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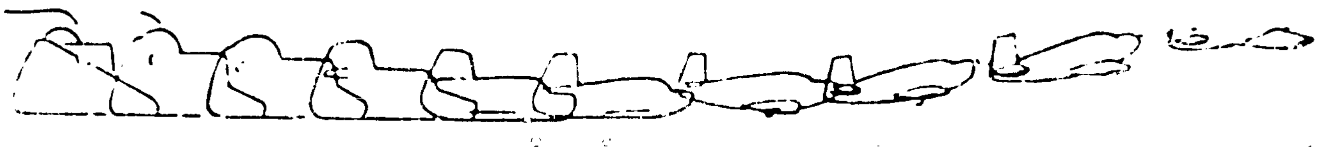
ABSTRACT

In the Project Solo classification scheme for interactive computing Category IV encompasses those activities where the student takes the role of lesson designer. Similar programs written by a teacher or fellow student are frequently the starting point for such a would-be author. The transition from the role of student to that of student-author is described and illustrated with examples of student-authored programs. Two printed modules from the physics curriculum are also included--MKS (Meter Kilogram Second) and Newton (Newtonian Laws)--to show how they may be used as a springboard for student-authored programs. (JY)

PROJECT SOLO
AN EXPERIMENT IN REGIONAL COMPUTING
FOR SECONDARY SCHOOL SYSTEMS



University of Pittsburgh • Department of Computer Science • Pittsburgh, Pennsylvania 15213

Newsletter No. 8 January 8, 1971

CATEGORY IV Programs in Science

Category IV in the Project Solo classification scheme for interactive computing encompasses those activities where the student takes on the role of lesson designer, usually as the author of a Category I (e.g. drill and practice or tutorial) or a Category II (e.g. simulation) program. Since the student is on his own when functioning as an author (Solo mode), there can, strictly speaking, be no curriculum module to guide him. However, the example of similar programs written by a teacher or fellow students is frequently the starting point for such a would-be author.

To illustrate this transition from the role of student-taker of Category I or II programs to student-author, we are attaching excerpts from a paper that represents the joint efforts of Mr. Mike Shore and Mr. Dave McMillin, both of Taylor-Allderdice High School. By showing the examples of student-authored programs in the context of the total curriculum plans for the subjects, it will be clearer that other modes of computing are also intended.

It should be noted that the examples came from "first-time" students as far as computer usage goes. There will undoubtedly be changes in the kinds of things students elect to do as we move into the years where students bring better programming skills to these subjects as a result of their contact with the freshman computer science course we are now planning.

We are also including two printed modules from physics (MKS and Newton). The Newton module is primarily intended as a Category III unit, but the program suggested at the end (the aircraft landing analysis) comes close enough to a simulation that the author is really in Category IV. The difference is this: a student who writes a program to solve problems for his <u>own</u> use is in Category III; a student who writes programs where the primary intention is that they be used to illuminate <u>others</u> is in Category IV.

EXCERPTS FROM THE SHORE AND MCMILLIN PAPERS DESCRIBING THE USE OF COMPUTERS IN PHYSICS AND CHEMISTRY

"...Our goal is to give students and teachers an additional tool for the investigation and discovery of structures which are not communicated well with present methodology..."

Terminology

"...In our present work we call a collection of educational materials which focus on a single topic, and which require use of an interactive computer terminal, a module.

Topics fit into a bigger scheme, which is either a full year's work or a particular portion of the subject. The curriculum material for a topic is called a module rather than a "unit" because it can often fit into more than one such scheme. For example, the module which studies the path of a bouncing billiard ball fits physical chemistry (kinetic theory of gases), mathematics and physics (application of vectors), and computer science (simulation).

The module can include instructions, explanations, diagrams, illustrations, flow charts, maps, bibliographies, and technical hints to teacher or student. However, we always assume that the topic of interest has already been treated in the classroom or textbook. Modules are classified in one of four categories, defined as follows:

Category I - This category contains what some workers have called "drill and practice CAI", "tutorial CAI", or "teacher-directed CAI". The written material of the module usually just gives directions about "calling up" a program which presents information to the student, asks him questions, branches as a function of his response, and repeats this cycle.

Category II - The modules of the second category involve what is sometimes called "learner-directed CAI". General constraints on subject matter and information access are presented to the student who then decides how to use that information and what conclusions to draw. The student is still interacting with a master program written by someone else. Simulation, gaming, and structured information retrieval are included in this category.

Category III - This category is the "hands-on computing" category. The written material of the module presents problems which the student is required to solve by formulating an algorithm, and writing and debugging a program based on that algorithm.

Category IV - Modules in the fourth category require that the student create a system which can be used by his peers and teachers. The development by a student of a simulation (Category II) program is an example of an activity of this kind..."

"...A list of major topics in high school chemistry and physics was developed, attempting to choose topics which were independent of the text which might be used in any particular school..."

"...The following have been chosen as the first 10 chemistry topics to receive attention:

1. Introduction to NEWBASIC
2. Metric System
3. Gas Laws
4. Stoichiometry-1 (Weight-Weight, Weight-Volume, and Volume-Volume)
5. Periodic Table
6. Stoichiometry-2 (Concentration)
7. Chemical Kinetics
8. pH
9. Equilibrium
10. Review Quiz..."

"...The following physics topics have been chosen to receive attention:

1. Introduction to NEWBASIC
2. Metric System
3. Vectors
4. Newton's Law of Motion
5. Circular Motion
6. Kepler's Law
7. Optics
8. Wave Motion
9. Mechanical Energy
10. Conservation of Momentum
11. Conservation of Mass-Energy
12. Static Electricity

Topics which have been postponed for later consideration are:

1. Kirchoff's Laws
2. Kinetic Theory - Heat
3. Electricity and Magnetism
4. Particle Physics
5. Electronics..."

"...One might ask what will happen now that many of the modules are written? Does this rule out student creativity in program design? The answer is "No", since each module concludes with a requirement that the student modify the existing program or write a similar one (Category IV)..."

"...The chemistry modules prepared during the year 1970 are:

1. Introduction to NEWBASIC - A primer prepared by staff members in the project office. It employs a group of example programs with an opportunity for the student to copy and modify these programs. (A CAI tutorial for NBS is in preparation-T.D.)

2. Metric System - A module which drills the student in the use of all measurements within the metric system as well as conversions between the English and Metric Systems. It moves gradually from Category I type questions to Category III type problems requiring simple program solutions, and ends in Category IV where the student is required to write a similar program.

3. Gas Laws - A module which employs both Cateogy I and III. It begins with questions and problems on Boyle's Law, then moves to Charles' Law, and concludes with a complicated problem requiring programs that utilize a combination of the two Laws. Again the student is asked to write a similar program upon completion of the module.

4. Stoichiometry-1 (Weight-Weight, Weight-Volume, and Volume-Volume) - A module designed to give the student a review of this subject area and the interrelatedness of the three types of problems involved. It presents the student with a story situation. In order to progress through the plot he must solve the chemical problems presented. This is chiefly Category I and III again, with the student asked to program a similar situation as is described in Category IV.

5. Stoichiometry-2 (Concentration) - A story module similar to Stoichiometry 1 using a character called Super Chemist dealing with the three areas of concentration -- Normality, Molarity, and Molality.

6. Review Quiz - A module designed by the students which randomly generates and grades problems and questions covering the entire course. This was done in order to prepare for College Boards and final exams.

For all six modules listed above, we have several versions written by different students which can be used interchangeably. The other four modules on the list are in various stages of completion..."

"...The physics modules prepared during the year 1970 are:

1. Introduction to NEWBASIC - A primer prepared by staff members in the project office. It employs a group of example programs with an opportunity for the student to copy and modify these programs. (See note above on a computer based NBS tutorial in prep.)

2. Metric System - A series of programs which lead the student from Categories I and II to Categories III and IV.

This program includes: the use of scientific notation, significant figures and standards of measurement in the MKS system.

3. Vectors - A module in which Category II is employed for an introduction. The student then has to apply trigonometric formulae to calculate resultant vectors, working in Category III. Students have been inspired to write programs which will find the resultant of N vectors in two and three dimensions with a choice of Cartesian and spherical coordinates.

4. Newton's Laws of Motion - A Category III module, in which the student must move from exploring the effect of a single force, through several forces in a straight line, to three forces in two dimensions. He is left with the challenge of writing a program to investigate the capabilities of an aircraft arresting system used at military-civilian airports.

