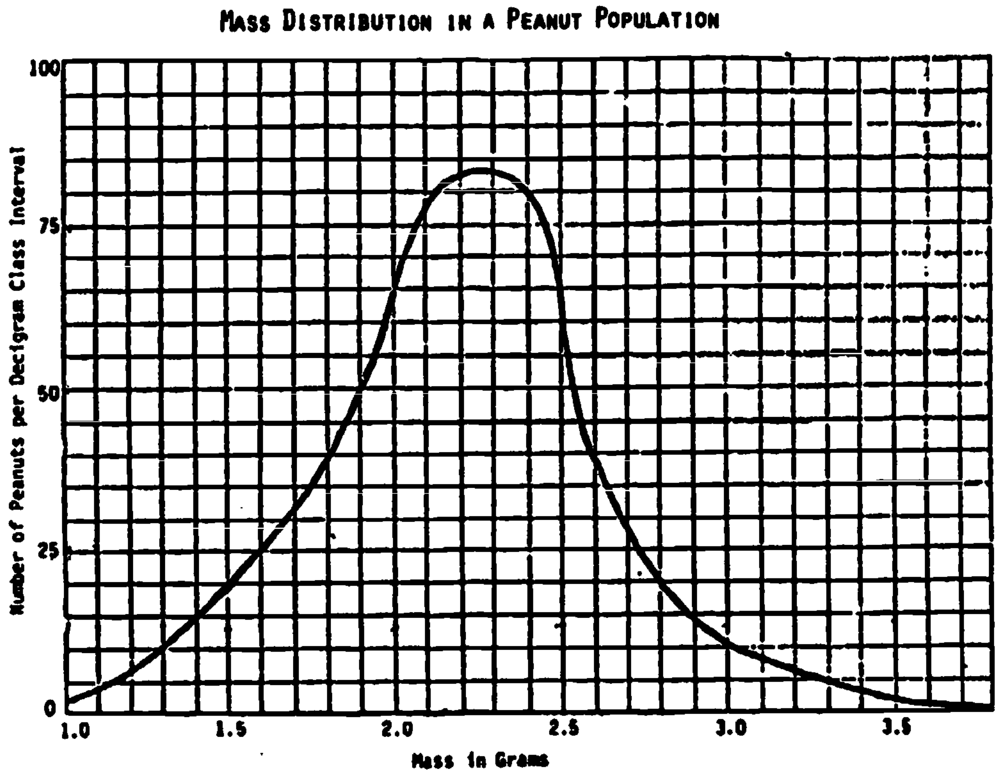


Figure 10. A smoothed-out version of the bar-graph histogram, drawn with a French curve.

6.4 *Statistical Descriptions of a Population.*

Often it is found useful to describe a distribution in numerical rather than graphical terms. The *range* of a variable is the difference between its highest and lowest values, and this difference often is described by stating those values. In the case of the peanuts, the range in mass value was 2.9g and the largest and smallest values were 3.9g and 1.0g, respectively. These values are found at the extremes of the curve of the smoothed-out histogram, Figure 10, as well as in Column A of Figure 11.

There are three statistical measures of central tendency called *arithmetic mean, median,* and *mode.* The arithmetic mean, sometimes symbolized $\bar{x}$, is the sum of all of the values divided by the number of values. In our peanut example this is 1,681.8g divided by 777, or 2.16g. (This is often called the average value.)

The mode is the class interval or individual value that occurs most often. On the peanut histogram, Figure 9, the mode occurs at 2.2g, with 82 entries falling in this class interval.

The median is the middlemost item in a distribution. In the peanut example the median lies between 2.1 and 2.2g, which is found by dividing 777 by 2 and by counting to that number in Column B of Figure 11.

Two other relatively simple calculations result in measures of dispersion about the arithmetic mean. ***Average deviation*** is obtained by summing the absolute values of the differences between each individual value and the arithmetic mean, and then dividing by the number of values. For the peanuts the average deviation is 0.35g. ***Percentage deviation*** is obtained by dividing the average deviation by the average value and multiplying by 100. For the peanuts, this works out to 16%. This is a more significant statistical measure than the average deviation because it is a simple and direct measure of the degree of spread in a population of values. For example, if you were to weigh a hundred pennies using a sensitive balance you would find their mass values to have a percentage deviation of less than 1%; the stamping machine does a much better job in regard to product uniformity than does Mother Nature.

The five statistical measures just described are readily calculated and

A Mass Intervals grams	B Peanuts in Interval $n_1, n_2, n_3 \ldots$	C Total Mass in Interval grams	D Cumulative Sum $n_1 + n_2 + \ldots$	E Cumulative Percentage of Total Mass %	F Percentage per Interval %/0.1g
1.0	3	3.0	3	0.4	-
1.1	6	3.6	9	1.2	0.9
1.2	9	10.8	18	2.3	1.7
1.3	18	23.4	36	4.6	2.3
1.4	18	25.2	54	6.9	2.8
1.5	25	37.5	79	10.2	3.4
1.6	27	43.2	106	13.6	3.3
1.7	21	35.7	127	16.3	4.3
1.8	43	77.4	170	21.8	6.5
1.9	58	110.2	228	29.3	7.5
2.0	57	114.0	285	36.7	8.9
2.1	81	170.1	366	47.1	10.5
2.2	82	180.4	448	57.7	10.5
2.3	81	186.3	529	68.1	10.1
2.4	76	182.4	605	77.9	7.7
2.5	43	107.5	648	83.4	5.3
2.6	40	104.0	688	88.5	3.9
2.7	21	56.7	709	91.2	2.6
2.8	19	53.2	728	93.7	2.0
2.9	12	34.8	740	95.2	1.4
3.0	10	30.0	750	96.5	1.1
3.1	6	18.6	756	97.3	1.0
3.2	9	28.8	765	98.5	0.9
3.3	5	16.5	770	99.1	0.4
3.4	1	3.4	771	99.2	0
3.5	0	0	771	99.2	0.2
3.6	3	10.8	774	99.6	0.4
3.7	2	7.4	776	99.9	0.1
3.8	0	0	776	99.9	0.1
3.9	1	3.9	777	100.0	0

Figure 11. Statistical data related to the mass values of a sample of 777 peanuts. Column F values obtained by Method of Moments.

