ASTRONOMY

... don't know ?

You're wrong, go back , don't coll... $200 and try it again.

?

Ego frame 1.
This book was programmed by ______________________.

William E. Smythe .

Ego frame 2.
This book was researched by ______________________.

G. Christopher Essex .

Ego frame 3.
Cover, diagrams and production by ______________.

Eric J. Clinton .

Ego frame 4.
The Greatest responsibility for this book rests on the shoulders of

(a) Eric J. Clinton see frame 5A
(b) G. Chris Essex see frame 5B
(c) Bill E. Smythe see frame 5C

Ego frame 5 (A,B,C).
Your answer is Incorrect.
Don't bother to go back to Ego frame 4. to correct your answer because all the others are wrong as well. However we would suggest that you proceed to frame 1. of this book after reading the introduction. Thankyou.

frame 2002.
Do you feel ASTROLOGY is more important to Science than astronomy ?

(a) I sure do. see frame 0.36°
(b) no comment ! see frame 5:28
(c) It's out of the question? see ...
(d) Only when it snows in Tanzania... see frame 47%

frame 0.36° Your answer, I sure do.
Are you out of your mind? Did you ever consider ...

"A ... PROGRAMMED LEARNING APPROACH"..

....

A S T R O N O M Y :

A

PROGRAMMED LEARNING

A P P R O A C H

....

A C K N O W L E D G M E N T S

We would like to thank the following groups for their help in the production of this book:

LONDON BOARD OF EDUCATION

MONTCALM SECONDARY SCHOOL, LONDON, ONT.

OPPORTUNITIES FOR YOUTH

ROYAL ASTRONOMICAL SOCIETY OF CANADA

First Printing , August, 1973 , London, Ontario, Canada.

I watched, with awe,
Man's celestial
Exploration.
Life before
Was nothing more
Than meagre terrestrial
Occupation.

AN INTRODUCTION TO PROJECT ZUBENELGENUBI

49h2m -15°52' are the co-ordinates of the star Alpha Librae, found in the southern constellation of Libra, at a distance of approximately 66 light years. Centuries ago this star was named ZUBENELGENUBI, from an Arabian text; whereas, during the summer months of 1973, a group of amateur astronomers decided to use this unusual name as the title of an astronomy-oriented Opportunities For Youth (O. F. Y.) project. The project's original conception had little in common with projects that had been attempted in the past, and thus we were essentially an experimental project. We decided, in lieu of providing a direct benefit to a small number of people in one specific area of our community, as other projects had planned, that our group of three would provide an astronomy oriented, community benefitting program aimed at everyone interested in learning more about Modern Astronomy and related topics through discussion groups and actual visual observations at public star nights. Our project was designed to provide a type of general introduction to enable the public to understand more about the neglected aspects of this science, and encourage them to take part in the fecinating pursuit of amateur astronomy.

We chose the name of the project partially because it was interesting and catchy sounding; and meanwhile we explored the idea that our motto should reflect one of the aims of our endeavour. Our motto: "Have Telescope, Will Travel".

We commenced with our project early in May with the first of a three part plan. We visited a large number of students attending various Elementary and Separate Schools situated in London, and gave an illustrated talk on the Universe. The second and third parts of the project proved to be very time consuming. The book which you are now reading is a product of our hard work and effort for the remaining summer months. The third phase of the project, as I have already mentioned, was the nightly Star Nights held at various parks throughout the city.

Our hope is that Zubenelgenubi will be remembered not only as a double star in the night sky with an apparent magnitude (see page 73) of 2.76, but as a successful summer project whose final aim was not to die out as simply a memory, but to exist years in the future in the form of this new source book of knowledge.

Eric Clinton
Amateur Astronomer

It is indeed a feeble light that reaches us from the starry sky. But what would human thought have achieved if we could not see the stars ....?

JEAN PERRIN

AN INTRODUCTION TO ASTRONOMY

Go out alone in the small hours of the morning, away from the harsh lights of the city. Let the soothing darkness envelop your soul. Then stand quietly; look at the horizon, and listen. You hear silence; silence that is only marginally violated by the distant sounds of leaves whispering in the cool breeze that dances pleasantly across your face. You smell the freshness of the unused air of a day yet to begin. However do not concern yourself with the day, as the Sun will not rise to banish the stars from the sky for several hours, and the night holds more joys to be experienced.

Turn your eyes now, onto the vault of the heavens above: in one short turn of the head you have gazed upon the Universe. It is filled with myriads of stars, randomly placed, and all intensely beautiful. You reach out as if to touch their glittering surfaces, even though you know these points of radiance are further away than you could travel in a hundred lifetimes. The only barrier between you and them is the ultimate barrier: space. The incredible numbers, the unimaginable distances and the alien beauty all bring forth the ancient fear of the unknown. You begin to feel alone and afraid. You would run because of the fear, but you remain frozen in your upward stare; there is no place to run to, from the Universe!

Rationality returns; the fear ebbs and changes to humility, and wonder. You are completely filled with awe and curiosity. You now suffer from a painful, but wonderful affliction, that makes one want to know everything, even though one understands that one never will. The first signs of dawn are showing themselves in the east; you shiver as the cool breeze has become a cold wind. The twinkling stars overhead have but little time before the comming Sun outshines them, into oblivion.

The last few twinkling stars fade away with the rising of the Sun, as you slowly return to the "reality" of daily life. In the future you will return to this place, to stand quietly at peace, to remember, and to be happy, while gazing upon the Universe; but for now, you are mourning the loss of your companions: the stars.

The stars will be your faithful companions for the rest of your life; you will get to know them well.

The night sky has a bewitching effect on those who would take the time to look at it, and think about it. This book is dedicated to those who do look and think, to those who appreciate the beauty of the night sky: the "afflicted". By means of the preceeding paragraphs, I have endeavoured to give the reader an answer to the question: "Why Astronomy?".

In this book we deal not only with Astronomy, but with relevant basic Physics and Mathematics; it is a good conceptual representation of the Universe for the interested beginner. Many of the concepts presented may be considered, by some, to be too complex for the beginner. However complexities are but large aggregations of simplicities. Thus, if taken step by step, as this book presents the material, complexities tend not to be so complex. Astronomy is a more complex subject than is presented here; however we believe that the beginner's astronomical knowledge will be greatly increased by the working through of this book.

In getting to know your Universe, I would suggest the practical as well as the conceptual approach; get to know the stars by name. There are many good books on the simple but enjoyable topic of constellations. When the stars are known conceptually, as well as practically, you will be a stranger to your Universe no longer.

Chris Essex
Astronomy Student

AN INTRODUCTION TO PROGRAMMED LEARNING

Programmed learning is presently one of the most neglected tools available to modern educators. Some of the reason for this neglect seems to be related to a misunderstanding, on the part of many educators, regarding the techniques and goals of programmed learning. It is appropriate, then, to include a discussion of some of these factors in the introduction to a book of this kind. Hopefully, this section, along with the section entitled "How to use this Book" will help the user derive the full benefit from the materials here presented.

Programmed learning has its origins in a rather well studied phenomenon in Psychology known as Operant Conditioning. This phenomenon involves a particular set of relationships that exist between the two variables stimulus and response. A stimulus can be defined as any environmental event to which a particular organism has the ability to respond, and that can be measured. It is clear that the status of a particular environmental event as a "stimulus" varies with the organism, in that the structure of receptor organs may differ from species to species. For example, sounds of frequencies in excess of 20,000 cycles per second may be regarded as stimuli, if the organism in question is a dog, but not if the organism is a human being. A response can be similarly defined as any single measurable activity that an organism produces. It is rather important to realize that any particular "response" is usually an aggregate of a series of smaller response units. For example, a response like "bar pressing" observed for a rat placed in an experimental chamber known as a "Skinner Box", might be further subdivided into the responses: "approaching the bar"; "rearing up on hind legs"; "touching the bar with fore-paws"; and "exerting a force downward on the bar". On yet a more microscopic level, this same response might be considered in terms of an even more complicated series of individual responses of nerve cells. Hence, the beginning and ending of one "response" are always arbitrary in Psychology, and are usually defined in a way that is appropriate to the kind of research work done. Mentalistic phenomena popularly associated with Psychology, such as "thoughts" and "feelings" are only quantifiable as responses when they produce reliable physical changes that can be measured. Current research methodology is extremely weak in this area. In fact, it is difficult to talk about such things, at present, in anything but a purely subjective way.