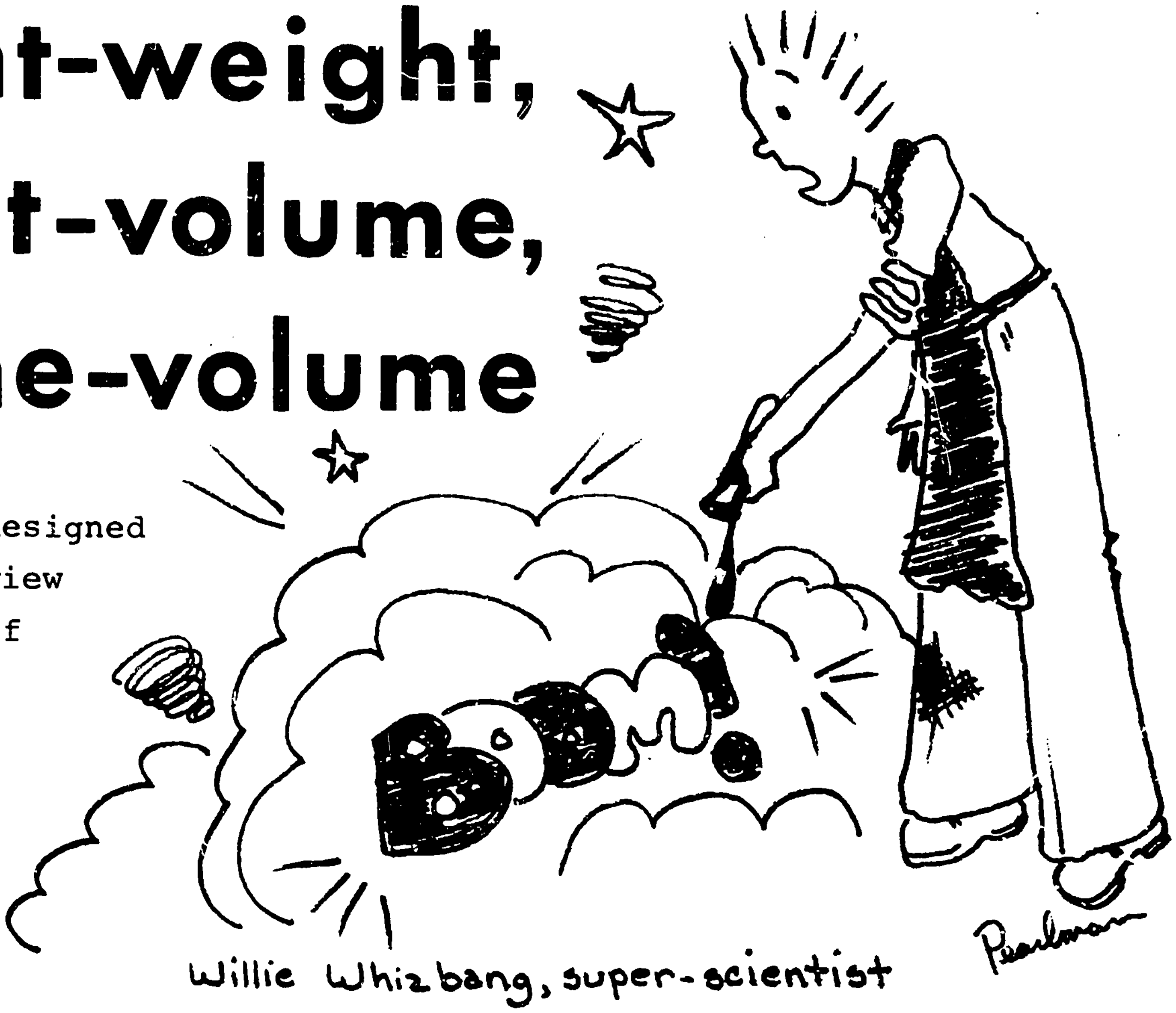
5. Kepler's Law - This is another Category III module in which the student writes a program to check Kepler's constant ($R^3/T^2 = K$) for the most accurate data available at the moment.

The student will have to make the assumption that the orbits of the major planets are circular and then combine laws of gravitation and centripetal force relations to determine a value for the mass of the sun determining that $M = 4\pi^2 K/G$.

6. Conservation of Momentum - A Category III module is employed with a Category I tutorial introduction to establish the student's readiness for the Category III module. The final problem involves nuclear particles in two dimensional collisions. It does not require prior knowledge of the particles but gives experience which is normally not received..."

[7. Circular Motion - A series of programs ranging through Categories I, II, III, & IV. Synthesizes the use of Newton's law of motion, centripetal acceleration, and Newton's law of gravitation in situations involving circular motion. Possible orbital situations about various bodies in the solar system are considered.]

Weight-weight, weight-volume, volume-volume



Willie Whizbang, super-scientist

This module is designed to drill and review your knowledge of the above relationships while you enjoy the adventures of Willy Wizbang, boy scientist. You may use the @NBS feature to program solutions to your problems. Remember to enter all answers without labels. To take this lesson:

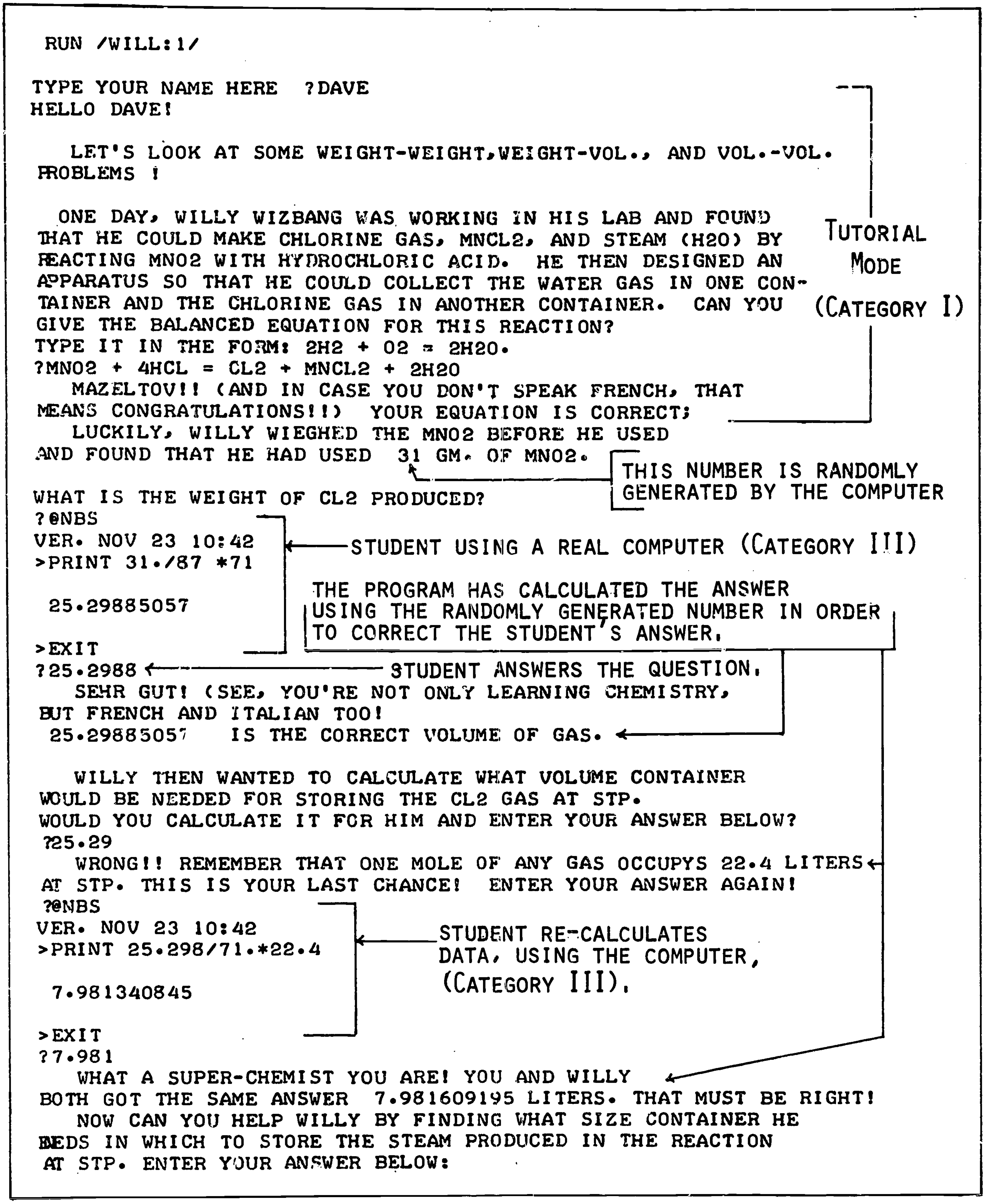
1. Logon the computer using the procedures previously given.
2. Then type the parts shown below not underlined.

```
-NBS
VER. AUG 26 9:37
>RUN 166DM /WILL:1/
```

At the completion of the lesson, you will be asked to write another adventure program using Willy or some other character. If you ask your instructor or computer room assistant he will give you a copy of one section of the program that you have just run. This can be used as a guide but don't hesitate to ask for help!!

When you have finished the lesson turn in your computer printout with your comments on it.

Cover for Stoichiometry-1



```
 RUN /WILL:1/

TYPE YOUR NAME HERE  ?DAVE
HELLO DAVE!

   LET'S LOOK AT SOME WEIGHT-WEIGHT,WEIGHT-VOL., AND VOL.-VOL.
PROBLEMS !

  ONE DAY, WILLY WIZBANG WAS WORKING IN HIS LAB AND FOUND
THAT HE COULD MAKE CHLORINE GAS, MNCL2, AND STEAM (H2O) BY
REACTING MNO2 WITH HYDROCHLORIC ACID.  HE THEN DESIGNED AN
APPARATUS SO THAT HE COULD COLLECT THE WATER GAS IN ONE CON-
TAINER AND THE CHLORINE GAS IN ANOTHER CONTAINER.  CAN YOU
GIVE THE BALANCED EQUATION FOR THIS REACTION?
TYPE IT IN THE FORM: 2H2 + O2 = 2H2O.
?MNO2 + 4HCL = CL2 + MNCL2 + 2H2O
   MAZELTOV!! (AND IN CASE YOU DON'T SPEAK FRENCH, THAT
MEANS CONGRATULATIONS!!)  YOUR EQUATION IS CORRECT;
   LUCKILY, WILLY WIEGHED THE MNO2 BEFORE HE USED
AND FOUND THAT HE HAD USED  31 GM. OF MNO2.

WHAT IS THE WEIGHT OF CL2 PRODUCED?
?@NBS
VER. NOV 23 10:42
>PRINT 31./87 *71

 25.29885057

>EXIT
?25.2988
   SEHR GUT! (SEE, YOU'RE NOT ONLY LEARNING CHEMISTRY,
BUT FRENCH AND ITALIAN TOO!
 25.29885057   IS THE CORRECT VOLUME OF GAS.

   WILLY THEN WANTED TO CALCULATE WHAT VOLUME CONTAINER
WOULD BE NEEDED FOR STORING THE CL2 GAS AT STP.
WOULD YOU CALCULATE IT FOR HIM AND ENTER YOUR ANSWER BELOW?
?25.29
   WRONG!! REMEMBER THAT ONE MOLE OF ANY GAS OCCUPYS 22.4 LITERS
AT STP. THIS IS YOUR LAST CHANCE!  ENTER YOUR ANSWER AGAIN!
?@NBS
VER. NOV 23 10:42
>PRINT 25.298/71.*22.4

 7.981340845

>EXIT
?7.981
   WHAT A SUPER-CHEMIST YOU ARE! YOU AND WILLY
BOTH GOT THE SAME ANSWER  7.981609195 LITERS. THAT MUST BE RIGHT!
   NOW CAN YOU HELP WILLY BY FINDING WHAT SIZE CONTAINER HE
NEEDS IN WHICH TO STORE THE STEAM PRODUCED IN THE REACTION
AT STP. ENTER YOUR ANSWER BELOW:
```

TUTORIAL MODE (CATEGORY I)

THIS NUMBER IS RANDOMLY GENERATED BY THE COMPUTER

STUDENT USING A REAL COMPUTER (CATEGORY III)

THE PROGRAM HAS CALCULATED THE ANSWER USING THE RANDOMLY GENERATED NUMBER IN ORDER TO CORRECT THE STUDENT'S ANSWER.