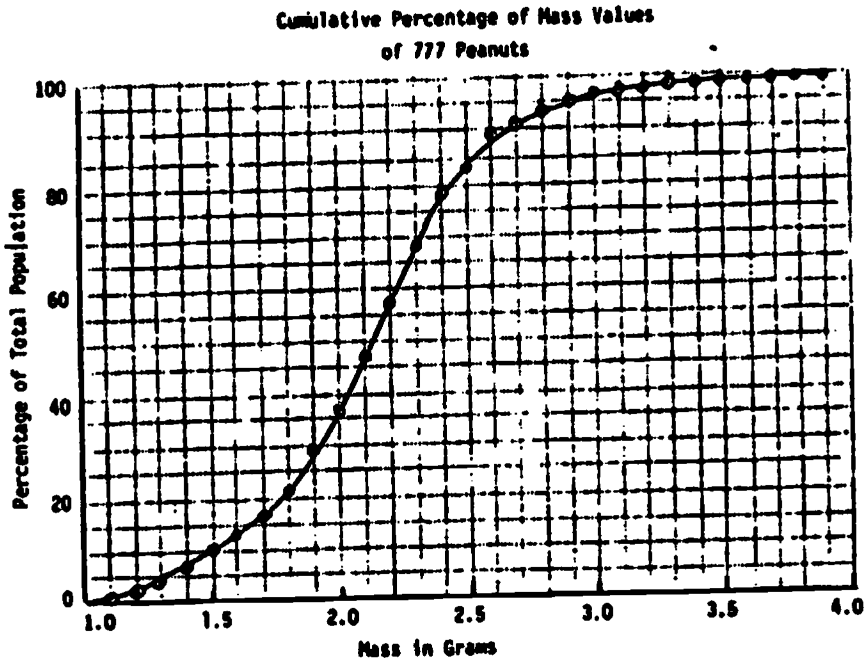


Figure 12. Cumulative percentage curve based upon data in Fig. 11. (Column E values plotted again Column A values.)

quite useful, but the researcher also from time to time needs to make some calculations that are a bit more sophisticated in order to get measures of "skewness" or asymmetry in a distribution of values, as well as other types of information. The numbers in columns C, D, E and F of Figure 11 constitute the data for the statistical measures to be described next.

6.5 *Cumulative Percentage Curve.*

Statistical measures of a nature more sophisticated than those just described can be obtained by first constructing a *cumulative percentage curve*.

To obtain such a curve, one first determines running totals of the individuals in the sample and then calculates *cumulative percentages*. For example, the Column D values in Figure 11 were found by summing the numbers (n) of individuals in Column B up to and through each class interval. Thus, there were 36 peanuts in the first four class intervals. Each Column E value was then obtained by dividing each running total by the total number of individuals (777) and multiplying by 100. Thus, 4.6 percent of all the peanuts were in the first four class intervals.

Figure 12 shows the resultant cumulative percentage curve. The graph line starts with zero percent on the x-axis at the lowest class interval, trends upward more and more rapidly, and then flattens out at the 100% level and the highest class interval.

6.6 *Frequency Distribution based on Cumulative Percentages.*

The cumulative percentage values are then used to obtain a *frequency distribution curve* (mathematically, the first derivative of the cumulative percentage curve; in other words, a plot of the slope, at each point, of the cumulative percentage curve).

The slope at a particular point can be obtained in either of two ways. These are essentially identical except that one employs graphical construction (in principle if not in fact) plus calculations, while the other employs adjacent numerical values from the data table and calculations. These processes are known respectively as the Method of Tangents and the Method of Moments.

The Method of Tangents is illustrated in Figure 13. In principle, one draws a tangent at each point on the cumulative-percentage curve and