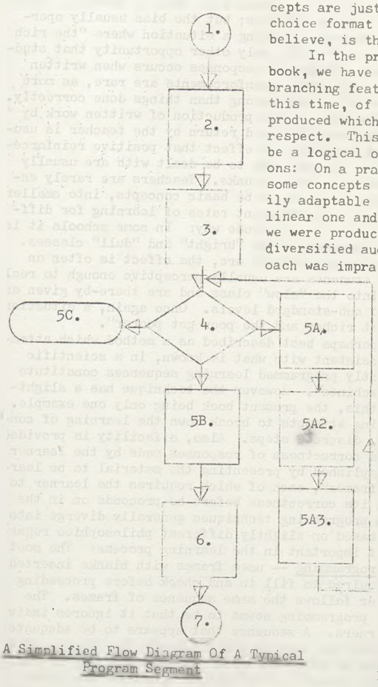
In operant conditioning, these two variables are considered in the temporal order: Response, followed by Stimulus. In other words, operant conditioning considers the case where a response is emitted which is followed, in a consistant manner, by some stimulus. Both variables affect eachother in a reciprocal fashion: The way in which the response affects the stimulus is determined by properties of the immediate environment; whereas the way in which the stimulus affects the response is determined by properties of the organism. It is the latter causal connection that will concern us here. Briefly, there are three ways in which a stimulus can affect a response: The stimulus can increase the probability that the response will be emitted in the future; it can decrease this probability; or it can leave it unchanged (in which case the stimulus is not really "affecting" the response at all). The term "reinforcement" was originated for the purpose of describing these relationships. For instance, when a stimulus increases the probability of some response, we say that the response has been positively reinforced by the stimulus, or that the stimulus has acted as a positive reinforcement. Likewise, a stimulus that acts to decrease the probability of some response is known as a negative reinforcement. The layman's way of visualizing such concepts is to regard positive and negative reinforcement as being analogous to reward and punishment respectively. This kind of analogy is very useful up to a point. For example, if a rat in a Skinner box presses a bar and the resulting stimulus is the presentation of food in a food magazine, the probability of the response called "bar pressing" will increase. If, instead, the resulting stimulus is a painful electric shock, administered through a grid on the floor of the Skinner box, the probability of the "bar pressing" response will decrease. It is clear that the experimental animal has been "rewarded" and "punished" in these instances. In other instances, the analogy breaks down. For example, several Psychologists have remarked that prisons tend to positively reinforce criminal behaviour. This is usually a very objective statement. What it means is that a prison term for some individual tends to increase the probability that he will perform more criminal acts after he is released. Here it is clear, in a statistical way, that the response we call "criminal behaviour" has been positively reinforced, but it is not clear that this behaviour has been "rewarded". The analogy for negative reinforcement and punishment breaks down in a similar way. Although we shall not elaborate on this point, research in the field of operant conditioning has shown that positive reinforcement is, all things considered, a more efficient way to shape behaviour than is negative reinforcement. This is an important fact to keep in mind, as "behaviour shaping" is at the centre of the activity that we call "learning".

In Psychology, learning is usually defined as any modification of behaviour that occurs as a consequence of experience. This suggests a somewhat more universal use for the term than that which is implied in ordinary conversation. For the purposes of the present discussion, we will be concerned with learning mostly as it applies to formal education. That is, we are going to consider the kind of learning that takes place in institutions whose purpose it is to increase the adaptability of individuals to future occupational situations. Pure and applied research in this area has suggested what might be enumerated as four general principles to facilitate efficient learning: (1) The amount of positive reinforcement administered during learning should be maximized; (2) This positive reinforcement should be immediate; that is, any time lag between the emission of a learned behaviour and the presentation of a positive reinforcement should be minimized; (3) Complex concepts should be broken down into smaller units and learned in a step-by-step progression, where positive reinforcement is administered for successive approximations of the final concept; (4) The rate of learning for an individual should be allowed to vary according to the extent of any relevant abilities and prior knowledge which he may possess. At this point, it should be remarked that the most effective positive reinforcement for the type of learning we are considering is simply the knowledge, on the part of the student, that he has responded correctly. Elaborate token economies of the sort that allow students special privileges for early completion of assignments etc. are usually quite unnecessary, even at the lower educational levels.

Even casual observation is sufficient to suggest that none of the above criteria is very well met by conventional educational systems. These systems, for the most part, have been refinements of older and more exploitive systems based on aversive control through the use of negative reinforcement (eg. --the birch rod). The result of the liberalization of these older systems was to remove most of the aversive control and leave, in its place, almost no control at all. Certainly the feasability of control through positive reinforcement has been ignored. The reason for this, perhaps, is that, not only are most teachers unaware that the efficiency of this sort of control has been empirically demonstrated; but control through positive reinforcement is a less visable and therefore less intuitively obvious form of control than is the aversive kind. The result of this [redacted] is that control, when applied at all in the modern classroom, is mildly aversive in nature. Threats of poor grades,detentions, extra assignments and "visits" with the principal serve as examples of this.

When positive reinforcement occurs at all, in conventional educational situations, it is quite sporadic. In the traditional teacher-centered situation, where concepts are being introduced through a question and answer approach, the probability that any one student in an average sized classroom will be called upon is about 1/30. What this means is that, if the teacher calls upon students at a rate of two per minute, the limit for the number of positive reinforcements that can be received in a one hour session by a particular student, will be something less than 4, usually. This number will, of course, vary between students; but the bias usually operates in favour of the better student, creating a situation where "the rich get richer and the poor get poorer". The only other opportunity that students have to receive feedback on their own responses occurs when written work is evaluated. Once again, positive reinforcements are rare, as more attention is usually given to things done wrong than things done correctly. Furthermore, the great time lag between the production of written work by the student and its subsequent correction and return by the teacher is usually sufficient to significantly reduce any effect that positive reinforcement might have created. Also, the concepts to be dealt with are usually presented, learned and evaluated in large chunks. Teachers are rarely encouraged to break up what seem, to them, to be basic concepts, into smaller units. Finally, matters relating to different rates of learning for different students are handled only in a very crude way: In some schools it is still traditional to divide students up into "bright" and "dull" classes. As well-intentioned as some of these efforts are, the effect is often an unfortunate one: The "dull" students are usually perceptive enough to realize that they have been put into the "slow" class and are there-by given an added incentive to perform at sub-standard levels. Once again, a situation is created where "the rich get richer and the poor get poorer".

Programmed learning is perhaps best described as a method which attempts to make teaching more consistant with what is known, in a scientific way, about learning. Frequently programmed learning sequences constitute the software for "teaching machines". However the technique has a slightly broader application than this, the present book being only one example. In general, programmed learning attempts to break down the learning of concepts into a series of small, discrete steps. Also, a facility is provided for immediate feedback on the correctness of responses made by the learner. These goals are usually accomplished by presenting the material to be learned in a series of written "frames", each of which requires the learner to make some response and check its correctness before he proceeds on in the program. Beyond this point, programming techniques generally diverge into two different schools, each based on slightly different philosophies regarding which variables are most important in the learning process: The most popular of these -- Linear Programming -- uses frames with blanks inserted in them which the user is required to fill in and check before proceeding on in the program. Every user follows the same sequence of frames. The chief disadvantage of linear programming seems to be that it ignores individual differences amoung learners. A sequence that appears to be adequate for some learners may be either too easy or too difficult for others. This difficulty is usually overcome by producing programs only for very specific age and ability levels. This, however, is a tedious process. The other kind of programming -- Branching Programming --attempts to direct users to different sequences of frames according to the extent of their comprehension of material already covered. This is done by incorperating a multiple choice type question into every frame, the answer to which determines where the user then proceeds, in the program. The criticism usually applied to branching programming is that, as its strength depends on several users answering incorrectly, it shapes behaviour, in part, by negative reinforcement. This point is, perhaps, not very well taken, as it relies on the assumption that the consequenses of answering incorrectly are always negatively reinforcing. Though this is certainly the case in conventional educational systems, it need not be the case in systems based on programmed learning. Another disadvantage of branching programming is that some concepts are just not adaptable to a multiple choice format of questioning. This, we believe, is the more serious objection.



A Simplified Flow Diagram Of A Typical Program Segment

In the program which appears in this book, we have incorporated both linear and branching features. We are not aware, at this time, of any programs that have been produced which are similar to our's in this respect. This method, however, seemed to be a logical one, to us, for several reasons: On a practical level, we found that some concepts in Astronomy were more readily adaptable to a branching format than a linear one and vice-versa. Certainly, as we were producing the book for a rather diversified audience, a pure linear approach was impractical. A pure branching format, on the other hand, was considered to be too rigid for our purposes. On a theoretical level, we concluded that a combination of both formats would help to reduce the disadvantages present in either one used by itself. The basic structure of our program is linear, with branching frames embeded in it. Frequently associated with branching frames is a feature that we call a "corrective linear sub-program", designed to deal with incorrect answers. The presence of branching frames makes this basically linear program more adaptable to different ability levels; while the presence of corrective sub-programs provides positive reinforcement for users who have made incorrect responses, and therefore overcomes one of the disadvantages of a pure branching format. A typical segment of our program is illustrated in the accompanying flow diagram: Regions 2, 3, 5B, and 6 represent linear frames which are part of the main body of the program; region 4 represents a branching frame; and regions 5A, 5A2, and 5A3 represent parts of a corrective sub-program. Other features of this segment are regions 1 and 7 which are connectors that link this segment to others in the program, and region 5C, which represents an abort frame: This is simply a feature that momentarily terminates the user's progress in the program,if it appears that he has become exhausted or bored.