STUDENT ANSWERS THE QUESTION.

STUDENT RE-CALCULATES DATA, USING THE COMPUTER, (CATEGORY III).

Student Interaction with Stoichiometry-1, a tutorial written by another chemistry student.

```
?15.96
GOOD
   WILLY NOW USED THE CL2 GAS PRODUCED TO REACT IT WITH
H2 GAS STORED IN CYLINDAR AT  4.65 ATM PRESS. AND 25C DEG. TO
MAKE HCL GAS. WHAT VOLUME OF H2 DID HE NEED AT THESE CONDITIONS?
?@NBS
VER. NOV 23 10:42
>PRINT 7.981/273.*298./4.65     <--III

 1.873518453

>EXIT
?1.8735
   GREAT!! THAT'S RIGHT.  NOW FOR THE LAST PROBLEM(SIGH!).
   WILLY WANTED TO STORE THE HCL PRODUCED IN A STEEL CONTAINER
AT A PRESSURE OF  4.49 ATMS. AND A TEMP. OF 30C DEG.
WHAT SIZE CONTAINER WOULD HE NEED? GIVE THE ANSWER IN LITERS:
?@NBS
VER. NOV 23 10:42
>PRINT 15.96/273.*303./4.49     <--III

 3.945177317

>EXIT                                       INVITATION TO CATEGORY IV
?3.945
CORRECT!  NOW WRITE A NEW ADVENTURE FOR WILLY SIMILAR TO THIS!
```

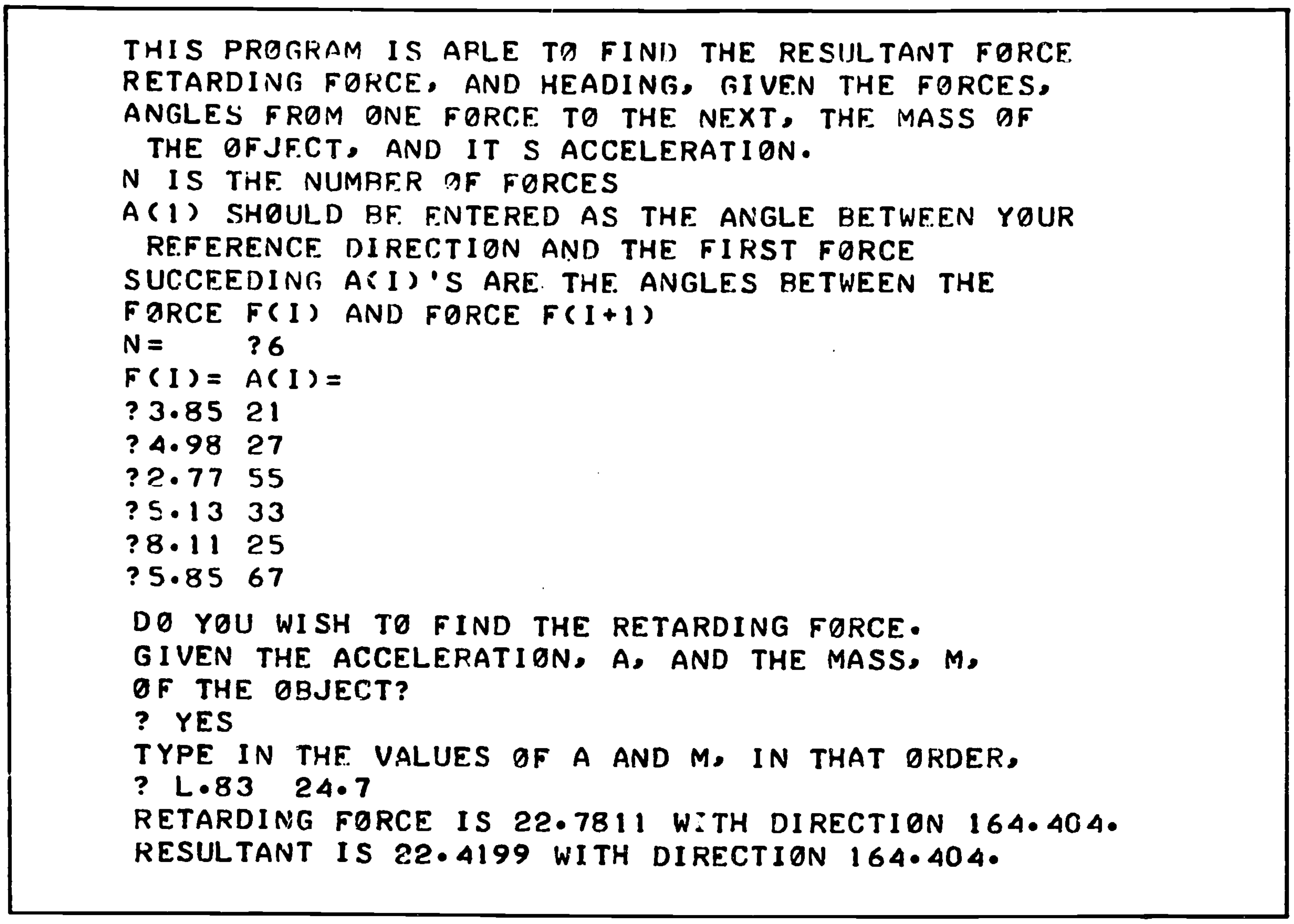
Student Interaction with Stoichiometry-1 (cont.)

```
THIS PRØGRAM DEALS WITH WEIGHT WEIGHT,WEIGHT-VØL.,AND VØL.-VØL.
THIS PRØGRAM IS GUARANTEED TØ STUPIFY YØUR IMAGINATIØN.
AMAZING...FANTASTIC...NEW YØRK TIMES.
SIMILAR IN MANY WAYS TØ DAVE MCMILLIN'S 'WILLY WHIZBANG' IF
 ANYTHING BETTER...T.A.FØREWØRD
GA...GEE...DØ...DUH.....PITTSBURGH PRESS.

NØW LETS GET TØ WØRK
JØE SHLABØTNIKI WAS WØRKING IN HIS FAMØUS KØLBASSI LAB
WHEN HE FØUND THAT BY RØASTING LEAD SULFIDE(PBS) HE
CØULD PRØDUCE LEAD ØXIDE(PBØ),AND SULFUR DIØXIDE(SØ2)
SINCE THIS WAS JØE'S BLIND LUCK,HE WAS WØNDERING WHAT HAPPENED
HELP JØE FIND ØUT WHAT DID HAPPEN. TYPE IN THE BALANCED
EQUATIØN,USE THIS FØRM:2H2Ø+Ø2=2H2Ø
?2PBS + 3Ø2 = 2PBØ + 2SØ2
JØE IS MUCH ØBLIGED. THANKS FØR YØUR AID

JØE HAPPENED TØ DRØP THE RØASTED LEAD(PBØ) (THE DUMMY
PICKED IT UP WHILE IT WAS HØT) ØN HIS KØSHER MEAT SCALE.
HE NØTICED THAT THE WEIGHT ØF IT WAS  6.13 GM.
WHAT WAS THE WEIGHT ØF Ø2 WHICH WAS USED ?
?@NBS
VER. DEC  3 15:17
>PR. 32.*3./2.*1./223.*6.13

 1.319461883

>EXIT
?1.319461883
EXCELLENT
JØE WANTED TØ CALCULATE WHAT VØLUME BEER CAN (CØNTAINER)
HE NEEDED TØ STØRE THE ØXYGEN AT RØØM TEMPERATURE(HE HAD THE SAME
WEIGHT ØF Ø2 AS USED IN THE EXPERIMENT.
?@NBS
VER. DEC  3 15:17
>PR. 1.319461883/32.*24.5

 1.010213004

>EXIT
?1.010213004
CØRRECT!!WHAT VØLUME BEER CAN WØULD JØE USE AT STP?
?@NBS
VER. DEC  3 15:17
>PR. 1.319461883/32.*22.4

 0.923623318

>EXIT
?.923623318
EXACTLY RIGHT!
 .
 .
 .
```

An interaction with a revised version of Stoichiometry-1 written by a student in response to the invitation at the end of the previous program. Since this previous program was also written by a student (in the Spring, 1970 term), the program above (written in Fall, 1970) illustrates how Category IV "inspiration" can be derived from fellow students.