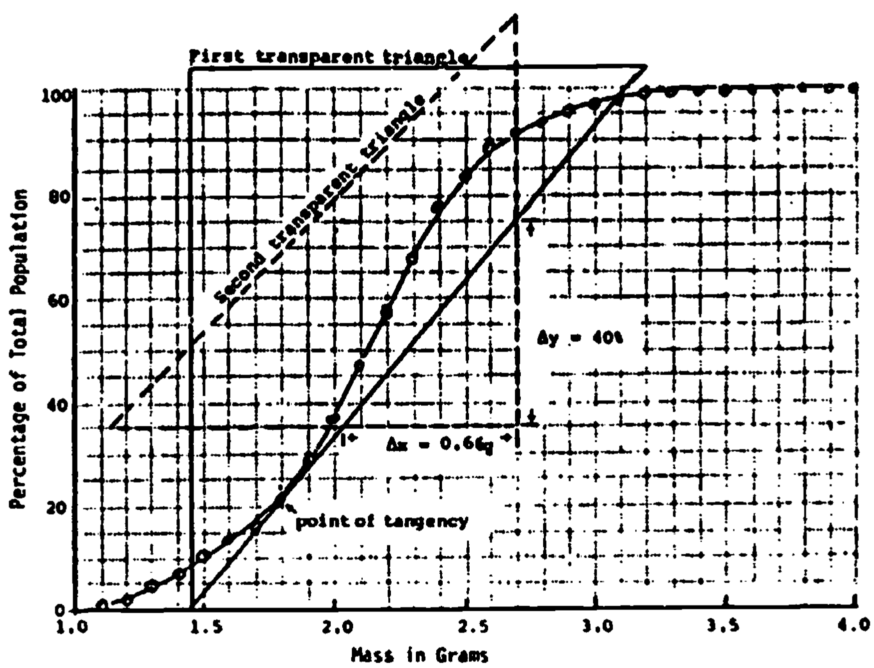


Figure 13. Determination of slope ($\Delta y/\Delta x$) by Method of Tangents. At $x = 1.8g$. $\frac{\Delta y}{\Delta x} = \frac{40\%}{0.66g} = 60.6\ \%/g = 6.1\ \%/0.1g$.

determines its slope, the ratio of rise to run, so to speak, designated as Δy and Δx, respectively. To avoid making a large number of construction lines on the graph paper one can lay a transparent triangle in a tangential position against each plotted point, and then slide a second transparent right triangle along the tangent line, oriented as shown in Figure 13, endeavoring to find a location such that either Δy or Δx will equal a whole number of divisions (which will make the calculations simpler.) In any case, one reads off pairs of values of Δy and Δx. The ratio $\Delta y/\Delta x$ is a measure of the slope at that point, accurate within the limits of measurement and calculations.

The Method of Moments employs adjacent values. This method is best described through a numerical example: In Column E of Figure 11, the percentage values above and below the value 36.7 are 47.1 and 29.3. Their difference, Δy, is 17.8%. They correspond to a span of 0.2 grams, which is Δx. Therefore

$$\text{Slope} = \frac{\Delta y}{\Delta x} = \frac{(47.1 - 29.3)\%}{0.2g} = \frac{17.8\%}{0.2g} = 89.0\%/g.$$

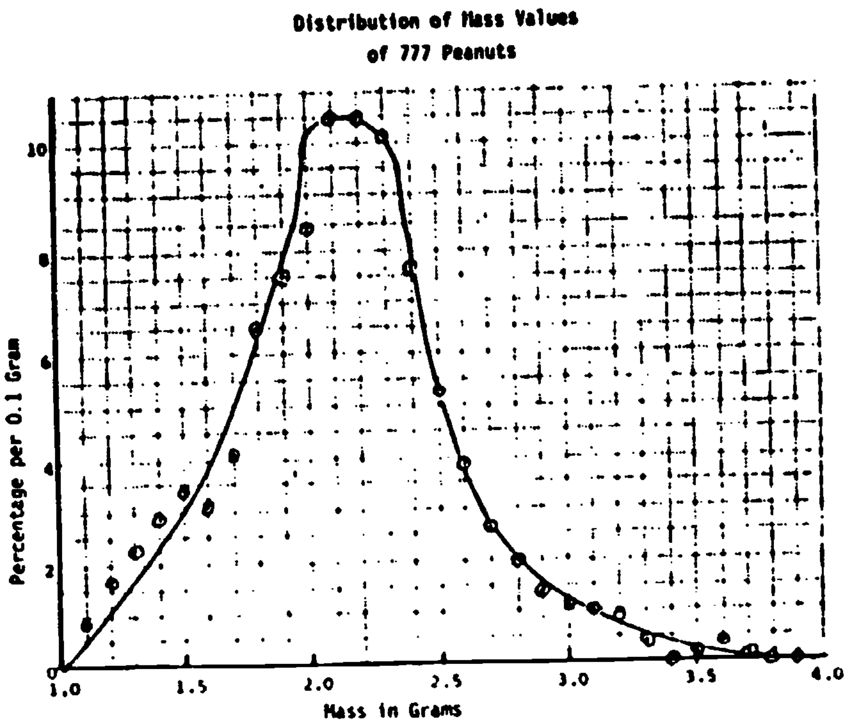


Figure 14. Distribution of mass values derived from cumulative percentage curve of mass values.

However, in this example, it is more suitable to have values "per 0.1 gram," and so the value written in Column F is 8.9%/0.1g, one-tenth of the above value.

Figure 14 is a curve based upon the values in Column F of Figure 11 plotted against those in Column A. The points do not fall as smoothly in a line as those in Figure 12 because irregularities which were of minor significance in the Column D values have become magnified by having gone through two steps of calculation. In principle, the values on Column F should add up to 100%. Actually they sum to 99.3%. This is indicative of the variations that can creep into data as a result of calculations based on numbers consisting of only two significant digits.

It is to be noted that the three measures of central tendency mentioned earlier in this chapter (mean, median, and mode) are readily determined from the cumulative percentage and frequency-distribution curves illustrated by Figures 12 and 14. The mode is the x-value that corresponds to the highest percentage value in Figure 14. The median is the x-value that corresponds to the 50% value in Figure 12. The mean is obtained to a good approximation by employing x-values at the indicated percentage levels and calculating:

$$\text{Mean} = \frac{x_{16\%} + x_{50\%} + x_{84\%}}{3} = \frac{1.7\text{g} + 2.14\text{g} + 2.52\text{g}}{3} = 2.12\text{g}.$$