Other features of this program will indicate, to those knowledgable in this area, that we have not followed traditional methods of programming very closely: We have, for example, made occaisional use of lengthy linear frames which are usually discouraged in programmed learning. This has been done mostly for the purpose of breaking the monotony of our format by inserting facts that the user is not specifically requested to recall. We have also taken advantage of the fact that we were producing a book and not a program for a teaching machine, by encouraging the user to go back to previous frames to retrieve various pieces of information that he may have forgotten. Finally, we have (though I hesitate to use the word) "invented" what we refer to as "data frames" for the purpose of providing pieces of numerical information that are usefull at various points in the program. It is our hope that these features, taken together, will make the book somewhat more "readable" than it would otherwise be.

The last thing that should be pointed out, in this introduction, is that studies of the merits of programmed learning systems as compared to conventional systems, have, so far, yielded conflicting results. This suggests that proper controls have not been used in these investigations. Certainly, further studies of this matter are required. Even in the absence of this sort of evidence, however, there are several factors that suggest the feasability of an educational system based on programmed learning: One of these is the problem of evaluation. In conventional systems, evaluations are usually so imprecise, that they can only determine student progress in a very crude way. If a mark like 60%, for example, indicates that a student has learned 60% of the work, there is nothing to say which 60% it is that he knows. When a "pass -- fail" analysis is applied to this mark, one of two decisions is then made: Either the student is allowed to proceed to the next level of difficulty in the subject matter, or his progress is set back one year. Which of these options is pursued is determined by an arbitrary "cut-off" level which, for the sake of argument, is called a "passing grade". In primary and secondary levels of education, cut-off levels are typically quite low. This creates a certain amount of redundancy in the teaching process due to the excessive amounts of "review" that are made necessary from year to year. At the university level, this problem is usually dealt with by raising cut-off levels substantially. This is done, however, at the expense of dissapointing a number of worthwhile candidates who find themselves the victims of "bad fortune". In programmed learning, evaluations are a good deal more precise than this. The cumulative record that the student produces while working through programmed materials is quite sufficient to indicate, in a concise way, where his strengths and weaknesses lie. Furthermore, in highly efficient programs, the mere position of the student in the sequence can serve to adequately indicate his level of mastery of the subject matter.

If, as some people would like to claim, programmed learning systems are proven to be no more effective than conventional systems, then only one of two possible conclusions can be made: Either the scientific assumptions on which programmed learning is based, are incorrect (a possibility which, at this point, must be considered unlikely), or more work has to be done to refine this technique for use in practical situations. In either case, the conclusion is an important one. Hopefully, the present book will, in some way, demonstrate the effectiveness of this technique.

Bill Smythe
Psychology Student

HOW TO USE THIS BOOK

This is a programmed book. To derive the full benefit from its contents, you should be prepared to work through it. It is not "read" in the way that most books you are familiar with are.

The material in this book is organized into a series of "frames" which are marked off by horizontal lines and numbered consecutively throughout. Each frame will require you to make some response. Usually you will be asked to fill in a blank with some appropriate word, phrase or number. The method that we recommend for working through frames such as this is to take a piece of paper or cardboard and cover up all the material below the frame you are considering. When you have filled in the blank in question with what you believe to be the appropriate response, then you may slide the paper down the page to reveal the correct answer to the blank and then the next frame. Answers appear in capital letters directly below the lines which are used to mark off frames. Another kind of frame that you will come across has a multiple choice question incorporated into it. Here you simply choose the option that you believe to be the most appropriate, then proceed to the frame refered to alongside the option you have chosen. To find this frame it is a good idea to cover up all the material to the right of the frame numbers and then proceed until you find the appropriate number. When you have done this, proceed with the material in that frame, covering up any material which may appear either above or below it. You may want to keep a record of all your responses. This can be done by writing them down on a pad of paper along with the accompanying frame numbers. This same pad of paper might also be used to calculate the correct answers to numerical problems presented in the book.

For users whose acquaintance with the subject of Astronomy has not been great, most of the concepts presented in this book will be quite new. A more mathematically-oriented topic that appears in this book might, however, be familiar to several users: this is the topic Scientific Notation. For users who believe themselves to be knowledgable on this topic, you may save yourself some time, as you work through the program if, when you reach frame 195, you immediately proceed to frames 265, 274 and 444. If you are able to do each of the questions presented in these frames correctly, than you may proceed to frame 277 and continue from there.

Finally, it should be pointed out that programmed learning, though enjoyable, is not necessarily "easy". You should be prepared to consider the material presented here, in some detail. However, things like incorrect answers should not cause you any anxiety: In this program, you sometimes stand to learn quite a bit by answering incorrectly. To reduce the probability that you will answer incorrectly, however, you would be well advised to read the material presented very carefully and to, when "stuck" on a question, review material in previous frames to help you out.

We hope that you are successful in this learning experience.

1. In the first segment of this program we are going to teach you something about Astronomical distances. To talk about these distances in terms of units you are familiar with (miles, kilometers) would involve numbers that are much too large. Obviously, then, these units are much too (large, small) ______ to be conveniant for Astronomers.

SMALL

2. For example, the distance from our solar system to the next nearest star is 25,200,000,000,000 miles. This number is much too (large/small) ______ to be very conveniant. Hence the unit "miles" is too (large/small) ______ for our purposes.

LARGE; SMALL

3. Some units that Astronomers use for distance are based on the speed of light. To understand these it is necessary for you to realize that light has a speed. Light travels at a rate of 186,000 miles per second. This means that, in one second, light would travel a distance of (how many?) ______________ miles.

186,000

4. In one minute, light would travel 186,000 X ___ miles.

60

5. In one hour, light would travel 186,000 X 60 X ___ miles.

60

6. In one day, light would travel 186,000X ___ X ___ X ___ miles.

60; 60; 24

7. In one year, light would travel 186,000 X ______________ miles (use multiplication signs).

60 X 60 X 24 X 365

8. This means that ____________________ miles is the distance that light travels in one year (use a mathematical expression).

186,000 X 60 X 60 X 24 X 365

9. To understand how units for distance are derived out of a speed, you should know how the concepts of distance, time, and speed relate to each other. If 'v' represents speed, 'd' represents distance, and 't' represents time, then which of the following is correct?

(a) v = t/d   see frame 10A
(b) v = d/t   see frame 10B
(c) v = d X t   see frame 10C

10 . Your answer: v = t/d
is incorrect.
You seem to have it backwards. Suppose you were to travel from London to Toronto (a distance of 120 miles) in 2 hours. This would mean that, on the average, you would have travelled at a speed of 60 miles per hour*.
60(v) is 120(d) divided by ____(t).

2

10A2. So then, speed(v) is given by ____ divided by ____ and the expression v= d/t is (correct/incorrect) ____.

DISTANCE; TIME; CORRECT

10A3. Now go back to frame 9 and choose the correct answer.

10B. Your answer: v = d/t
is correct.
Your are to be congratulated on your perceptiveness. Re-arranging this expression to derive an expression for distance would give us which of the following?

(a) d = v X t see frame 11A
(b) d = v/t see frame 11B
(c) d = t/v see frame 11C

10C. Your answer: v = d X t
is incorrect.
To derive the correct answer, let us suppose that we are on an immaginary trip from London to Toronto (a distance of 120 miles) that takes us 2 hours to complete. This means that, on the average, we would have been travelling at a speed of (how many?) ____ miles per hour.

60

10C2. 60(v) is 120(d) divided by ____ (t).

---

2 Proceed now to frame 10A2.

11A. Your answer: d = v X t
is correct.
Recall that ________________ (expression)is the distance that light travels in one year.

186,000 X 60 X 60 X 24 X 365 MILES Proceed, now, to frame 12

11B. Your answer: d = v/t
is incorrect.
To derive an expression for d, out of the expression v = d/t, we must multiply both sides by a common letter so that d remains by itself on one side. If we multiply the right side by the letter ____, d now stands by itself.

---

t

11B2. We have multiplied the right side by t. This gives us d/t X t = d. To keep the expression equal, we must multiply the left side by the letter ____ as well. This gives us ________.

t; v X t

11B3. We now have, in our equation, ____ on the right side, and ____ on the left side.

d; v X t

11B4. We can now say, then, that d = ______.

v X t

11B5. Now go back to frame 10B and choose the correct answer.

11C. Your answer: d = t/v
is incorrect.
To derive an expression for d, out of the expression v = d/t, we must multiply both sides by a common letter so that d remains by itself on one side. If we multiply the right side by the letter ____, d now stands by itself.

t Now proceed to frame 11B2

12. This distance is known as a Light Year. A light year is a measure of (time/speed/distance)____________.

DISTANCE

13. A light year is, in fact, the distance that light travels in (what time period?) ______________.

ONE YEAR

14. Recall that distance is related to time and speed by the expression d = ______.

v X t

15. The source of the terminology "Light Year" should now be clear: This distance equals the speed of light(v) multiplied by a time period of one year (t). Out of this, we derive the term: Light Year. A light year is (defn.) ______________________________.