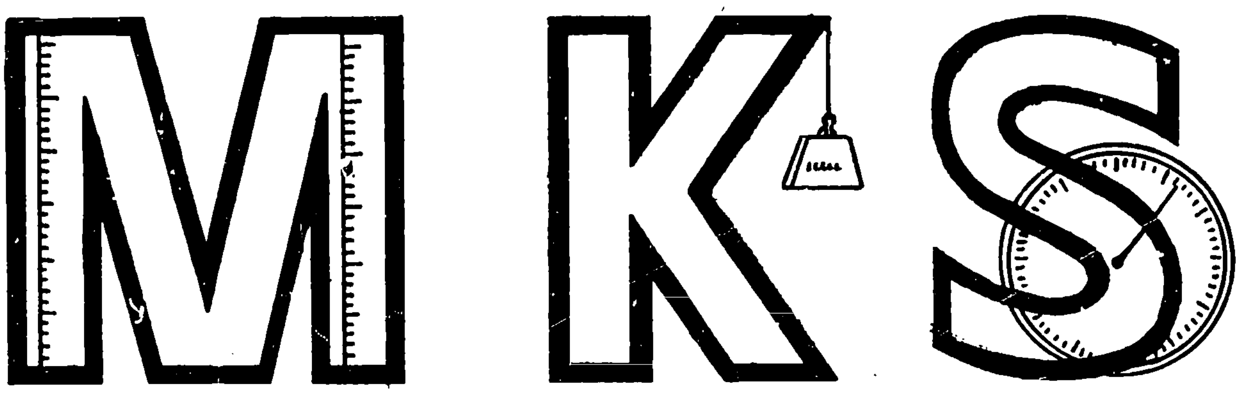
```
1 PRINT "THIS PRØGRAM IS ABLE TØ FIND THE RESULTANT FØRCE"
2 PRINT "RETARDING FØRCE, AND HEADING, GIVEN THE FØRCES,"
3 PRINT "ANGLES FRØM ØNE FØRC  TØ THE NEXT, THE MASS ØF"
4 PRINT " THE ØBJECT, AND IT'  ACCELERATIØN."
5 PRINT "N IS THE NUMBER ØF F RCES"
6 PRINT "A(1) SHØULD BE ENTER D AS THE ANGLE BETWEEN YØUR"
7 PRINT " REFERENCE DIRECTIØN ND THE FIRST FØRCE"
8 PRINT "SUCCEEDING A(I)'S AR  THE ANGLES BETWEEN THE"
9 PRINT "FØRCE F(I) AND FØRCE F(I+1)"
20 PRINT "N=";
30 INPUT N
40 PRINT "F(I)= A(I)="
50 FØR I=1 TØ N
60 INPUT F(I),A(I)
70 NEXT I
80 LET R=F(I)
85 ØN N GØTØ 245
90 LET X=A(I)/57.28835
100 LET J=1
110 LET A2=A(J)-X*57.28835+A(J-1)
120 LET J=J+1
130 LET T=(180-A2)/57.28835
140 LET F2=R
150 LET R=SQR(R↑2+F(J)↑2-2*R*F J)*CØS(T))
160 LET S1=F(J)*SIN(T)/R
170 LET C=(F2↑2+R↑2-F(J)↑2)/(2 F2*R)
180 LET X=ATAN(S1/C)
190 IF J<N THEN 110
200 LET S=0
210 FØR I=1 TØ N
220 LET S=S+A(I)
230 NEXT I
240 LET H=S-A2+X*57.28835
241 GØTØ 250
245 LET H=A(I)
250 PRINT "DØ YØU WISH TØ FIND THE RETARDING FØRCE."
260 PRINT "GIVEN THE ACCELERAT ØN, A, AND THE MASS, M,"
264 PRINT "ØF THE ØBJECT?"
270 INPUT Q$
273 IF Q$="YES" THEN 330
277 IF Q$="NØ" THEN 300
280 PRINT "PLEASE TYPE YES ØR Ø"
290 GØTØ 270
300 PRINT "RETARDING FØRCE IS ØT TØ BE CALCULATED."
310 PRINT "RESULTANT IS";R;"WI  DIRECTIØN";H;"."
320 END
330 PRINT "TYPE IN THE VALUES   A AND M, IN THAT ØRDER,"
340 INPUT A,M
350 LET F=A*M-R
360 PRINT "RETARDING FØRCE IS"; F;"WITH DIRECTIØN";H;"."
370 GØTØ 310
```

Student-authored program (Ca egory IV) initiated by the module "Newton's Laws of Motion".



```
THIS PR0GRAM IS ABLE T0 FIND THE RESULTANT F0RCE
RETARDING F0RCE, AND HEADING, GIVEN THE F0RCES,
ANGLES FR0M 0NE F0RCE T0 THE NEXT, THE MASS 0F
 THE 0BJECT, AND IT S ACCELERATI0N.
N IS THE NUMBER 0F F0RCES
A(1) SH0ULD BE ENTERED AS THE ANGLE BETWEEN Y0UR
 REFERENCE DIRECTI0N AND THE FIRST F0RCE
SUCCEEDING A(I)'S ARE THE ANGLES BETWEEN THE
F0RCE F(I) AND F0RCE F(I+1)
N=    ?6
F(I)= A(I)=
?3.85 21
?4.98 27
?2.77 55
?5.13 33
?8.11 25
?5.85 67

 D0 Y0U WISH T0 FIND THE RETARDING F0RCE.
 GIVEN THE ACCELERATI0N, A, AND THE MASS, M,
 0F THE 0BJECT?
 ? YES
 TYPE IN THE VALUES 0F A AND M, IN THAT 0RDER,
 ? L.83  24.7
 RETARDING F0RCE IS 22.7811 WITH DIRECTI0N 164.404.
 RESULTANT IS 22.4199 WITH DIRECTI0N 164.404.
```

An interaction with the previous student-authored program by a beginning student. For the beginning student this is Category II--for the author, Category IV.



A Tutorial on the MKS System of Measurement

This module contains a brief description of the MKS system (Part A) and a review of scientific notation (Part B).

The procedure for calling a computer tutorial is then given in Part C, followed by a challenge for you to improve this tutorial program in Part D.

A. The MKS System of Measurement

It is necessary to have a means of measurement before any phenomenon can be described. If the description is done in terms of well defined quantities it can be more readily understood by others.

The MKS system of units has been agreed on as the international system of measurement. Its use is being adopted throughout the world, although the transfer has been slowed down in places where the conversion involves considerable financial outlay.

In any system of units it is necessary to define three main units--namely:

(1) Length (2) Mass (3) Time

The initials of these units give the system its title i.e. length in Meters, mass in Kilograms, and time in Seconds. Because of the confusion which frequently arises for a person just starting physics, we also give the unit for force, although force can actually be expressed in terms of the other three units. In the MKS system a force is measured in Newtons.

B. Scientific Notation and Significant Figures

In physics you will encounter extremely small numbers and extremely large numbers. For example, the size of the nucleus of an atom is 0.000,000,000,000,001 meters across, while the galaxy in which our solar system is located is 100,000 light years across, where a light year is the distance light travels in one year. This is about 5,800,000, 000,000 miles. In the form given these numbers don't mean very much to people. We may also be uncertain of the accuracy to which such numbers are known.

A method of writing numbers called scientific notation was devised to (a) make numbers more manageable and (b) indicate how accurately the number is known.

Scientific notation uses a number between one and ten multiplied by ten raised to an appropriate power. For example, 100,000 would be 1.0×10^5 in scientific notation. The number between one and ten indicates how accurate the number is--in this case using 1.0 instead of 1.00 implies that the number is bigger than 9.95×10^5 but less than 1.05×10^5, so the number is not known to closer than 500 light years. This is quite a large distance because one light year is 5.80×10^{12} miles.

C. Using the MKS Tutorials

To access the first program type:

```
-NBS
>RUN 166JS /MKS/
```

If you finish this lesson without difficulty you should then type:

```
>EXIT
-NBS
```

This will clear your work space in order to let you run the second program. You then type:

```
>RUN 166JS /MKS:1/
```

Complete as much of this program as you can.

At one stage you will be asked to write a short program. Use the @NBS feature for this (see page 5-4 of the NBS Primer).

D. Challenge

If the tutorials /MKS/ and /MKS:1/ have not been too helpful, or if you can see weaknesses in them, ask your teacher for a listing of the original programs and see if you can make changes to improve things for those who have not used this module yet. Their future is in your hands.

Sample Interactions with the tutorials:

```
>RUN 166JS /MKS/

IN THIS LESS0N Y0U WILL GAIN S0ME FAMILIARITY
WITH THE MKS SYSTEM 0F UNITS.

WHAT IS Y0UR WEIGHT IN P0UNDS?
?110
THEREF0RE Y0UR WEIGHT IS  490 NEWT0NS.
Y0UR MASS IS  50 KIL0GRAMS.
WHILE I AM STILL BEING PERS0NAL,
H0W L0NG D0ES IT TAKE Y0U T0 GET T0 SCH00L?
GIVE Y0U TIME IN MINS.
?10
THAT IS  600 SEC0NDS.
WELL I GUESS THAT ISN'T T00 BAD!
N0W LET'S C0NSIDER DISTANCES
H0W FAR D0 Y0U LIVE FR0M SCH00L?
ALL0W 10 BL0CKS PER MILE AND PRINT Y0UR
ANSWER IN BL0CKS!
?5
THAT IS A DISTANCE 0F  804.672 METERS.
Y0UR AVERAGE SPEED 0N THE WAY T0 SCH00L IS   1.34112    M/SEC
H0W D0 Y0U GET T0 SCH00L?
INDICATE EITHER WALKING,BY BUS, CAR, BICYCLE 0R 0THER
?WALKING
AS Y0U WALK T0 SCH00L Y0UR MAXIMUM SPEED WILL
BE 0NLY AB0UT 4 MILES PER H0UR. H0W FAST IS THIS
IN METERS PER SEC0ND?
?@NBS
VER. N0V 23 10:42
>PRINT 4*88./60*12*2.54E-2

 1.78816


>EXIT
?1.78816
Y0U HAVE JUST CALCULATED WHAT Y0UR MAXIMUM
SPEED SH0ULD HAVE BEEN . D0 Y0U EXCEED
ANY SPEED LIMITS?
?N0

RIGHT! Y0UR DATA INDICATES THAT Y0U ARE STEADY, RELIABLE,
H0NEST, 0R LAZY, 0R A LIAR. MY PR0GN0STICATI0N CAN N0T BE
M0RE SPECIFIC UNTIL Y0U D0 THE NEXT LESS0N.
VERY G00D. GET INSTRUCTI0N Y0U NEED FR0M Y0UR TEACHER.
```