6.7 *Standard Deviation.*

A frequency distribution like that pictured in Figure 14 can be very sharply peaked, even knife-edged in shape, or quite flattened out, depending upon the degree of scatter in the individual values. While Mother Nature makes peanuts in widely-scattered mass values, the U.S. Mint makes pennies quite uniformly and a frequency distribution of penny mass values determined by means of a very sensitive balance would be quite knife-edged. A sometimes useful numerical measure of variability is called *standard deviation.* Fundamentally it is determined by finding the differences between the individual values and the mean, squaring the differences (which produces positive values only), averaging the squared differences, and taking the square root of that average. A reasonable approximation of this "root mean square" value can be found graphically by taking the difference between the x-values at 84% and 16% on the cumulative percentage curve and dividing that number by 2. Employing such values from Figure 12,

$$\text{Std. Dev.} = \frac{x_{84\%} - x_{16\%}}{2} = \frac{2.52\text{g} - 1.68\text{g}}{2} = \frac{0.84\text{g}}{2} = 0.42\text{g}.$$

6.8 *Symmetry and Skewness.*

Another statistical description of a distribution has to do with the amount of symmetry in the frequency distribution curve; it may be symmetrical, or it may be skewed in one direction or the other. *Skewness*, like the standard deviation, can be calculated by means of a complicated formula resulting in a number lying betwee: −1 (which describes a curve tailed to the left) and +1 (which describes a curve tailed to the right). A truly symmetrical distribution has a skewness of 0 (zero).

Skewness can be approximated from the cumulative percentage curve by a formula shown below and applied to values obtained from Figure 12:

$$\text{Skewness} = \frac{x_{16\%} + x_{84\%} - 2x_{50\%}}{x_{84\%} - x_{16\%}} = \frac{1.68 + 2.52g - 2(2.14g)}{2.52g - 1.68g} = -0.07.$$

The value −0.07 is close to zero and could be interpreted as indicating an almost symmetrical distribution of mass in the sample of peanuts. A skewness above 0.3 is considered very strongly positive-skewed, and a value below −0.3 is a strong negative skewness. You may wish to include the skewness value in a description of a population because this value will communicate the nature of your results to other scientists in specific terms.

6.9 *Probability Distribution and Kurtosis.*

If one were to toss ten pennies many thousands of times and after each toss count the number of heads that show up (ranging from 0 to 10), the data thus obtained would result in a symmetrical, bell-shaped *probability* distribution. The most probable event is that 5 heads would show: less probable, that 4 or 6 would show, and still less probable that 3 or 7 would show, and so on. The plotted points in Figure 15 form curve B which closely approximates the anticipated probability distribution.

Kurtosis, k, is a numerical measure of how peaked or flattened a distribution curve is when compared to the probability distribution. Curve A of Figure 15 is more peaked and has a k value greater than unity. For curve B, the k value is unity. For curve C, k is less than unity. Kurtosis can be determined by the formula shown below and applied to values obtained from Figure 12:

$$k = \frac{X_{95\%} - X_{5\%}}{2.44\,(X_{75\%} - X_{25\%})} = \frac{2.95 - 1.25}{2.44(2.40 - 1.85)} = 1.25$$

The number 2.44 is a constant for this calculation that yields a k value

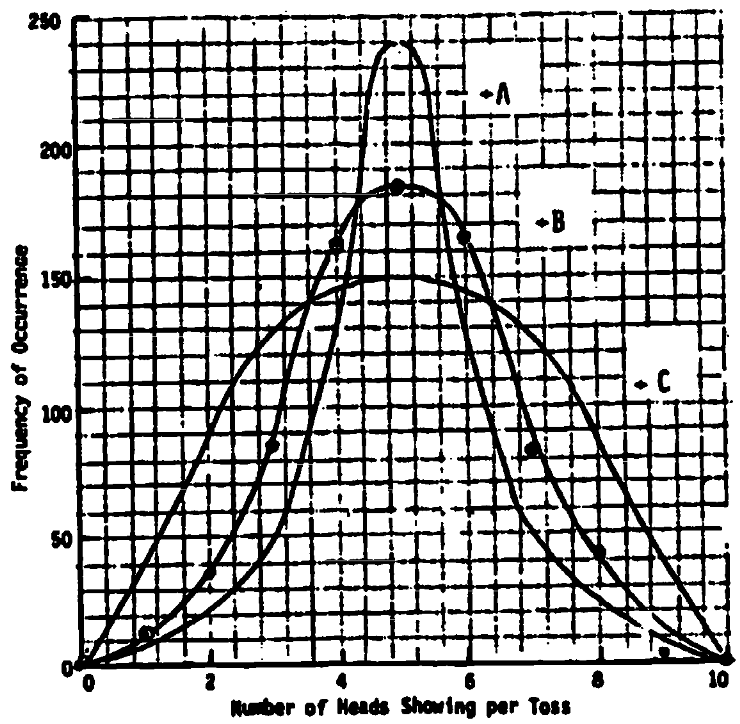


Figure 15. Graphical description of kurtosis. Plotted points show frequency of occurrence of 0 to 10 heads when ten pennies are tossed 777 times. The points correspond closely to the anticipated probability distribution for which $k = 1$. For A, $k > 1$; for C, $k < 1$.

of 1.00 when applied to a probability distribution. The result shown above, 1.25, indicates that the peanut mass distribution is more peaked than a pure probability distribution.

6.10 *Comparison of Two or More Distributions.*

The statistical measures described thus far: range, mean, median, mode, standard deviation, skewness, and kurtosis are adequate to describe a distribution quantitatively. By use of these seven parameters the distribution of a property such as mass in the example of a peanut crop can be described.