THE DISTANCE THAT LIGHT TRAVELS IN ONE YEAR

16. Suppose, now, that a certain star happens to be 10 light years away from us. What this means is that the light we see from that star took (how long?) __________ to reach us.

10 YEARS

17. In other words, the light we see from that star is (how many?) ______ years old. We are seeing the star, then, as it appeared (how long?) ________ ago.

10; 10 YEARS

18. From what you learned in frame 17, would you now say that, whenever you look at stars in the night sky, you are looking back into time?

(a) Yes — see frame 19A.
(b) No — see frame 19B.
(c) Not Necessarily — see frame 19C.
(d) Yes, except if your great aunt has post-nasal drip. — see frame 19D.

19A. Your answer: Yes
is correct.
This is a very astute observation on your part. Suppose, now, that you were to take an immaginary trip to that same star (10 light years away) at 18.6 miles per second (recalling that the speed of light is ____________. It would take you (how many?) __________ years to make the trip.

186,000 MILES PER SECOND; 100,000   Proceed, now, to frame 20

19B. Your answer: No
is incorrect.
We have already pointed out that the light from a particular star is ten years old. Most starlight is a good deal older than this. Go back to frame 18 and think some more about this concept. Then choose a better answer.

19C. Your answer: Not Necessarily
is incorrect.
We have pointed out that the light from a certain star is ten years old. Most starlight is a good deal more ancient than this. Why, then, did you say that looking at the stars was "not necessarily" looking back into time? Go back to frame 18, think about this concept some more, and then choose a better answer.

19D. Your answer: Yes, except if your great aunt has post-nasal drip
indicates not so much a lack of understanding as a feeling of exhaustion on your part. In fact, you have unwittingly stumbled upon an abort frame. You are advised to set the book down for a while. When you feel properly refreshed, we suggest that you go back to frame 18 and select a better answer.

20. Would you estimate that 18.6 miles per second is a fast speed to be travelling, compared to present speeds at which man is able to travel?
(a) Yes — see frame 21A
(b) No — see frame 21B

21B. Your answer: No; is incorrect. Go back and try again.

21A. Your answer: Yes
is correct.
18.6 miles per second is, indeed, a fast speed to be travelling. In fact, this is almost four times as fast as man is able to travel at present. On this basis, would you now say that interstellar (between stars) travel is, at present:

(a) Feasable see frame 22A.
(b) Out of the question see frame 22B.

22A. Your answer: Feasable
is incorrect.
Come, come now!! Unless you expect to live to a ripe old age of well over 100,000 years, you could not, yourself, visit even some of the nearest stars at present. Go back and choose the correct answer.

22B. Your answer: Out of the question
is correct.
You have realized that, to travel to even the nearest stars at present speeds, would involve a journey of such length that you would find yourself long dead on arrival. Would you now think that it is possible to measure short distances (distances you are familiar with) in light years?

(a) Yes see frame 23A
(b) No see frame 23B

23A. Your answer: Yes
is correct.
You have realized that, although it is inconveniant to measure small distances with such a large unit, it is, just the same, quite possible. To give you an example: suppose that the grocery store is one half mile away from your home. If there are, approximately 6,000,000,000,000 miles in one light year, how many light years would you have to travel to go there to do some shopping?

(a) 1/3,000,000,000,000 light years see frame 24A
(b) 1/12,000,000,000,000 light years see frame 24B
(c) 3,000,000,000,000 light years see frame 24C
(d) ½ mile see frame 24D

23B. Your answer: No
is incorrect.
You have been confused by the fact that, although measuring small distances in light years would be extremely inconveniant due to the awkward fractions involved, it is, never the less, quite possible, since a light year is a unit of distance like an inch or a kilometer. Go back, now, to frame 22B and select the correct answer.

24A. Your answer: 1/3,000,000,000,000 light years
is incorrect.
It is clear, however, that you have the right idea. Let us construct the correct answer: 6,000,000,000,000 miles makes up one light year. Therefore 1 mile makes up (fraction) ____________ light years.

1/6,000,000,000,000

24A2. We are talking, however, of a distance of one half mile. ½ X 1/6,000,000,000,000 = ____________.

1/12,000,000,000,000

24A3. So, then, in one half mile, there are (how many?) ______ light years.

1/12,000,000,000,000

24A4. Now go back to frame 23A and choose the correct answer.

24B. Your answer: 1/12,000,000,000,000 light years is correct.
You are to be commended on your well thought out arithmetic (if you got this the first time). What we have pointed out here, then, is that the light year is indeed a measure of (time, speed, distance) __________; and there is nothing particularly mysterious about it.

DISTANCE Proceed, now, to frame 25

24C. Your answer: 3,000,000,000,000 light years is incorrect.
You have failed to notice that your answer is totally unrealistic. To travel 3,000,000,000,000 light years to the grocery store would be to take a very indirect route. What is more -- you would not live long enough to walk even a very small fraction of this distance. Go back to frame 23A and choose a better answer.

24D. Your answer: ½ mile is incorrect.
You have used the wrong units: We asked for the distance in light years, and you gave it in miles. Go back to frame 23A and choose a better answer.

25. In review of the concepts you have learned, so far, a light year is (defn.) ____________________.

THE DISTANCE THAT LIGHT TRAVELS IN ONE YEAR.

26. This distance is equivalent to (expression) ________ miles.

186,000 X 60 X 60 X 24 X 365

27. The terminology "Light Year" comes from an expression for distance (d) in terms of speed (v) and time (t). This expression is: ______.

d = v X t

28. Most importantly, the unit "Light Year" is based on the speed of _____ which travels at a rate of __________.

LIGHT; 186,000 MILES PER SECOND

29. The light year is not the only unit that Astronomers use to measure astronomical distances. Two other units which are used are known as the Astronomical Unit (A.U.) and the Parallax Second (Parsec). The Astronomical Unit (A.U.) and the Parallax Second (Parsec) are units of ____________.

DISTANCE

30. Parsec is derived from an abbreviation of ____________; and A.U. is an abbreviation for ____________.

PARALLAX SECOND; ASTRONOMICAL UNIT

31. Three units that Astronomers use for distance are: ____________, ____________, ____________.

LIGHT YEAR; A.U. or ASTRONOMICAL UNIT; PARSEC or PARALLAX SECOND

32. An Astronomical Unit is simply the average distance from the Earth to the Sun. This means that a trip from our planet to the sun would involve a distance of (how many?) _____ A.U.(s)

ONE

33. One A.U. is equal to 92,957,000 miles. This is the average distance from ____________ to ____________.

THE EARTH; THE SUN

34. One Astronomical unit is (larger/smaller) ____________ than one light year. A good definition for an Astronomical Unit would be that it is ____________.

SMALLER; THE AVERAGE DISTANCE FROM THE EARTH TO THE SUN

35. The unit Parsec is a little more complicated. It involves something called parallax. An understanding of parallax will help us understand the unit which we call the ____________.

PARSEC

36. So now we will attempt to explain the parsec by explaining something called ____________.

PARALLAX

37. First, we would like you to try an experiment: Take a pencil (or some similar sort of object) and hold it at arms length. Close one eye. Notice where objects in the background appear to be relative to the pencil. Now close the eye you were using and open the other one. When you do this, you will notice that ____________ appear(s) to have shifted, but ____________ appear(s) to stay stationary.

THE PENCIL; OBJECTS IN THE BACKGROUND

38. Since (hopefully) you did not move the pencil yourself during the experiment, this shifting is not real but apparent. Parallax, then, has to do with _____________ movement.

APPARENT

39. The reason for this apparent shift has to do with the fact that there is a significant distance between your two eyes. Thus, when you change from one eye to the other, you are actually observing the pencil from two different _____________.

POSITIONS or LOCATIONS

40. Parallax, then, can be defined as the apparent shift against some background that an object undergoes when it is observed from two different _____________.

POSITIONS or LOCATIONS

41. Another property of Parallax can be demonstrated by another variation of the same experiment: Take the same pencil and move it closer to you than arms length. Now repeat the experiment outlined in frame 37. The apparent shift is now (greater/less) __________ than that which was observed in the previous experiment.

GREATER

42. This suggests a very conveniant generalization: The farther away an object is, the (greater/less) __________ will be the apparent shift against some background when it is observed from two different positions.

LESS

43. It is clear, then, how parallax can be used to find distances: The distance to an object may be found by measuring the _____________ it undergoes when viewed from two different _____________.

APPARENT SHIFT; POSITIONS

44. Distant objects will undergo (much/little) _______ apparent shifting, while closer objects will undergo (much/little) _________ apparent shifting.

LITTLE; MUCH

45. Before we go on to explain the Parsec, you should recall the definition of Parallax which is the _____________ that an object undergoes against a _____________ when it is viewed from two different _____________.

APPARENT SHIFTING; BACKGROUND; POSITIONS

46. In Astronomy, Parallax can be used to calculate the distance to some of the nearer stars. The apparent shift that these stars undergo is observed against the background of the more distant stars (which are too far away to show any observable shifting effect). Now all that we need is a way to accurately measure the amount of shifting so that we can calculate distances. We will, for the sake of convenience, consider the sky to be the inside surface of a sphere (or ball) called the Celestial Sphere, which is then divided along its circumference into 360 equal parts known as degrees. At any one time, looking up at the night sky, we can see only half this much or (how many?) ___ degrees.