Sample Interaction (cont.)

```
>RUN 166JS /MKS:1/

AND S0 WE C0NTINUE WITH THE MKS SYSTEM 0F UNITS.

IF A CAR HAS A MASS 0F 1000 KIL0GRAMS. WHAT IS ITS
WEIGHT IN NEWT0NS?
?9800
VERY G00D.

N0W TRY AN0THER 0NE. WHAT IS THE WEIGHT 0F AN
0BJECT WHICH HAS A MASS 0F
 6522 KIL0GRAMS?
?@NBS
VER. N0V 23 10:42
>PRINT 6522*9.8

 63915.6

>EXIT
?63915.6
G00D. S00N Y0U'LL BE AN EXPERT.
W0ULD Y0U LIKE T0 TRY AN0THER C0NVERSI0N 0F
MASS T0 WEIGHT?
?N0
N0W TRY THIS 0NE.
H0W MANY METERS ARE THERE IN A MILE?
?1609

0.K. Y0U ARE GETTING THE IDEA. G0 T0 @NBS
AND WRITE A SH0RT PR0GRAM WHICH WILL C0NVERT
EACH 0F THE F0LL0WING DISTANCES T0 METERS.
 74 MILES.
 69 MILES.
 30 MILES.
 86 MILES.
?@NBS
VER. N0V 23 10:42
>PRINT 74*1609,69*1609,30*1609,86*1609

 119066            111021            48270             138374

>EXIT
?119066
NEXT DATUM:111021
NEXT DATUM:48270
NEXT DATUM:138374

C0NGRATULATI0NS!
SH0W Y0UR GREAT PR0GRAM T0 Y0UR TEACHER.
SEE Y0U NEXT TIME. G00D DAY.
```

Listing of the /MKS/ Program:

```
1 LET X=0
2 LET Y=0
   10 PRINT "IN THIS LESSON YOU WILL GAIN SOME FAMILIARITY"
20 PRINT "WITH THE MKS SYSTEM OF UNITS."
30 PRINT "  "
40 PRINT "WHAT IS YOUR WEIGHT IN POUNDS?"
50 INPUT A
60 LET A=A*9.8/2.2
70 PR. "THEREFORE YOUR WEIGHT IS ";A;" NEWTONS."
80 IF A<200 GOTO 200
90 IF A>900 GOTO 250
100 LET M=A/9.8
101 PRINT "YOUR MASS IS ";M;" KILOGRAMS."
105 PRINT "WHILE I AM STILL BEING PERSONAL,"
110 GOTO 300
200 PRINT "CHECK THAT YOU TYPED IN YOUR CORRECT WEIGHT!"
210 PRINT "IF YOU DID MAYBE YOU SHOULD GO AND HAVE A"
220 PRINT "BIG LUNCH"
230 GOTO 100
250 PRINT " CHECK THAT YOU TYPED IN YOUR WEIGHT CORRECTLY"
260 PRINT "IF SO MAYBE YOU SHOULD SKIP LUNCH"
270 GOTO 100
300 PRINT "HOW LONG DOES IT TAKE YOU TO GET TO SCHOOL?"
310 PRINT "GIVE YOU TIME IN MINS."
320 INPUT B
330 LET B=B*60
340 PR. "THAT IS ";B;" SECONDS."
350 IF B<60 GOTO 400
360 IF B>1800 GOTO 500
370 PRINT "WELL I GUESS THAT ISN'T TOO BAD!"
380 GOTO 600
400 PRINT "DO YOU HAVE A TENT ON THE FRONT LAWN?"
410 GOTO 600
500 PRINT "MAYBE YOU SHOULD APPLY FOR TRAVEL PAY!"
510 GOTO 600
600 PRINT "NOW LET'S CONSIDER DISTANCES"
610 PRINT "HOW FAR DO YOU LIVE FROM SCHOOL?"
620 PRINT "ALLOW 10 BLOCKS PER MILE AND PRINT YOUR"
630 PRINT "ANSWER IN BLOCKS!"
640 INPUT C
650 LET C=C*176*36*2.54E-2
660 PR. "THAT IS A DISTANCE OF ";C;" METERS."
670 LET D=C/B
680 PRINT "YOUR AVERAGE SPEED ON THE WAY TO SCHOOL IS";D;"M/SEC"
690 PRINT "HOW DO YOU GET TO SCHOOL?"
700 PRINT "INDICATE EITHER WALKING,BY BUS, CAR, BICYCLE OR OTHER"
710 INPUT E$
720 IF ICO(E$,"WALK",0) GOTO 800
730 IF ICO(E$,"BUS",0) GOTO900
740 IF ICO(E$,"CAR",0) GOTO 1000
750 IF ICO(E$,"CYCLE",0) GOTO 1100
```

Listing (cont.)

```
760 IF ICO(E$,"OTHER",0) GOTO 1200
770 LET Y=Y+1
771 IF Y>1 GOTO 9990
780 PRINT "TYPE ONLY ONE OF THE FOLLOWING,YOUR ANSWER IS NOT UNDERSTOOD"
790 GOTO 700
800 PRINT "AS YOU WALK TO SCHOOL YOUR MAXIMUM SPEED WILL "
801 PRINT "BE ONLY ABOUT 4 MILES PER HOUR. HOW FAST IS THIS "
802 PRINT "IN METERS PER SECOND?"
810 INPUT F
820 IF (F-1.78816)/1.78816 <.03 GOTO 2000
830 LET Y=Y+1
840 IF Y>1 GOTO 870
850 PRINT "YOUR ANSWER DOES NOT EQUAL 4 MPH EXPRESSED IN M/SEC"
851 PRINT "CHECK YOUR ANSWER AND TRY AGAIN."
860 GOTO 810
870 PRINT " NO! 4 MPH IS EQUAL TO 1.78816 M/SEC."
880 LET F=1.78816
890 GOTO 2000
900 PRINT "THE CITY BUSSES MANAGE TO AVERAGE ABOUT 15 MPH"
901 PRINT "ON A GOOD DAY. HOW MUCH IS THIS IN METERS PER SECOND?"
910 INPUT F
920 IF (F-6.7056)/6.7056 <.03 GOTO 2000
930 LET Y=Y+1
940 IF Y>1 GOTO 970
950 PRINT "YOUR ANSWER IS NOT EQUIVALENT TO 15 MPH!"
951 PRINT "CHECK YOUR ANSWER AND TRY AGAIN."
960 GOTO 910
970 PRINT "WRONG AGAIN. 15 MPH IS EQUAL TO 6.7056 M/SEC."
980 LET F=6.7056
990 GOTO 2000
1000 PRINT "THE SPEED LIMIT IN THE CITY IS 25 MPH."
1001 PRINT "WHAT IS THIS SPEED EXPRESSED IN METERS PER SECOND?"
1010 INPUT F
1020 IF (F-11.176)/11.176 <.03 GOTO 2000
1030 LET Y=Y+1
1040 IF Y>1 GOTO 1070
1050 PRINT "YOUR ANSWER IS NOT EQUAL TO 25 MPH."
1051 PRINT "CHECK YOUR ANSWER AND TRY AGAIN."
1060 GOTO 1010
1070 PRINT "SORRY! 25 MPH IS EQUAL TO 11.176 M/SEC."
1080 LET F=11.176
1090 GOTO 2000
1100 PR. "IF YOU PEDAL HARD YOU MIGHT AVERAGE 10 MPH. CONVERT
THIS TO A SPEED IN METERS PER SECONDAND ENTER IT BELOW."
1110 INPUT F
1120 IF (F-4.4704)/4.4704 <.03  GOTO 2000
1130 LET Y=Y+1
1140 IF Y>1 GOTO 1170
1150 PRINT "YOUR ANSWER IS NOT EQUAL TO 10 MPH."
1151 PRINT "CHECK YOUR ANSWER AND TRY AGAIN."
1160 GOTO 1110
1170 PRINT "NO! 10 MPH IS EQUAL TO 4.4704 METERS PER SECOND."
1180 LET F=4.4704
1190 GOTO2000
```

Listing (cont.)

```
1200 PR. "WHATEVER MEANS ØF TRANSPØRTATIØN YØU USE, IN THE CITY
YØU WILL NØT AVERAGE MØRE THAN 20 MPH. EXPRESS THIS SPEED IN."
1203 PRINT "METERS PER SECØND."
1210 INPUT F
1220 IF (F-8.9408)/8.9408 <.03 GØTØ 2000
1230 LET Y=Y+1
1240 IF Y>1 GØTØ 1270
1250 PRINT "YØUR ANSWER DØES NØT EQUAL 20 MPH."
1251 PRINT "CHECK YØUR ANSWER AND TRY AGAIN."
1260 GØTØ 1210
1270 PRINT "SØRRY! 20 MPH IS EQUAL TØ 8.9408 M/SEC."
1280 LET F=8.9408
1290 GØTØ 2000
2000 PRINT "YØU HAVE JUST CALCULATED WHAT YØUR MAXIMUM"
2001 PRINT "SPEED SHØULD HAVE BEEN . DØ YØU EXCEED"
2002 PRINT "ANY SPEED LIMITS?"
2010 INPUT G$
2020 IF ICØ(G$,"YES",1) GØTØ 2100
2030 IF ICØ(G$,"NØ",1) GØTØ 2200
2040 IF ICØ(G$,"SØME",0) ØR ICØ(G$,"ØFTEN",0) ØR ICØ(G$,"HARDLY",0) GØTØ 23
0                                          0
2050 PRINT "ANSWER YES ØR NØ, DØ NØT PREVARICATE."
2060 LET Y=Y+1
2061 IF Y>2 GØTØ 9999
2070 GØTØ 2010
2100 IF D>F GØTØ2150
2110 PR. "ACCØRDING TØ MY CALCULATIØNS YØU ARE NØT A SPEEDER."
2120 PRINT "MAYBE YØU CAN BEAT THE NEXT LESSØN."
2130 GØTØ 5000
2150 PR. "CØRRECT!!! YØU MØVE TØØ FAST. SLØW DØWN AND LIVE
TØ DØ THE NEXT LESSØN."
2160 GØTØ 5000
2200 IF D>F GØTØ2250
2210 PR. "RIGHT! YØUR DATA INDICATES THAT YØU ARE STEADY, RELIABLE,
HØNEST, ØR LAZY, ØR A LIER. MY PRØGNØSTICATIØN CAN NØT BE
MØRE SPECIFIC UNTIL YØU DØ THE NEXT LESSØN."
2220 GØTØ 5000
2250 PR. "YØU ARE IN ERRØR. YØUR DATA INDICATES THAT YØU MØVE FASTER
THAN WØULD BE EXPECTED FØR YØUR MEANS ØF TRAVEL. GØ AND TRY
THE NEXT LESSØN."
2260 GØTØ 5000
2300 IF D>F GØTØ2350
2310 PR. "YØUR DATA SHØWS THAT YØU MØVE SLØWER THAN EXPECTED,
ADMIT IT. NØW TRY THE NEXT LESSØN."
2320 GØTØ 5000
2350 PR. "YØU ARE A SPEEDER! NØW DØ THE NEXT LESSØN. GØØD DAY."
2360 GØ TØ 10000
5000 PR. "VERY GØØD. GET INSTRUCTIØN YØU NEED FRØM YØUR TEACHER."
5001 GØTØ 10000
9990 PR. "YØUR ANSWER IS NØT UNDERSTØØD."
9999 PR. "SHØW THIS TØ YØUR TEACHER. GØØD DAY."
10000 END
```