Suppose it is desired to study the effect upon a peanut crop of some influencing factor, such as total rainfall per season. A way to do this is to employ values related to a number of crops. Their mean values of peanut mass can be taken as measures of "effect," assuming that the larger this value, the better was the crop. Statistical comparison of the set of mean mass values with the amounts of total rainfall will reveal the degree of correlation between crop quality and rainfall. These

numbers can also establish a measure of the amount of mass improvement produced by a certain amount of rainfall.

However, a subtle consideration must be recognized in connection with calculations of this type. In the example case cited above, the rainfall values are simple totals, while the mass values are based upon sampling. There is a chance that the mean mass values are to some extent erroneous because too small sample sizes may not precisely reflect the amounts of rainfall. This concern becomes more acute as sample size becomes smaller. For example, if such calculations were based upon samples of only ten peanuts, one could not have much confidence in the findings. Their truthfulness would be in doubt.

Statistical operations exist that will reveal the level of confidence that can be attached to the results of such calculations. Generally, researchers prefer to design experiments so that their confidence levels exceed 95%. For additional reading in this area, consult a textbook on statistics in sections pertaining to the "T" test or Chi square test.

6.11 *Conclusion*

In this chapter you have been presented with a survey of some statistical measures that are employed in research. At first glance the procedures employed may appear highly mathematical, but really, only arithmetic is involved, and the alphabetic symbols that you have seen in the preceding sections are used only as guides as to what arithmetic steps you should take. It may be that your particular research problem will not require any statistical analysis. If it does, the guidance given here may be adequate; if it is not, seek some explanatory help.

Lord Kelvin once said, "I often say that when you can measure what you are speaking about and express it in numbers, you know something about it; but when you cannot express it in numbers your knowledge is of a meagre and unsatisfactory kind."

CHAPTER 7:

Instrumentation Employed in Research

7.1 *General Considerations.*

We turn now to the instruments employed to obtain numerical values to be entered into data tables. Much research equipment is standard and can be borrowed or obtained without great difficulty. Some of the equipment employed in research is specially constructed for specific purposes and may be very sophisticated in design. Figure 16 contains a list of the quantities most frequently measured, together with the primary metric and British units for these quantities. Then in Figure 17 a list is presented of the devices commonly employed to make measurements in the sciences.

7.2 *Metric Measurement.*

Whenever possible, metric units should be employed. For each measurable property there is a *primary* metric unit called an SI (Système Internationale) unit, plus a number of alternative units that are larger or smaller than the SI unit by factors or multiples of the number ten. For example, the SI unit for length is the meter, and the cm, dm, mm, km, etc are alternative units. Column 1 of Figure 16 lists the more common measurable quantities. Column 2 names the SI units, and Column 3, alternative units which make up a system based upon the centimeter, gram, and second of time. Column 4 lists British Engineering units. Each of these columhs describes a *coherent* system of units: each system was created by starting with three units arbitrarily chosen with respect to size [mks; cgs; foot, lb(force), sec] and then making combinations of the first three to create the other units of that system.

	Coherent Systems of Units		
Name of Quantity	SI (mks)	cgs	British Engineering
length	meter (m)	centimeter (cm)	foot (ft)
mass	kilogram (kg)	gram (g)	slug
time	second (s)	second (s)	second (sec)
area	m^2	cm^2	ft^2
volume	m^3	cm^3	ft^3
density	kg/m^3	g/cm^3	$slug/ft^3$
displacement	m	cm	ft
velocity	m/s	cm/sec	ft/sec
force	newton (N)	dyne	pound
pressure	pascal (N/m^2)	$dyne/cm^2$	lb/ft^2
work, energy	joule (N-m)	erg (dyne-cm)	ft-lb
power	watt (J/s)	erg/sec	ft-lb/sec
frequency	hertz (s^{-1})	cycle/sec	cycle/sec

Figure 16. Principal units of the SI, cgs, and British Engineering systems.

In practice, measuring instruments are scaled in units that are convenient in use. For example, rulers are scaled in inches and centimeters rather than in feet or meters. Consequently, tables of data very commonly are expressed in alternative rather than in SI units: for example, grams rather than kilograms. Some journals that print research articles now ask that all values be expressed in SI units followed by suitable powers of ten, regardless of the units in which they were initially measured or calculated. Other journals are willing to accept values in alternative units because in many cases the magnitudes will be more readily understood.

Therefore, collect data and tabulate it in whatever units you find convenient to use, such as the units in which your instruments are scaled. However, the calculations that follow the data-taking should nearly always be performed with the quantities expressed in one of the three systems shown in Figure 16.

7.3 *Number-Producing Instruments.*

Figure 17 first lists a number of measurable properties and then names instruments designed to measure them directly.

It should be noted that some of the listed quantities can also be evaluated by employing instruments that measure quantities that are more primary, and then employing arithmetic. Here are some examples:

Area: Two measurements of length, followed by multiplication.

Density: mass and volume, followed by division.

Pressure: force and area, followed by division.

Electrical energy: power and time, followed by multiplication.