180

---

47. Each degree is further divided into 60 units called minutes, each of which is divided into 60 units called seconds. So, the order of these units from smallest to largest is: ________, ________, and ________.

SECONDS; MINUTES; DEGREES

---

48. (how many?) ____ seconds make up one minute, (how many?) ____ minutes make up one degree, and (how many?) ____ degrees make up the Celestial Sphere, (how many?) ____ of which we are able to see at one time.

60; 60; 360; 180

---

49. On the basis of what you have learned so far, how many seconds around is the part of the sky (celestial sphere) that you are able to see at one time.

(a) 60 seconds — see frame 50A
(b) 1,296,000 seconds — see frame 50B
(c) 648,000 seconds — see frame 50C
(d) 3600 seconds — see frame 50D
(e) 7½ days — see frame 50E

50A. Your answer: 60 seconds
is incorrect.
What you have given is the number of seconds in one minute. This is not what was asked for. Let us develop the correct answer: You already know that there are 60 seconds in one minute, (how many?) _____ minutes in one degree and (how many?) _____ degrees in the Celestial Sphere, (how many?) _____ of which can be seen at one time.

60; 360; 180

50A2. So, the number of seconds in one degree is given by 60 X ___ = ____.

60; 3600

50A3. This number should now be multiplied by the number of degrees in half the Celestial Sphere which is (how many?) ____. This gives us ______ X _____ = _________.

180; 3600; 648,000

50A4. Now go back to frame 49 and choose the correct answer.

50B. Your answer: 1,296,000 seconds
is incorrect.
You are quite close, however: What you have given is the number of seconds in the Celestial Sphere, calculated by the expression 60 X 60 X 360 = 1,296,000. The amount of sky that you can see at any one time, however, is equal to only half of the Celestial Sphere. Therefore, you must divide the answer you gave by ____ to get the correct answer. This gives you (how many?) ____________ seconds.

2; 648,000

50B2. Now go back to frame 49 and choose the correct answer.

50C. Your answer: 648,000 seconds
is correct.
If you got this answer on the first attempt, congratulations are in order for the accuracy of your numerical reasoning. You will recall that our purpose in developing the concepts of parallax and seconds of arc was to explain the unit known as the __________.

PARSEC — Proceed, now, to frame 51

50D. Your answer: 3600 seconds
is incorrect.
What you have given is the number of seconds in one degree calculated by the expression ____ X ____ = 3600.

60; 60 — Proceed, now, to frame 50A3

50E. Your answer: 7½ days
is incorrect.
This answer is meaningless because the unit "days" is totally inappropriate. We want an answer in terms of seconds of arc. Go back to frame 49 and select a better answer.

51. You will remember that parallax is defined as ____________________

and that the observable sky is divided into (how many?) ________ seconds of arc.

THE APPARENT SHIFTING THAT AN OBJECT UNDERGOES AGAINST A BACKGROUND WHEN IT IS VIEWED FROM TWO DIFFERENT LOCATIONS; 648,000

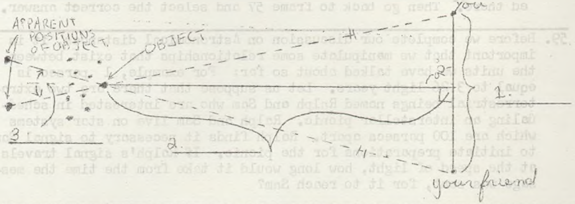
52. We now have most of the tools we need to measure distances to stars, using parallax. We have a background against which to observe apparent shifting (the distant stars) and a way to measure the extent of this shifting (in seconds of arc). All that we need to do now is to observe the star from two different locations, separated by some convenient _____________, to observe a parallax effect.

DISTANCE

53. The distance that we are talking about (called a "baseline") has to be large if we wish to observe a parallax effect with the nearer stars. The distance between your eyes, for instance, is much too small. The baseline that is used to define a parsec is the average distance from the Earth to the Sun which, you will recall, is called a(n) ________ ________________.

ASTRONOMICAL UNIT (A.U.)

54. A parsec, in fact, is defined as the distance at which an object would have to be to appear to have shifted one second of arc when observed from two different positions, separated by a distance of one A.U. at right angles to the distance to the object. The diagram below will make this clear (fill in the blanks).



1. 1 A.U.; 2. 1 PARSEC; 3. 1 SECOND OF ARC

55. It is not possible or, at least, convenient to observe the star in question from Earth, and then have your friend travel one Astronomical Unit out into space to observe it again, so that you can determine its parallax. A better idea would be to observe the star as it appears now, then wait half a year to observe it again when the Earth is on the other side of its orbit. This would make the distance between the two locations from which you viewed the star equal to (approximately how many?) _____ Astronomical Units.

2

56. If you went through this procedure and found that the star in question had a parallax of 2 seconds of arc, you would be able to conclude that it was (how many?) _____ parsec(s) away.

1

57. All of the stars that we have parallax measurements for show less apparent shifting than the hypothetical star which we considered in frame 56. This means that all of these stars are:

(a) more distant than one parsec see frame 58A
(b) less distant than one parsec see frame 58B

58A. Your answer: More distant than one parsec is correct
You have remembered that the less apparent shifting there is, the more distant the object in question will be. For example, if we repeated the procedure outlined in frame 56, and found a parallax of one second of arc, we would now conclude that the star in question was (how many?) ____ parsec(s) distant.

2; Proceed, now, to frame 59

58B. Your answer: Less distant than one parsec is incorrect.
You have forgotten that the less apparent shifting there is, the more distant the object in question will be. If you are still uncertain about this, return to frame 42 and review the material presented there. Then go back to frame 57 and select the correct answer.

---

59. Before we complete our discussion on Astronomical distances, it is important that we manipulate some relationships that exist between the units we have talked about so far: For example, 1 parsec is equal to 3.26 light years. Let us suppose that there are two extraterrestrial beings named Ralph and Sam who are interested in scheduling an interstellar picnic. Ralph and Sam live on star systems which are 100 parsecs apart. Ralph finds it necessary to signal Sam to initiate preparations for the picnic. If Ralph's signal travels at the speed of light, how long would it take from the time the message was sent, for it to reach Sam?

(a) 3.26 hours see frame 60A
(b) 100 years see frame 60B
(c) 3,260 years see frame 60C
(d) 1,000 light years see frame 60D
(e) 326 years see frane 60E

60A. Your answer: 3.26 hours is very unrealistic. The time period we are talking about will be much greater than this. Go back to frame 59 and select a better answer.

60B. Your answer: 100 years is incorrect.
The answer would be 100 years if Ralph and Sam lived 100 light years apart, however they live 100 parsecs apart, and a parsec is not the same as a light year. A parsec is equal to 3.26 light years. Go back to frame 59 and select a better answer.

60C. Your answer: 3,260 years
is incorrect.
You are reasonably close, however, as your answer is only out by a factor of 10. You recall that 1 parsec = 3.26 light years and that Ralph and Sam live 100 parsecs apart. Go back to frame 59 and select a better answer.

60D. Your answer: 1,000 light years
is incorrect.
You have used the wrong units. The light year is a unit of distance. The answer that is required is a time period. Go back to frame 59 and select a better answer.

60E. Your answer: 326 years
is correct.
From this, we would have to conclude that Ralph and Sam have relatively __________ lifetimes.

LONG Proceed, now, to frame 61

---

61. 1 light year is equal to 63,200 astronomical units. Given that the solar system is 80 astronomical units across, and that the nearest star to our system is about 4 light years away, how many solar systems could we fit between the sun and this star?

(a) 252,800 see frame 62A
(b) 3,160 see frame 62B
(c) 31,600 see frame 62C
(d) 790 see frame 62D

62A. Your answer: 252,800
is incorrect.
What you have calculated is the number of Astronomical units to the nearest star (4 X 63,200). Our solar system, however, is 80 A.U.s across. So, to find how many solar systems you could put in that distance, you must divide your answer by ____.

80

62A2. This now gives you __________ divided by ____ which equals __________.

252,800; 80; 3,160

62A3. Now go back to frame 61 and choose the correct answer.

62B. Your answer: 3,160
is correct.
You have done well if you got this answer on the first attempt. In any event, this answer should indicate to you that the stars are rather widely spaced. We will return to such matters later in the program. At this point, however, it is time for review: All through this part of the program we have been discussing __________ __________.

 Proceed, now, to frame 63

62C. Your answer: 31,600
is incorrect.
You have the right idea, but you are out by a factor of ten. Let us develop the correct answer: The number of A.U.s in one light year equals 63,200, and the number of light years from our solar system to the next nearest star is 4. Therefore, the number of Astronomical units from our Sun to the next nearest star is ______ X ____ = ______.

63,000; 4; 252,800

62C2. The solar system is 80 A.U.s across. Therefore we must divide the answer in the previous frame by _____ to find the number of solar systems that would fit in this distance.