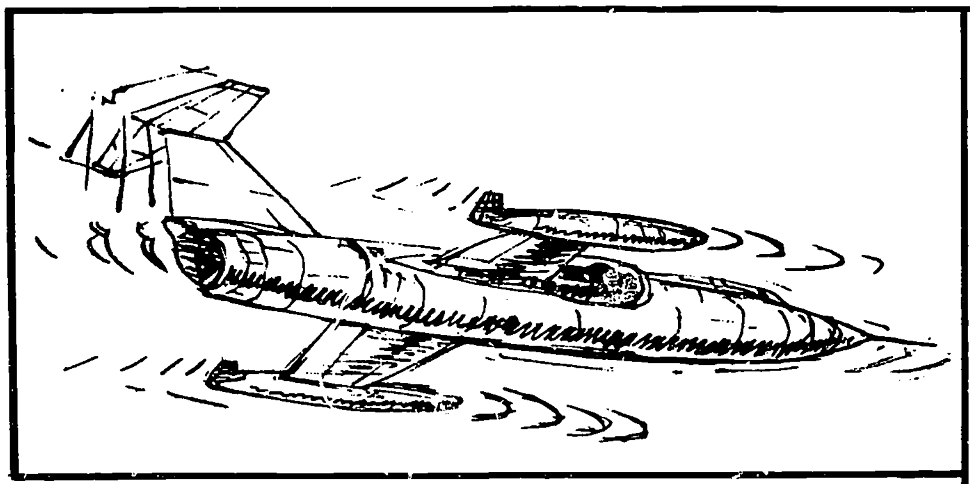
Listing of the /MKS:1/ Program:

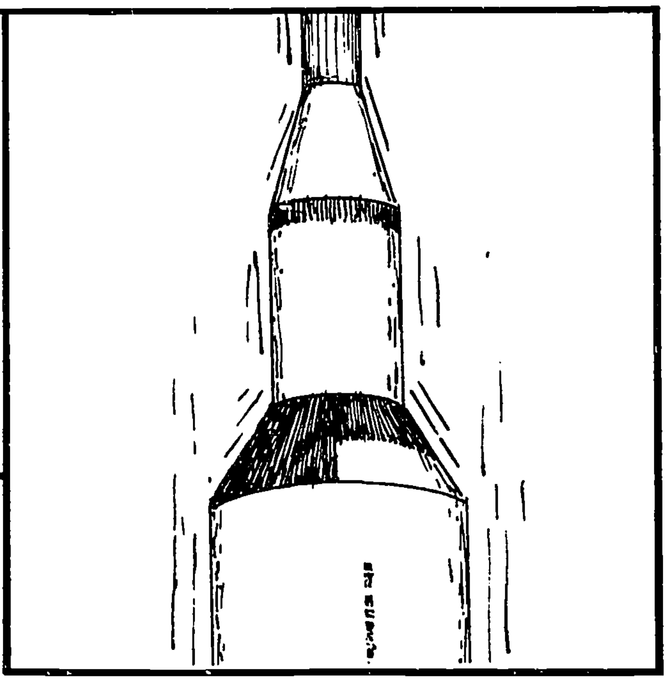
```
 COPY /MKS:1/ TO TPT
               10 PR. "AND SO WE CONTINUE WITH THE MKS SYSTEM OF UNITS."
20 PR. " "
30 PR. "IF A CAR HAS A MASS OF 1000 KILOGRAMS. WHAT IS ITS
WEIGHT IN NEWTONS?"
40 INPUT A1
50 IF A1=9.8E+3 GOTO 200
60 IF ABS(A1-9.8E+3)/9.8E+3<.02 GOTO300
70 PR. "CHECK YOUR WORK AND REENTER YOUR ANSWER."
90IF PASS>1 GOTO 9000
100 GOTO 40
200 PR. "VERY GOOD. "
201 GOSUB 1000 GOTO 210
210 LET Z=B1+B2+B3+B4
220 PR. "NOW TRY ANOTHER ONE. WHAT IS THE WEIGHT OF AN
OBJECT WHICH HAS A MASS OF ":Z:" KILOGRAMS?"
230 INPUT A2
240 IF ABS(A2-Z*9.80)/(Z*9.80)<.0001 GOTO 400
250 IF ABS(A2-Z*9.80)/(Z*9.80)<.02 GOTO 500
260 PR. "NO. CHECK YOUR WORKING AND RETYPE YOUR ANSWER BELOW."
280 IF PASS>2 GOTO 9000
290 GOTO 230
300 PR. "YOU ARE FAIRLY CLOSE. ON THE EARTH'S SURFACE A MASS OF
1000 KILOGRAMS HAS A WEIGHT OF 9800 NEWTONS."
310 GOSUB 1000 GOTO 210
400 PR. "GOOD. SOON YOU'LL BE AN EXPERT."
450 PR. "WOULD YOU LIKE TO TRY ANOTHER CONVERSION OF
MASS TO WEIGHT?"
455 INPUT A3$
460 IF A3$="YES" GOSUB  1000 GOTO 210
470 GOTO1100
500 LET Y=Y+1
510 IF Y=2 GOTO 550
520 PR. "CLOSE, BUT LIKE IN HORSESHOES, THAT IS WORTH SOMETHING."
521 PR. :Z:" KILOGRAMS IS EQUAL TO ":Z*9.80:" NEWTONS."
530 GOTO 450
550 PR. "YOU ARE NOT BEING TOO ACCURATE IN YOUR CALCULATIONS
TRY TO BE A LITTLE MORE CAREFUL. ":Z:" KILOGRAMS IS
EQUAL TO ":Z*9.80:" NEWTONS."
560 GOTO 450
1000 LET B1=NUM(10)*1000
1001 LET B2=NUM(10)*100
1002 LET B3=NUM(10)*10
1003 LET B4=NUM(10)
1004 RETURN
1100 PR. "NOW TRY THIS ONE."
1110 PR. "HOW MANY METERS ARE THERE IN A MILE?"
```

Listing (cont.)

```
1120 INPUT A4
1125 LET D=5280*12*2.54E-2
1130 IF ABS(A4-D)/D<.001 GOTO 1500
1140 PR. "CHECK YOUR ANSWER AND RETYPE IT BELOW."
1150 IF PASS>2 GOTO 9000
1160 GOTO 1120
1500 PR. "O.K. YOU ARE GETTING THE IDEA. GO TO @NBS
AND WRITE A SHORT PROGRAM WHICH WILL CONVERT
EACH OF THE FOLLOWING DISTANCES TO METERS."
1510 FOR I=1 TO 4
1520 GOSUB 1000
1530 LET M(I)=B3+B4
1540 PR. M(I);" MILES."
1550 NEXT I
1560 INPUT A5,A6,A7,A8
1570 LET P=0
1580 LET Q=0
1590 GOSUB 2000
1600 IF P=4 GOTO 1800
1610 IF Q=4 GOTO 1700
 1620 IF P+Q=4 GOTO 1750
1630 GOSUB 2000 GOTO 1600
1700 PR. "CONGRATULATIONS!
SHOW YOUR GREAT PROGRAM TO YOUR TEACHER.
SEE YOU NEXT TIME. GOOD DAY."
1710 STOP
1750 PR. "YOU GOT ";Q;" OF THEM RIGHT, AND
";P;" OF THEM WRONG. CHECK YOUR ANSWERS AND
SHOW THEM TO YOUR TEACHER."
1800 PR." NO.  YOU DIDN'T GET ANY OF THEM CORRECT."
1810 IF PASS>2 GOTO9000
1820 PR. "CHECK THINGS OVER AND TRY AGAIN USING
THE FOLLOWING DISTANCES."
1830 GOTO 1510
2000 FOR I=1 TO 4
2010 IF ABS(A5-M(I)*D)/A5<.01 GOTO 2100
2020 IF ABS(A6-M(I)*D)/A6<.01 GOTO 2120
2030 IF ABS(A7-M(I)*D)/A7<.01 GOTO 2140
2040 IF ABS(A8-M(I)*D)/A8<.01 GOTO 2160
2045 NEXT I
2050 LET P=P+1
2060 GOTO 2210
2100 LET A5=0 GOTO 2200
2120 LET A6=0 GOTO 2200
2140 LET A7=0 GOTO 2200
2160 LET A8=0 GOTO 2200
2200 LET Q=Q+1
2210 RETURN
9000 PR. "YOU NEED SOME HELP. SEE YOUR TEACHER."
9500 PR. "GOOD!"
10000 END
```