In choosing the instruments for your research you should pay attention to the following considerations:

	Quantity	Measurement Instruments
1	length	metric ruler, meter stick, tape measure, surveyor's wheel, micrometer caliper, vernier caliper
2	mass	lever-arm balance, spring balance, weights. Values are obtained by counting weights, associating a number with a scale location, or by reading a digital display on the more sophisticated balances.
3	time	clock, stopwatch
4	area	planimeter. User moves a pointer around periphery of surface in question on graph or map and learns amount of surface traversed from scales on instrument.
5	density	hydrometer (for liquids)
6	volume	graduated cylinder, pipette, burette, measuring cup
7	angle	protractor, surveyer's transit, sextant
8	velocity	speedometer, anemometer (wind), velometer
9	force	spring balance
10	pressure	mercury barometer, collapsing-disc barometer, mechanical pressure gauge, differential liquid manometer
11	temperature	liquid-in-glass thermometer, bimetallic differential expansion, helical bar, thermocouple, pyrometer
12	mechanical power	prony brake
13	elec. potential	voltmeter, potentiometer & standard cell
14	elec. current	ammeter, coulometer (deposition of metal)
15	elec. resistance	ohmmeter, Wheatstone bridge
16	elec. power	wattmeter (indicates V x I)
17	elec. energy	watthourmeter (integrates V x I x t)
18	heat	calorimeter
19	light intensity	photoelectric cell, calorimetric photometer
20	frequency	tachometer, strobotac, electronic oscillator
21	sound intensity	sound level meter, audiometer
22	acidity	pH meter, litmus paper
23	humidity	psychrometer, hygrometer
24	viscosity	viscometer
25	surface tension	Jolly balance

Figure 17. Instruments for measurement of various common quantities. Qualifying statements supplied in some cases to avoid confusion.

Range of measurement.

Sensitivity—the smallest value-difference detectable.

Accuracy—amount or percentage of incorrectness in a particular reading. Note that this often varies at different points in the calibration range: this is true particularly in electrical indicating instruments and thermometers.

The catalogs of equipment suppliers often supply useful information on such characteristics as those listed above. Textbooks and technical manuals may also yield helpful information.

Each instrument should be read to as many significant digits as its scales will permit; however, remain cognizant of the fact that its accuracy of calibration may not be as great as the closeness of measurement implied by the significant digits.

7.4 *Research Equipment in General.*

Observational devices that are not of the number-producing type are often employed in research. These include the optical microscope, electron microscope, telescope, and many photographic devices.

Your research may require the use of chemical glassware, such as glass tubing, rubber or neoprene tubing, electrical or gas heating equipment, etc. and perhaps a vacuum pump.

Research perf·rmed in the field may require transportation by car or boat, the use of flashlights, etc. All such factors should be thought of, listed, and procured before starting the research, to insure that when you are part way through you are not stopped through the lack of necessary apparatus.

CHAPTER 8:

Experimentation Involving Animals

8.1 *Seriousness of Experiments on Animals.*

Experimentation with vertebrate animals can have serious consequences if it results in needless suffering. It can arouse serious moral and legal objections from the public. It is the researcher's responsibility to justify experimentation on the basis of its eventual worth to mankind. This type of research should not be pursued unless its value clearly outweighs any distress caused to the animals.

8.2 *Guidelines on Use of Animals.*

Fortunately, guidelines exist to aid researchers in this sensitive area. The following statement appeared in the 1974 *Handbook of the North Carolina Student Academy of Science.*

> The basic aims of experiments involving animals are to achieve an understanding of life processes and to further man's knowledge. Such experiments must be conducted with a respect for life and an appreciation of humane considerations that must be afforded all animals. To assure humane treatment of animals, a qualified adult supervisor with training in the proper care of laboratory animals must assume responsibility for the conditions of any experiment involving live vertebrates. Experiments involving the use of anaesthetic drugs, pathogens, ionizing radiation, carcinogens, or surgical procedures must be performed under the immediate supervision of a bio-medical scientist experienced in the field of investigation.

Also a copy of *Guide for the Care and Use of Laboratory Animals*, stock number 1740–0343, can be requested from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. The National Science Teachers Association, 1201 16th St., N.W., Washington, D.C. 20036, may also provide assistance.[5]

[5]Swilling, *Handbook of the North Carolina Student Academy of Science*, p. 9.

CHAPTER 9:

Library Resources

9.1 *Library Searches.*

If you have access to a college library, you will find many useful resources. Still, if a public library in your community is your only resource, you should nevertheless be able to locate material to aid in your project. First it will be necessary to become familiar with the areas of the library that are likely to be productive. If specific references are not available, an awareness of applicable catalog numbers and sections should be acquired by "browsing."

A librarian can provide valuable assistance in conducting a library search. A specially trained reference librarian should be able to make helpful suggestions as to appropriate journals and other sources such as abstract bulletins and indexes.

9.2 *Possible Sources.*

The job may be made easier because of the existence of a publication called the *Public Library Catalog* prepared in New York for use by libraries throughout the United States. In it are summaries of desirable books on a variety of topics. Several sections relate to possible research situations. These are classified under the Dewey Decimal catalog number 507. Some of these books may be found in a local library. The following books in particular may be helpful:

Harvard Case Histories in Experimental Science, James B. Conant, ed. and others. Harvard University Press, 1957

Science for Camp and Counselor, by William T. Harty. ASN Press, 1964

The Case for Going to the Moon, by Neil P. Ruzic. Putnam, 1965

The Scientific American Book of Projects for the Amateur Scientist, C. L. Strong. Simon & Schuster, 1960

Build-it-yourself Science Laboratory, by Raymond E. Barrett. Doubleday, 1964

Science and Common Sense, by James B. Conant. Yale University Press, 1951

700 Science Experiments for Everyone, UNESCO. Doubleday, 1964

You can quickly determine whether your library has these books, through its catalog.

Another place to survey is the reference section of the library, which will yield valuable authoritative works in each subject area. Often while searching for one piece of material you may accidentally discover an even better resource. Unique solutions to your problem may be found by consulting scientists, teachers, and fellow researchers.