80 Proceed, now, to frame 62A2

62D. Your answer: 790
is incorrect.
What you have calculated is the number of solar systems that would fit, end to end, along the distance of one light year (63,200 divided by 80). However, the distance to the nearest star is 4 light-years. Therefore, to get the correct answer, you must multiply this answer by _____.

4

62D2. This gives you _____ X ___ = _______.

790; 4; 3,160

62D3. Now go back to frame 61 and choose the correct answer.

63. You will recall that we defined the light year as ______________________________.

THE DISTANCE THAT LIGHT TRAVELS IN ONE YEAR

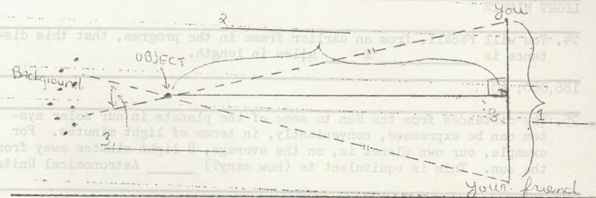
64. The Astronomical Unit (A.U.) is defined as ______________________________.

THE AVERAGE DISTANCE FROM THE EARTH TO THE SUN

65. The Parsec (or Parallax Second) is defined as ______________________________ ______________________________.

THE DISTANCE AT WHICH AN OBJECT WOULD HAVE TO BE TO APPEAR TO HAVE SHIFTED ONE SECOND OF ARC WHEN OBSERVED FROM TWO DIFFERENT POSITIONS, SEPARATED BY A DISTANCE OF ONE A.U. AT RIGHT ANGLES TO THE DISTANCE TO THE OBJECT.

66. The diagram below can be labelled in the following way, to illustrate the concept of the Parsec.



1. 1 A.U. ; 2. 1 PARSEC; 3. 1 SECOND OF ARC

67. You have finished the segment of this program on Astronomical distances. If you have not taken a break yet, we suggest that you do so before continuing on in the program.

68. This segment of the program will concern itself with the Solar system. The solar system consists, principally, of the nearest star to us (the Sun), our own planet, eight other planets and an asteroid belt between the orbits of Jupiter and Mars. We are not aware, at present, of the existance of any other planetary systems, although there is no reason to assume that such systems do not exist. Each of the planets in our system has a unique average distance from the Sun. These distances are best expressed in terms of units based on the speed of light. One such unit with which you are already familiar is known as the ________________.

LIGHT YEAR

69. Light travels at a speed of ______________.

186,000 MILES/SEC.

70. You will remember that a light year is defined as ______________ ______________.

THE DISTANCE THAT LIGHT TRAVELS IN ONE YEAR

71. If we were to consider a new unit, which is defined as the distance that light travels in one second, a good name for this unit would be the "light __________".

SECOND

72. The length of this unit (in miles) would be ______________.

186,000 MILES

73. Another unit called the ______________ is defined as the distance that light travels in one minute.

LIGHT MINUTE

74. You will recall, from an earlier frame in the program, that this distance is __________ X ___ miles in length.

186,000; 60

75. The distances from the Sun to some of the planets in our solar system can be expressed, conveniantly, in terms of light minutes. For example, our own planet is, on the average, 8 light minutes away from the sun. This is equivalent to (how many?) _____ Astronomical Units.

ONE

76. In fact, the ______________________ would also be a conveniant unit to use, when discussing distances to planets.

ASTRONOMICAL UNIT (A.U.)

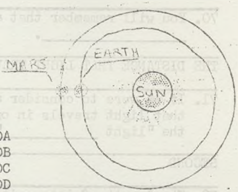
77. From the content of frame 75, you should be able to conclude that 1 A.U. = ___ light minutes (approximately).

8

78. The planet Mercury is about 3 light minutes away from the sun. This distance, in A.U.s, is (how much?) ______ (approximately)

3/8 or .375 A.U.s

79. The planet Mars is 1½ (or 1.5) A.U.s away from the sun. How long, then, would a trip from Earth to Mars take, on the average, when the Earth is situated on a straight line between the sun and Mars (as shown in the diagram), if you were travelling at the speed of light?



(a) 4 minutes see frame 80A
(b) 12 years see frame 80B
(c) ½ A.U.s see frame 80C
(d) 12 minutes see frame 80D
(e) 35,000,000 miles see frame 80E

80A. Your answer: 4 minutes
is correct.
Another unit for distance (from the speed of light) based, this time, on hours instead of minutes, is called the ________ and is defined as ______________________________.

LIGHT HOUR; THE DISTANCE THAT LIGHT TRAVELS IN ONE HOUR

Proceed, now, to frame 81

80B. Your answer: 12 years
is incorrect.
Take a look at your units. We are considering units expressed in small numbers of light minutes. This means that, travelling at the speed of light, it should take you much less than 12 years to cross such distances. Go back to frame 79 and choose a better answer.

80C. Your answer: ½ A.U.s
is incorrect.
We asked for an answer that consists of a time period, and you gave us a distance. However you do have part of the answer: ½A.U.s is the average distance from the Earth to Mars when the two planets are situated as shown in the diagram on frame 79. You will recall that there are (how many?) ____ light minutes in one Astronomical Unit.

8

80C2. Therefore, a distance of ½ A.U.s would be equal to ____ X ____ = ____ light minutes.

½; 8; 4

80C3. So, then, to travel this distance at the speed of light would take you (how long?) ____________.

4 minutes

80C4. Go back, now, to frame 79 and select the correct answer.

80D. Your answer: 12 minutes
is incorrect.
What you have calculated is the time required to take a trip at the same speed (the speed of light) from the Sun to Mars. This was not what was asked for. You will recall that the Earth is (how many?) ____ light minutes away from the Sun.

8

80D2. So, to derive the correct answer, you must subtract ________ from your answer.

8 MINUTES

80D3. This leaves ____ - ____ = ____ minutes.

12: 8; 4

80D4. Go back, now, to frame 79 and choose the correct answer.

80E. Your answer: 35,000,000 miles
is incorrect.
The units you have used are inappropriate. The answer that was asked for was a time period. You responded with a distance. Go back to frame 79 and choose a better answer.

81. Average distances beyond Jupiter are best discussed in terms of light hours. One light hour, naturally, is equivalent to (how many?) ____ light minutes.

60

82. The planet Saturn (next furthest out beyond Jupiter) is, for example, about 80 light minutes away from the Sun. This distance, in light hours, is ______________.

1 1/3 or 1.33... LIGHT HOURS

83. This means that sunlight takes (how long?) __________ to travel from the surface of the Sun to Saturn.

1 1/3 HOURS or 80 MINUTES

84. The planet Pluto (the farthest planet out in our system, to our knowledge) is, on the average, 5½ light hours away from the Sun. This means that our solar system has an average diameter (or distance across) of __________.

11 LIGHT HOURS

85. In the late 1700's, a German Astronomer by the name of Johann Bode made famous a law which, it seemed, allowed him to describe something about the orbits of the planets. Laws, in Science, are typically named after those who were associated with them. Therefore, we would suspect that this law that Bode made famous would be called ____'s law.

BODE

86. Bode's law begins by taking the series of numbers 0,3,6,12,... doubling the last number each time to obtain the next one. The next four numbers in this series will be ___, ___, ___, ___, ...

24; 48; 96; 192

87. The number 4 is now added to each term in the series. When we do this to the eight term series which we developed in frame 86, the result is the series: ______________________.

4, 7, 10, 16, 28, 52, 100, 196...

88. The final thing that is done is to divide each term in this new series by 10. This leaves us with the series: ______________

0.4, 0.7, 1.0, 1.6, 2.8, 5.2, 10.0, 19.6 ....

89. The series that we have been developing can also be generated by the following Mathematical Expression: $a = 0.4 + 0.3 \times 2^n$ where "2^n" means "n 2's multiplied together". For example, 2^3 = ____ x ____ x ____ = ____.

2; 2; 2; 8

90. The "a" in the expression $a = 0.4 + 0.3 \times 2^n$ can be any term of the series we have been talking about, depending on what number we let "n" be equal to. For example, if we let "n" equal 1, "a" would equal ____ (Hint: $2^1 = 2$)

1.0

91. This just happens to be the distance from the Sun to the Earth in Astronomical units. Frame 92, a data frame, presents some more interesting results from the expression a = ____________.

$0.4 + 0.3 \times 2^n$

92. DATA FRAME ON BODE'S LAW:

Planet	n	a	Actual Distance (from the Sun, in A.U.S)
Earth	1	1.0	1.00
Mars	2	1.6	1.52
Ceres (Minor "planet" in Asteroid belt)	3	2.8	2.77
Jupiter	4	5.2	5.20
Saturn	5	10.0	9.52
Uranus	6	19.6	19.18

After you have examined the contents of the above table, proceed to frame 93.

93. You noticed, when you examined the table in frame 92, that the values for "a" and those for "Actual Distance" are almost ________.

EQUAL or THE SAME

94. What can you conclude from this data?

(a) Bode's law adequately describes the distances of all the bodies in the solar system. see frame 95A.