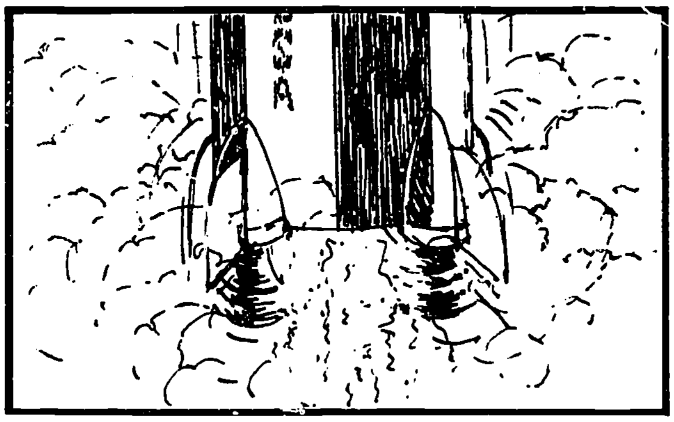
NEWTON'S LAWS OF MOTION

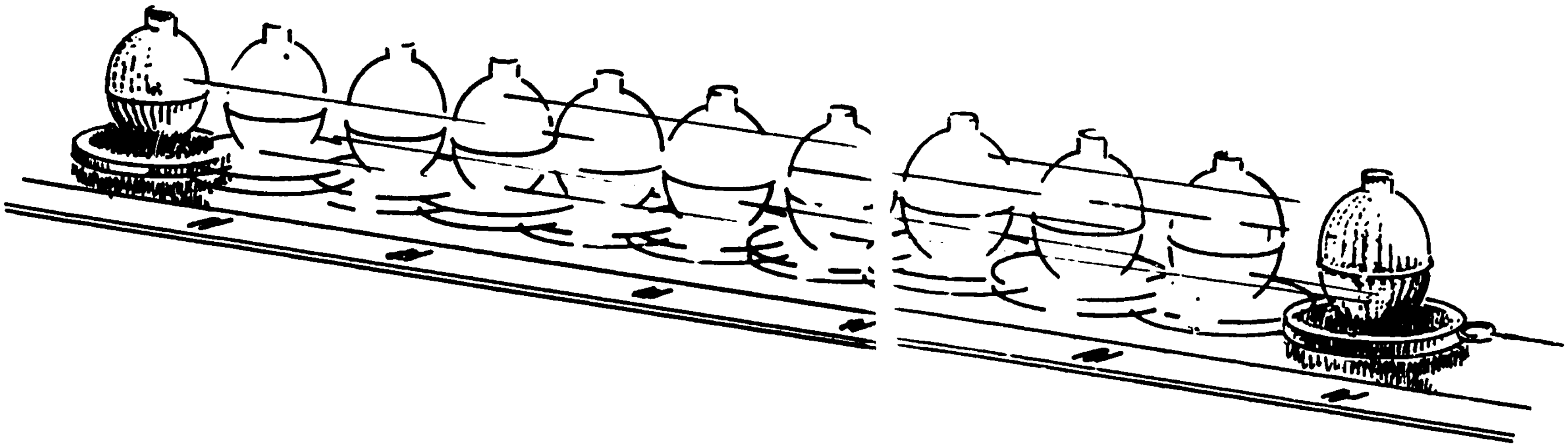




Long ago in sunny England an apple fell off a tree! It just so happened that the law of probability was working against Isaac because he was beaned by it. As a result of this beaning Isaac got a knighthood and everyone had to call him Sir Isaac, except his wife who called him lumpy.

That however is another story and what we want to investigate now are the results of Newton's thinking after the apple and before the knighthood.





In your class you have already learned three so-called laws, namely:

1. A body in motion will remain in the same constant motion, and a body at rest will remain at rest, unless acted upon by some unbalanced external force.

2. When an unbalanced external force acts on a body, the body experiences an acceleration which is equal to the ratio of the force to the mass of the body ($\vec{F} = m\vec{a}$).

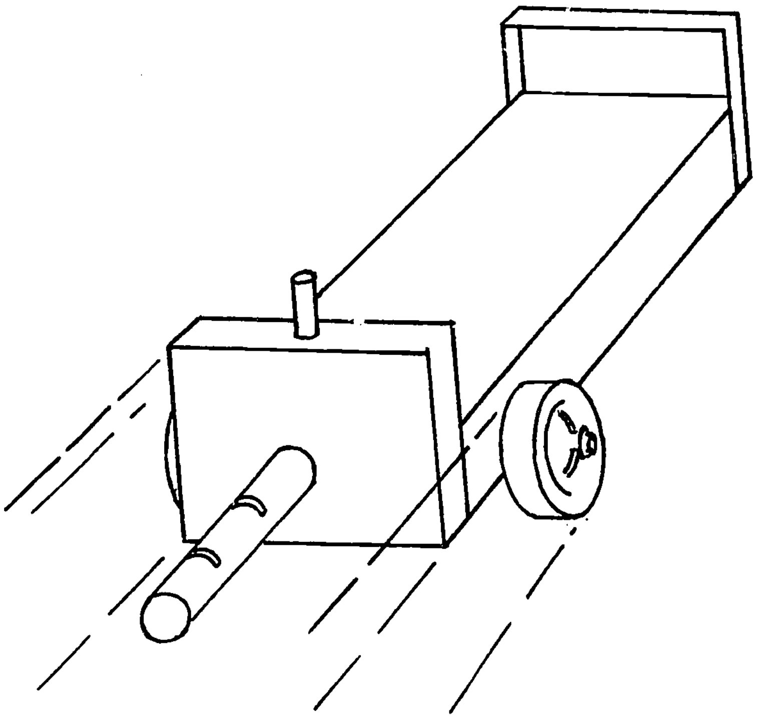
3. For every action force there is an equal and opposite reaction force.

Although all three laws above are due to Newton, the second law is the one we most often employ directly in calculation. The simplest application of this law occurs when a single force acts. Problem 1 on the next page is a worked out example of such a situation. You should imitate if you are not experienced in the use of computers. Problems 1.5, 2, and 3 also deal with single forces, since they all assume that the force of friction is negligible. Ask yourself which other problems in this module neglect friction as you move ahead.

Notice that laws you learned previously (such as V = V0 + A * T) are combined with Newton's second law in solving some of the problems. You will also have to use the previously learned principles of vector addition when you work with problems that involve several forces.

NEWTON'S LAWS

We will illustrate the application of these ideas with several problems, each of which you should solve by using the computer.



EXAMPLE--Problem 1

If a cart, mass 3.84 kg, is moving along a horizontal table at 2.05 m/sec, when a force of 1.83 nts is exerted on it for 0.77 sec. in the same direction as it is moving. (a) What will be the acceleration of the cart? (b) What will be the final velocity of the cart?

To solve part (a), it is necessary to apply Newton's second law of motion, which states that the acceleration of a mass is equal to the ratio of the applied force to the mass.

In the form of a formula this becomes:

A=F/M

It is therefore necessary to do several things:

(a)
(1) Give a value of 1.83 to a variable F
(2) Give a value of 3.84 to a variable M
(3) Calculate the value of the ratio of the value given to F to the value given to M
(4) Give the value calculated in (3) to a variable A
(5) Write the value given to A as the acceleration of the mass.

For part (b) a similar process has to take place in order to solve for the relationship between final velocity, initial velocity acceleration, and time. When the acceleration is constant this can be expressed by the following equation:

V = V0 + A * T

The steps which must be followed are:

(b)
- (1) Give a value of 2.05 to a variable V0
- (2) Give a value of 0.77 to a variable T
- (3) Retain the value given to A in part (a)
- (4) Multiply the value given to A by the value given to T.
- (5) Add the value given to V0 to the product determined in step (4) and give this sum as the value of a variable V.
- (6) Write the value given to V as the final velocity of the mass.

These two sets of procedures will provide the required answers for Example 1.

In order to solve Example 1 on the computer it is necessary to convert each step of the algorithm to a language that the computer can handle. The five[*] steps of part (a) then become:

```
     (1)          10 LET F= 1.83
     (2)          20 LET M= 3.84
(a)  (3)  &  (4)  30 LET A= F/M
     (5)          40 PRINT A
     (6)          RUN
```

The numbers 10, 20, etc. make it possible to save this work as a program which can be run for several problems.

To make the program suitable for more problems it may be better to combine steps (1) and (2) in a single statement, which asks you to type in values for F and M. This makes part (a) of your program appear as follows:

```
10 INPUT F,M
20 LET A=F/M
30 PRINT "A=":A
```

Part (b) can then be added on to the same program as follows:

```
40 INPUT V0,T
50 LET V=V0+A*T
60 PRINT "V(METERS/SEC)=":V
```

---

[*] Part (a) could also be solved by using the direct statement:
PR. "A=":1.83/3.84
As you read on, ask yourself what disadvantages this simple approach can have.

By giving the computer the command RUN it will perform all indicated calculations and print (depending how you input data):

```
either  >RUN                      or  >RUN
        ? 1.83                        ? 1.83  3.84
        MORE ? 3.84                   A= 0.47656
        A= 0.47656                    ? 2.05  0.77
        ? 2.05                        V= 2.41695
        MORE ? 0.77
        V= 2.41695
```

Problem 1.5

Use the above program to fill in the following table which studies acceleration for 3 cars. HINT: Add the statement

```
70 PR. "V(MI/HR)=":V*(.00062)*3600
```

Assume V_0= 0 m/sec

CAR	MASS (KG)	FORCE (NT)	ACCEL. (M/SEC^2)	TIME (SEC)	FINAL VELOCITY	
					METERS/SEC	MILES/HR
Compact	570	985		3		
	570	985		10		
Medium	1100	3800		3		
	1100	3800		10		
Super GT	1690	7120		3		
	1690	7120		10		

It has been well established that the acceleration of a falling body close to the earth is 9.8 m/sec^2 if air friction is negligible, which is usually the case for compact objects moving at slow speeds.