CHAPTER 10:

Papers and Abstracts

10.1 *Communication.*

Once the research part of the project is complete, it is desirable to communicate the results to others. A common means of communication among researchers is the writing and presentation of scientific papers. Various scientific organizations sponsor symposia in which research scientists meet to exchange information about their research. These meetings often are open to the public or media coverage so that the public is made aware of new discoveries in science. Publications containing transcripts of papers, abstracts, and proceedings also contribute to communication about happenings in the field of research.

10.2 *Research Reports and Research Papers.*

If a complete *report* on a research project is desired, the following outline may be employed:

1. Title: a concise identification of the project.
2. Abstract: a summary of the main points as described in Section 10.3
3. Procedure: a description of the logic and design of the investigation, given in sufficient detail to allow it to be repeated by someone else.
4. Instrumentation: types and specifications of the equipment employed; description of any equipment designed and built for the project.
5. Data: presentation of primary data to an extent that will permit confirmation of your calculations.
6. Analysis: sample calculations (no arithmetic!), graphs, analyses.

7. Results: discussion of findings; conclusions; limits of reliability.
8. Bibliography: a list of specifically pertinent resource material.
9. Acknowledgments: credit given to persons and institutions that helped or advised.

A *paper* (to be given orally or sent to a learned society for publication) may also be based on an outline like that above but should not include details that an educated auditor or reader can be expected to take for granted. For example, if reference to procedure is necessary, restrict it to identification of method or type of process or test employed. A statement like "I poured 10.0 m*l* of the 5 percent solution into the 18 percent solution and the temperature rose 2 degrees" is, as a rule, too detailed. Graphs serve excellently to convey information compactly. If a graph, data table, diagram, or drawing is included in a paper given orally, the speaker should not take it for granted that the audience will instantly understand it, but should describe it. Even though a properly-made graph will have a legend along each axis, the speaker should *name* the dependent and independent variables and *state* the significance of the position and shape of the graph line. In an oral presentation it is not good policy to flash a large number of slides before the audience, but to use no more than necessary and to *talk* about them. If your oral report requires the use of any highly specialized words, *define* them. Consider yourself to be teaching the audience what you want them to know, particularly if it is a high school audience, assuming that their knowledge is general and is not specialized in your research area. It is undesirable, though legitimate, to read aloud a written paper, because reading it is much less effective. You can make your talk *sound* and *be* more nearly spontaneous by using a series of visuals and talking about them. Generally this also makes it more easily understood.

There are writing manuals that help in technical writing. Considerable attention should be given to sentence structure, grammar, spelling, and punctuation. Your colleagues' opinions of your work will be affected by the composition and presentation of your paper. It is legitimate for another person, such as an English teacher, to edit your draft if the editing is done in your presence so that you can learn from the experience. "Dry runs" made befoie a critical audience can also contribute to your skill development.

10.3 *Writing an Abstract.*

An important part of a completed research investigation is the writing of a concise statement called an *abstract*. It is through abstracts that the products of research are most likely to be disseminated. Think of the abstract as a first announcement that has been carefully written to convey the essence of what has been done and to spur the reader to take a closer look if the project is in one of his fields of interest.

Scientists read and explore bound volumes of abstracts, sometimes old ones as well as new ones. These volumes are part of the system through which the scientific and engineering communities keep their members up-to-date and help them avoid re-doing a project completed successfully years earlier. Progress, new research, and new applications of existing knowledge often result from ideas, questions, and even doubts sparked in the minds of readers as they thumb through collections of research abstracts. Therefore, it will be desirable for you to try to write an abstract that fits into this established system of communication.

The abstract should be no longer than one-half of an 8-1/2 x 11 inch page, single-spaced. It is not an in-depth treatment of the project. If it is considered essential, the *object* of the project may be stated but its reason for performance need not be justified. The abstract *may* give some information concerning the project's origin or rationale. The body of the abstract should consist of short, precisely worded sentences, outlining what the researcher did. It identifies the quantities explored, the variables isolated and compared, and the *kinds* of analysis employed. Then, a conclusion is presented, a concise statement of what has been learned. The abstract that follows may be taken as an example. It is only a suggestion and does not actually represent any piece of research. This format is that employed in the abstract bulletins prepared in connection with the Army's Junior Science & Humanities Symposium program:

ABSTRACT

Name:	Smart, I. M.
Home Address:	602 Entropy Street, Gibbs, N.C.
School:	Gibbs High School
Title:	Effects of Heavy Metal Concentrations on Microscopic Bio-Mass.

Although less visible than sewage and suspended wastes, small quantities of heavy metal in water supplies have been shown to have detrimental impact on aquatic life in streams. The object of this project was to quantify the relationship between concentrations of the metal lead and the survival of microscopic life in pond water.

One hundred samples of viable pond water were maintained with respect to oxygen, food, and temperature. Ten samples were labeled as controls while the other 90 samples, in groups of 5, were subjected to single doses of Pb^{+2} ion beginning at 5.0×10^{-4}M and increased in 1.0×10^{-4}M increments. Records of initial and daily grid biocounts were taken over a two-week period.

After analysis, it was concluded that a threshold toxicity exists at about 7×10^{-4}M for Pb^{+2} ion. Population levels decline beyond that concentration in a near-linear fashion, approaching zero at 1.5×10^{-3}M. These stabilized population counts were achieved after roughly a 3-day "kill-off" period, while control populations remained stable from the initial count.

The main points in writing an abstract are (1) keep it short, (2) be precise, (3) stick to the topic. The task is to write what was done, how it was done, and what the findings showed. Expect writing an abstract to be a laborious task. Spend time on it. Do not underestimate its worth. It *may* convey the first news of your findings that the scientific world has received!