(b) Bode's law accounts for the structure of the solar system. see frame 95B.

(c) One can conclude very little from this data. see frame 95C.

(d) Both (a) and (b) see frame 95D.

(e) "The Queen to me a royal pain doth give" see frame 95E.

95A. Your answer: Bode's law adequately describes the distances of all the bodies in the solar system

is incorrect.

See frame 95A2 for the explanation.

95A2. In the first place, the table in frame 92 contains data on only some of the planets -- those for which Bode's law seems to work quite well. In fact, Bode's law completely fails to account for the distances to Neptune and Pluto unless you ignore Neptune and consider Pluto to be the eighth planet. Secondly, Bode's law is an Empirical law. This means that it has been contrived to explain data that are already known. It is not known to be based on any physical properties, and it, therefore, has no ability to predict. Therefore Bode's law can not be considered to be a usefull scientific law because it can not ____________.

PREDICT Proceed, now to frame 94 and select a better answer.

95B. Your answer: Bode's law accounts for the structure of the solar system

is incorrect.

See frame 95B2 for the explanation.

95B2. Mathematics, by itself, never "accounts for" anything, although it can sometimes be used as a reflection of physical processes. To find out why Bode's law fails in this respect, proceed to frame 95A2.

95C. Your answer: One can conclude very little from this data

is correct.

You have realized that, not only was the table in frame 92 incomplete (it did not include all the planets, and, in fact, Bode's law does not "work" for all the planets), but a law that is contrived to explain facts that are already known (called an empirical law) does not necessarily predict facts which are not known. A usefull scientific law should have the power to ____________.

PREDICT Proceed, now, to frame 96

95D. Your answer: Both (a) and (b)

is incorrect.

See frame 95B2 for the explanation.

95E. Your Answer: "The Queen to me a royal pain doth give" is incorrect.
You have given us the title of a famous P.D.Q. Bach Madrigal. Unfortunately this was not what was asked for. In fact, the incorrectness of your answer is only exceeded by its frivolousness. In short you have come to another abort frame. You are advised to set the book down momentarily and take a break. When you feel refreshed once more, we suggest that you go back to frame 94 and continue on in the program.

---

96. A law that is contrived to explain facts that are already known is called a(n) ________________ law.

EMPIRICAL

---

97. We are now going to introduce you to a scientific law that is, on the other hand, quite usefull in Astronomy. This law is known as Kepler's Third law. This law was developed by a man by the name of Johannes (last name) __________ (1571 - 1630).

KEPLER

---

98. Kepler's third law is usefull because, as with all good scientific laws, it is based on ______________ and can be used to __________ facts which are not known.

PHYSICAL PROPERTIES; PREDICT or DERIVE

---

99. This law attempts to relate the motion of any two bodies (or objects) to their distance apart and their masses (or weights). To understand it will require that you have an intuitive understanding of what something called Gravity is. Gravity can be thought of as a force that exists between any two objects. This is important when we start to consider the solar system because it is this thing called __________ which keeps all the planets in their orbits about the Sun.

GRAVITY

---

100. Any two objects (or bodies) in the universe exert a gravitational attraction on each other--ie.--The force of gravity acts on the two bodies to bring them together. However, the effect of this is not always observable because the strength of this force which we call __________ is affected by the weights (or masses) of the bodies and the distance between them.

GRAVITY

---

101. ______________ attraction between two bodies is affected by the ______________ and the __________ associated with the two bodies we are considering.

GRAVITATIONAL; DISTANCE; MASSES

---

102. The force of gravity is related to mass in the following way: The greater the product of the masses (one mass multiplied by the other) the greater the force of gravity. For example, if we were able to observe the effect of the gravitational attraction between two bodies and were then able to increase the mass of one of the bodies by 3 times, the new force of Gravity between them would now be ____ times as great as it was previously.

3

103. Distance and Gravity are related in a different way: If you increase the distance two objects in question by "n" times, then the force of Gravity between them decreases to one "n^2"th times as much as it was previously. Where n^2 means, as you will recall, ________.

n X n

104. For example, if we made the distance between the objects two times as great, the force of gravity is now only ¼ as much. If we now increase this distance to 3 times as much as the original, the force of gravity is now only ______ times as large.

1/9

105. You should now be able to explain why the effects of gravity are not always observable: For example, you can not detect the force of gravity between yourself and a chair that is in the same room with you, because the combined mass of you and the chair is much too __________.

SMALL or LITTLE

106. However you are constantly aware of the force of gravity between yourself and the Earth, because the combined ______ of you and the Earth is quite (large/small) _________.

MASS; LARGE

107. However, you are not aware of the force of gravity between yourself and some other hypothetical planet, about the same size as the Earth which is several hundred light years distant, in some other part of the universe, because this planet is too ____________.

DISTANT or FAR AWAY

108. You will recall that the force of gravity between two bodies increases as the ____________________________ increases.

PRODUCT OF THEIR MASSES

109. The way that a relationship like this is usually stated is to say that the force of gravity between two bodies is directly proportional to the product of their masses. If we let the force of gravity be represented by Fg, and the two masses be represented by M_1 and M_2, then the way to state this relationship mathematically is to write $Fg \propto M_1 X M_2$. Where "$\propto$" means "________________
________________.

IS DIRECTLY PROPORTIONAL TO

110. This means that, if we triple the quantity $M_1 X M_2$, Fg increases by (how many?) _____ times.

3

111. Another way to say the same thing is to write: $Fg = k X M_1 X M_2$, where "k" is some number that is put in to make both sides of the equation equal. This means that if we, in some way, change the equation, we must also change ________________.

THE NUMBER THAT WE LET "k" BE EQUAL TO

112. You will notice that the relationship we have been talking about still holds --ie.--if we multiply one side of this equation by a number "n", the other side becomes (how many?) ____ times as large.

n

113. In review, $Fg \propto M_1 X M_2$ means the same thing as Fg = ________ where "$\propto$" means ________________.

$k X M_1 X M_2$; IS DIRECTLY PROPORTIONAL TO

114. You will now recall that the force of gravity between two bodies decreases as the distance between them ________________, such that, as this distance is increased by "n" times, the Force of gravity becomes one ____th as strong.

INCREASES; n^2

115. A relationship like this is usually stated by saying that the force of gravity is inversely proportional to the distance multiplied by itself. This is stated, mathematically as $Fg \propto 1/d^2$, where "d" represents distance, d^2 means __________ and Fg represents ______ ____________.

d X d; THE FORCE OF GRAVITY

116. The relationship $Fg \propto 1/d^2$ can also be expressed mathematically, as Fg = __________.

$k \times 1/d^2$ or k/d^2

117. "k" is put in the above expression so that both sides of the equation will be ________. This "k" (is/is not) _____ the same number as the "k" in Frame 111.

EQUAL; IS NOT

118. Notice that, for example, if "d" is increased by 4 times, Fg now becomes (how many?) ______ times as large.

1/16

119. We will now attempt to combine these two expressions: You will recall that the force of gravity is related to mass by the expression $Fg \propto$ ________.

$M_1 \times M_2$

120. The force of gravity is related to distance by the expression: $Fg \propto$ ______.

$1/d^2$

121. Combining these two expressions gives us the expression:

$$Fg \propto \frac{M_1 \times M_2}{d^2}$$

Another way of saying this is to write: Fg = ___________.

$$\frac{k \times M_1 \times M_2}{d^2}$$

122. You realize, of course, that this "k" (is/is not) ____ the same number as any of the "k"s used elsewhere in the program.

IS NOT

123. This "k" is usually written as "G", which is just like giving another name to the same thing. "G" is known as the Gravitational Constant. The gravitational constant is put in so that ________________ ________________.

BOTH SIDES OF THE EQUATION WILL BE EQUAL

124. Using "G" in the place of "k" gives us the equation: ____________

$$Fg = \frac{G \times M_1 \times M_2}{d^2}$$

125. This is known as Newton's Law Of Universal Gravitation. It was developed, as you can guess, by a man named Isaac (last name) ________.

NEWTON

126. You will recall that we explained gravity in this amount of detail so that you might better understand a law which is called ________________________.

KEPLER'S THIRD LAW

127. Stated in a symbolic, mathematical way, Kepler's Third Law is this:

$$\frac{a^3}{p^2} = \frac{G}{4\pi^2}\left(M_1 + M_2\right)$$

You are already familiar with some of the terms in this expression. For example, "M_1" and "M_2" represent ________________________, and "G" represents the ________________________.

THE MASSES OF TWO BODIES ; GRAVITATIONAL CONSTANT

128. "a" in the above expression represents the distance between the centres of the two bodies we are considering. "a^3", of course, means ____________.

3 "a"s MULTIPLIED TOGETHER or a X a X a

129. "p" in this expression is put in to represent something which we call the "period". "p^2", of course, means ________________________.

2 "p"s MULTIPLIED TOGETHER or "p" TIMES ITSELF

130. "Period", in this case, simply means the time that elapses until a regular motion observed for two bodies in gravitational attraction begins once again. For example, if the two bodies we are considering are the Sun and one of its planets, a "period" would be the time it takes for that planet to ____________ one orbit.