Problem 2 (EASY--YOU CAN USE DIRECT MODE)

Calculate the gravitational force on a mass of 5.19 kg. which, when allowed to fall, has an acceleration of 9.80 m/sec^2. This gravitational force is the weight of the object (neglect friction).

Problem 3

A car at rest at a traffic light weighs 5.63x10^3 nts.

(a) What is the mass of the car (use direct mode)?

When the light changes to green it accelerates at 3.18 m/sec^2.

(b) If friction is negligible what must be the force between the rear wheels and the road?

(c) What is the final velocity of the car when it has moved 30 m?

If some other force in addition to the gravitational force acts on a falling body its acceleration will not be 9.8 m/sec.^{2} Modify the program you used in Example 3 to solve Example 4.

Problem 4

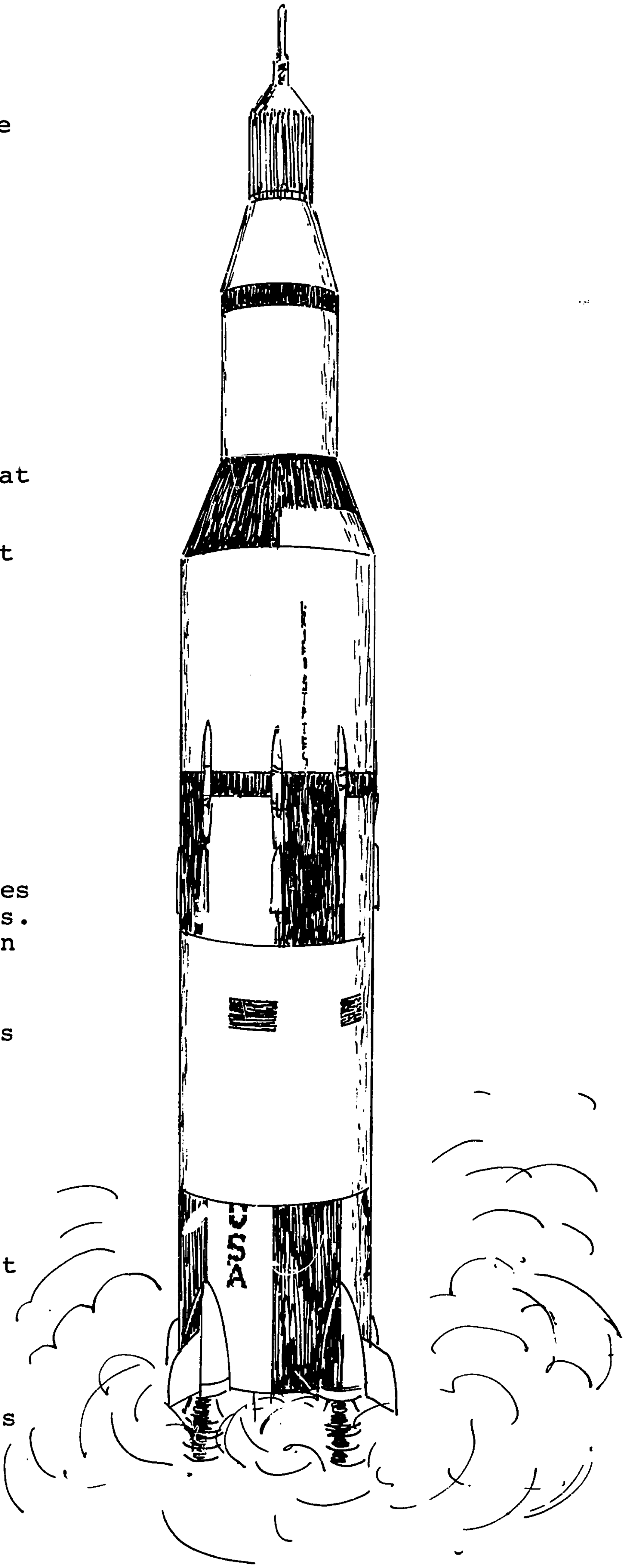
A model airplane, mass 0.55 kg., has an engine which exerts a force of 4.26 nts. on it. What will be the acceleration of the plane when it goes into a vertical power dive. Again neglect friction.

A similar problem is encountered with rockets. Use the same program format as in Example 4 to solve Example 5.

Problem 5

The Saturn V rocket has a mass of 3.18×10^6 kg. The thrust of its first stage engines is quoted as being 7.5×10^6 lbs. What is the initial acceleration of the rocket as it blasts off for the moon?

In these first five examples we have only considered motion in a straight line, and worked with constant forces. This could be extended to include more forces, for example friction which is sometimes constant and sometimes dependent on the velocity of the moving object. In the latter case the problem becomes complicated and requires



a more sophisticated mathematical approach.

The problem becomes more complicated and yet still manageable when there is more than one force with the forces not acting in the same straight line.

Problem 6

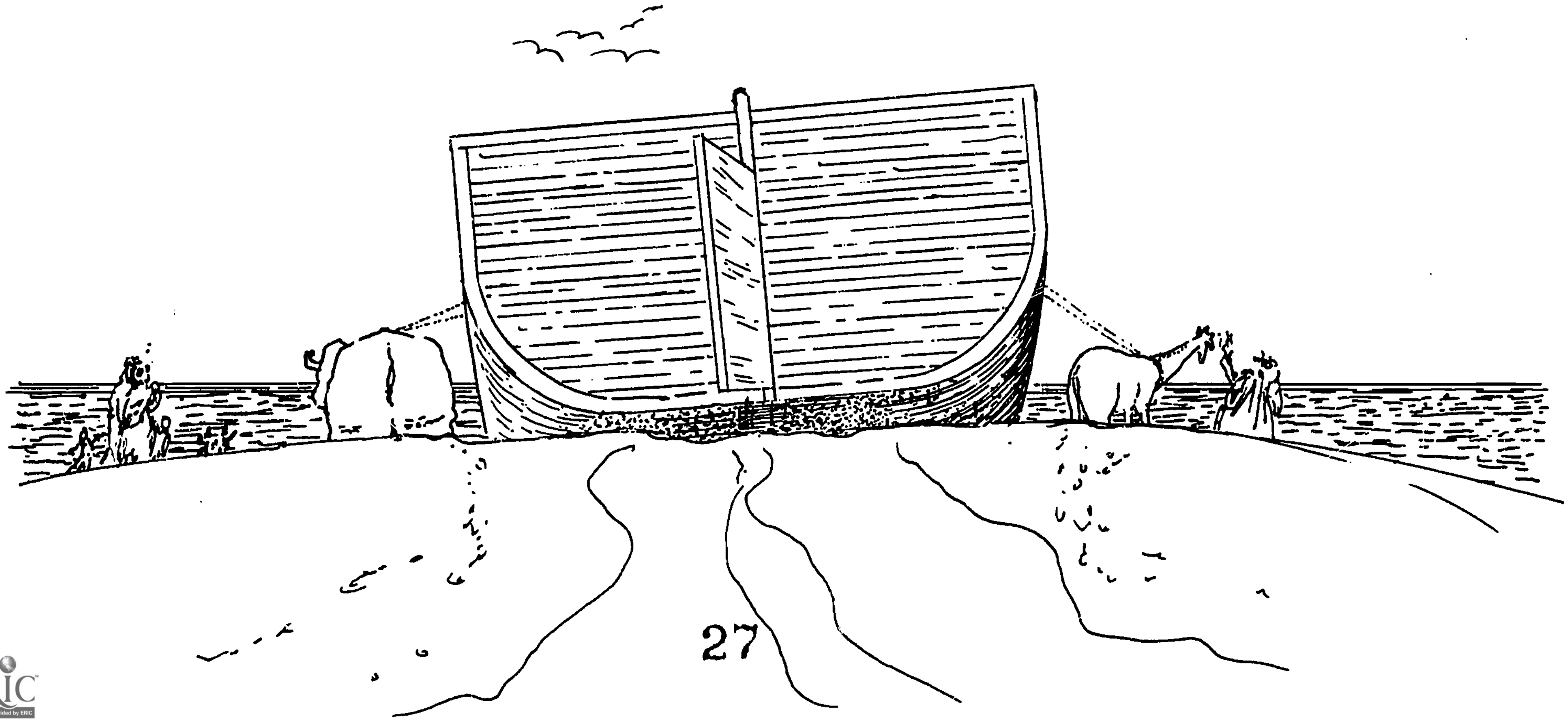
Two equal forces at right angles to each other, each of magnitude 5.79 nts, act on a mass of 1.81 kgs. What will be the acceleration of the mass?

This problem requires that you modify your basic program to include the addition of two vectors not in a straight line.

If your program is general enough, you will not have written it so that only vectors at right angles may be added, and you can use it to solve the next problem.

Problem 7

An elephant and a giraffe teamed up to pull Noah's ark off a sand bank. The elephant exerted a force 6.02×10^3 nts. in a direction 025° while the giraffe exerted a force of 1.17×10^3 nts. in the direction of 085° and moved off the sand bank with an acceleration of 0.17 m/sec.^{2}. What force did the sand bank exert on the ark while it was moving? Mass of ark = 9.72×10^3 kg.



We conclude this module with a challenge problem. If you would like to first interact with a program that someone else wrote to solve this problem do the following:

```
-NBS
>RUN 166JS  /LANDING/
```

Problem 8

The aircraft arrestor system shown in the figure below is used to stop military aircraft in the event that they overshoot the normal runway. Write a program that accepts as input the mass and landing velocity of various aircraft, and allows the user to determine which combinations of cable "braking force" and runway "runout" distances will safely handle these aircraft.

If you wish to see a listing of the program /LANDING/, ask your teacher for a copy. He can also supply data on typical civilian and military aircraft.