CHAPTER 11:

Safety

It is the researcher's responsibility to take precautions to safeguard all persons and property affected by his work. The public is extremely sensitive to the safety aspects of any project. Liability for injury or damage will be focused directly on the researcher. While taking measures to ensure the safety of others, the researcher must also avoid risks to himself.

The information and recommendations in this chapter should be considered to be general advice for situations in which accidents are known to have taken place. It is organized into four sections by topical areas:

11.1 *General Precautions.*

1. Attempt to recognize and remedy potential hazards
2. Do not conduct potentially hazardous experiments while alone
3. Practice good housekeeping in the laboratory area
4. Use protective equipment for the body and be especially careful to shield all eyes in the work area
5. Keep fire extinguishers operable and accessible

11.2 *Biological Precautions.*

1. Avoid poisionous plants—over 700 species are known to cause illness or death
2. Experiments with bacteria should only be conducted using nonpathogenic varieties
3. Seal all petri dishes with tape

4. Kill all cultures of bacteria before washing the culture dishes. Most cultures can be killed by heating for 20 minutes under steam pressure of 15 psi
5. Flame all wire loops before and after transferring microorganisms
6. Avoid insect-killing jars that contain potassium cyanide
7. Use only sterile, disposable lancets when taking blood samples
8. Wear protective equipment such as apron and gloves when working with bacteria cultures

11.3 *Physical Precautions.*

1. Employ eye and body protection when hammering or chipping rock samples
2. Do not directly view the sun or infrared and ultraviolet light sources
3. Work with electrical devices in dry areas and avoid touching grounded objects such as plumbing—110 volts AC or DC can kill
4. Avoid direct viewing of laser light
5. Remove all reflective objects from the path of a laser beam
6. Label all radioactive materials
7. Avoid contamination from radioactive materials by handling only with gloves or tongs
8. Avoid ingestion of materials associated with radioactive substances
9. Avoid sources of x-rays, including cold cathode ray tube demonstration devices

11.4 *Chemical Precautions.*

1. Remember that many chemicals are incompatible and that mixing can result in fire, explosion, or toxic fumes
2. Never taste an unknown chemical
3. Avoid breathing gases, especially in high concentrations
4. Take precautions when using or storing highly volatile or flammable liquids
5. Acid can be carefully poured into water, but never pour water into acid
6. Use proper safety equipment such as shields for eyes, aprons, gloves, tongs, fume hoods, respirators, and explosion shields when using potentially dangerous chemicals.
7. Avoid use of the chemicals listed below, which have been declared by OSHA to be cancer-causing agents—some of these materials are known by other names. This is only a partial list of carcinogens:

4-Nitrobiphenyl (4-NBP)
Alpha-Naphthylamine
(1-NA)
4,4'-Methylene bis
(2-chloroaniline)
Methyl chloromethyl ether
(CMME)
3,3' Dichlorobenzidine (and
its salts)
Bis (chloromethyl) ether
(BCME)
Beta-Napthylamine
(2-NA)
Benzidine
4-Aminodiphenyl
Ethyleneimine (EI)
Beta-Propiolactone (BPL)
2-Acetylaminofluorene
4-Dimethylaminoazobenzene (DAB)
N-Nitrosodimethylamine (DMN)

A researcher must be dedicated to maintaining safe conditions in the laboratory. He must be knowledgeable in all aspects of the use of the equipment and materials contained therein.[6]

[6]Division of Science. *Safety First in Science Teaching* (Raleigh, N.C.: North Carolina Department of Public Instruction, 1977).

APPENDIX H

EXAMPLE ABSTRACTS

Example of 100-word Abstract

NAME: Glick, Gary
HOME ADDRESS: 20 Surrey Road, Somerset, New Jersey 08873
SCHOOL: Franklin Township High School
SPONSOR/TEACHER:
TITLE: Characterization of Medieval Window Glass by Neutron Activation Analysis

The concentrations of 15 component oxides in medieval stained glass were determined by instrumental thermal neutron activation analyses. Three groups of glass were studied: 52 specimens from a set of 13th century French grisaille panels from a demolished royal chateau at Rouen; 10 samples from a grisaille panel in the collection of the Princeton University Museum of Art; and a set of 32 random fragments of varied provenance.

Significantly differing compositions were found. However, specimens from within individual and related groups of panels are compositionally similar even for different colors of glass, indicating a common origin for the related pieces.

Example of 175-word Abstract

NAME: Kornfeld, Stephen Kerry
HOME ADDRESS: 50 Villa Coublay, Frontenac, Missouri 63131
SCHOOL: Horton Watkins High School
SPONSOR/TEACHER: Charles Smith
TITLE: A Determination of the Oligosaccharide Binding Specificity of Lectins from Pisum sativum and Lens culinaris

Lectins agglutinate red blood cells by binding to cell surface glycoproteins. The lectins recognize and bind to the sugar portions of the glycoproteins. Because different lectins are specific for different sugar sequences, lectins are useful tools for fractionating and isolating glycoproteins. This study was to determine the precise oligosaccharide binding of the pea (Pisum sativum) and the lentil (Lens culinaris) lectins. The lectins were covalently bound to an insoluble support, Sepharose, which was suitable for affinity chromatography. A variety of radioactively labeled glycopeptides with different oligosaccharide structures were tested for binding to the lectin affinity columns. The conclusion is that affinity binding to the pea and lentil lectins requires at least two α-linked mannose residues that are not substituted at positions 3, 4, or 6 as well as the fucose residue. While the mannose and fucose residues are essential for high affinity binding, neither sugar residue by itself is sufficient for binding. With this information, these two lectins can become useful tools for fractionating the glycoproteins of animal cells.