COMPLETE or FINISH

131. The only other thing in this expression which we have not yet explained is "π". "π" is simply a number. Four our purposes, it is approximately equal to 3. In the expression, then, the term $4\pi^2$ is equal to the number:

(a) 144 see frame 132A
(b) 36 see frame 132B
(c) 24 see frame 132C
(d) 0 see frame 132D

132A. Your answer: 144
is incorrect.
You have not understood the meaning of "$4\pi^2$". It should be clear to you that "π^2" means ______________________.

---

2 "π"s MULTIPLIED TOGETHER or "π" TIMES ITSELF

132A2. "$4\pi^2$" means 4 X "π^2" or 4 times ______________.

"π" TIMES ITSELF

132A3. You should now be able to calculate the correct answer. Go back to frame 131 and try again.

132B. Your answer: 36
is correct.
You have understood the meaning of the expression "$4\pi^2$". If we measure time in years, mass in solar masses (1 solar mass = the mass of the sun), and distance in A.U.s, then we find that G has a value of about 36. You will recall that the expression for Kepler's third law is:

$$\frac{a^3}{p^2} = \underline{\qquad\qquad}.$$

$\frac{G}{4\pi^2}\left(M_1 + M_2\right)$ Proceed, now, to frame 133

132C. Your answer: 24
is incorrect.
You do not know the meaning of "$4\pi^2$". It is also possible that you have forgotten the meaning of "π^2". Let us consider some examples to bring this back to mind: $1^2 = 1$; $2^2 = 4$; $3^2 = 9$; $4^2 =$ ____.

16

132C2. Therefore, if "n" is any number "n^2" means ____________.

---

n X n; or n TIMES ITSELF

132C3. It should be clear, then, that π^2 is equal to ______.

π TIMES ITSELF. Proceed, now, to frame 132A2

132D. Your answer: 0
is incorrect.
In fact, this answer is meaningless. You will recall that Kepler's third law states that $\frac{a^3}{p^2}$ = __________.

$$\frac{G}{4\pi^2}\left(M_1 + M_2\right)$$

132D2. If you claim that $4\pi^2$ is equal to zero, then you will be left with the problem of dividing G by _____.

0

132D3. This is not possible, so that it is obvious that your answer is unrealistic. Go back to frame 131 and choose a better answer.

133. Recalling the value which we calculated for $4\pi^2$, $G/4\pi^2$ can now be calculated to be equal to ___.

1

134. Our expression for Kepler's third law, then, can be written more simply, as: __________.

$$\frac{a^3}{p^2} = M_1 + M_2$$

135. You remember, of course, that this way of writing Kepler's Third Law is only valid if time is measured in _______, mass is measured in ______________, and distance is measured in ______________.

YEARS; SOLAR MASSES; ASTRONOMICAL UNITS or A.U.s

136. From this expression --ie.-- $\frac{a^3}{p^2} = M_1 + M_2$, it is possible to predict something about the motions of planets, if we know their average distances from the Sun. First, we must consider a comparaison: You already know that the Sun weighs ____ solar mass(es).

1

137. The largest planet (Jupiter) weighs only 1/1,000 solar masses or (how many times?) _________ as much as the Sun.

1/1,000

138. So, if the two bodies we are considering are the Sun (whose mass we will represent by M_1) and a planet (whose mass we will represent by M_2), the quantity $M_1 + M_2$ will not be much different from ______.

M_1

139. Suppose now that we are considering two planets in our solar system: One (planet A) which is quite close to the Sun, and another (planet B) which is farther away. In the expression:

$$\frac{a^3}{p^2} = M_1 + M_2,$$

planet B will have a higher value for ____ than planet A.
(which letter?)

a

140. However, as we have already pointed out, the quantity $M_1 + M_2$ will stay about the same, regardless of which planet we are considering, because the mass of the Sun is so ______.

LARGE

141. Therefore, to keep $M_1 + M_2$ about the same (in the expression:

$$\frac{a^3}{p^2} = M_1 + M_2 \;)$$

when we have increased the value for "a", we must also change "P" so that it becomes ______.

GREATER or LARGER

142. This suggests a very convenient generalization: The farther away a planet is from the Sun, the (greater/less) ______ will be its period.

GREATER

143. "Period", in this case, can be defined as the time that it takes a planet to ______.

ORBIT THE SUN ONCE

144. Let us now go back to the example which we considered in frame 139: Suppose that planet B is exactly twice as far away from the Sun as planet A. This means that the value "a" for planet B would be (how many?) ____ times as great as it is for planet A.

2

145. Also, the value "a^3" for planet B would be (how many?) ____ times as great as "a^3" for planet A.

8

146. However, when we double the value for "p", "p^2" becomes only (how many?) ____ times as much.

4

147. Therefore, to keep the ratio a^3/p^2 about the same (that is, equal to $M_1 + M_2$), we must increase "p" by (more/less) ________ than 2 times every time we double "a".

MORE

148. What this means is that, in general, the farther a planet is from the sun, the (slower/faster) ______________ it travels in its orbit.

SLOWER

149. In review: Newton's Law Of Universal Gravitation is described by the expression:

________________.

$$Fg = \frac{G \times M_1 \times M_2}{d^2}$$

150. In the above equation, "Fg" represents ____________________, "G" represents ____________________, "M_1" and "M_2" represent ____________________, and "d" represents ____________________.

THE FORCE OF GRAVITY; THE GRAVITATIONAL CONSTANT; THE MASSES OF THE TWO BODIES; THE DISTANCE BETWEEN THE TWO BODIES

151. Kepler's third law is described by the expression:

________________.

$$\frac{a^3}{p^2} = \frac{G}{4\pi^2}\left(M_1 + M_2\right)$$

152. In the above equation, "a" represents ____________, "p" represents ____________, and "π" is a ____________ approximately equal to ____.

DISTANCE; PERIOD; NUMBER; 3

153. If time is measured in __________, distance is measured in ____________, and mass is measured in ____________, this equation can be simplified to

____________.

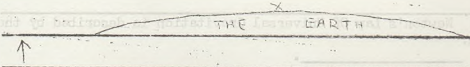
YEARS; ASTRONOMICAL UNITS (A.U.s); SOLAR MASSES; $\frac{a^3}{p^2} = M_1 + M_2$

154. Both Kepler's third law and Newton's law of Universal Gravitation are usefull scientific laws because they are based on ____________ ____________, and have the power to ____________.

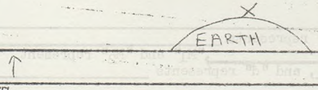
PHYSICAL PROPERTIES; PREDICT

155. Concepts associated with the question: "Which direction is up?" are are also quite important in Astronomy. Look at the diagram below and indicate, by drawing an arrow, which direction is up. You are standing at the spot labelled "X".

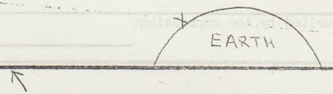
Do the same thing for the following series of frames.



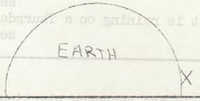
156.



157.



158.



159.

160.

161. On the basis of what you have learned in the sequence from frame 155 to frame 160, draw arrows to indicate every direction that could be considered to be "up" on the following diagram:

162. Would it now seem reasonable to you to say that "up" and "down" are important concepts in space?

(a) Yes — see frame 163A

(b) No — see frame 163B

(c) Only if it is raining on a Thursday afternoon — see frame 163C

163A. Your answer: Yes
is incorrect.
We have tried to point out, in the sequence starting from frame 155 that "up" and "down" are concepts associated with our lives here on Earth. That is to say, "up" is against the direction that gravity pulls us, and "down" is with it. In space there are large distances between bodies that exert gravitational forces, hence gravity has no appreciable effect. Therefore concepts like "up" and "down" become unimportant. Go back to frame 162 and select a better answer.

163B. Your answer: No
is correct.
You have realized that "up" and "down" are concepts that we learn here on Earth. In other words, "up" is simply in the (same/opposite) ______________ direction that gravity pulls whereas "down" is in the (same/ opposite) ______________ direction that gravity pulls us.

OPPOSITE; SAME   Proceed, now, to frame 164

163C. Your answer: Only if it is raining on a Thursday afternoon
is incorrect.
It should be clear that you have stumbled across another abort frame. Take a break, and then begin afresh at frame 162.

---

164. We will now consider some facts concerning the relative sizes of planets. Frame 167 is another data frame. In order to interpret its contents, however, you will need to understand the meaning of the unit "Earth mass". This will not be a difficult task, because an "Earth mass" is defined in the same way that we defined a "solar mass" earlier in the program. You will recall that 1 "solar mass" is equal to ______________________________.

THE MASS OF THE SUN

---

165. In a similar way, an "Earth mass" is defined in such a way that 1 "earth mass" will be equal to ______________________.

THE MASS OF THE EARTH

---

166. If we say, then, that a certain body weighs 10 Earth masses, we are saying that it weighs (how many?)_______ times as much as the Earth.

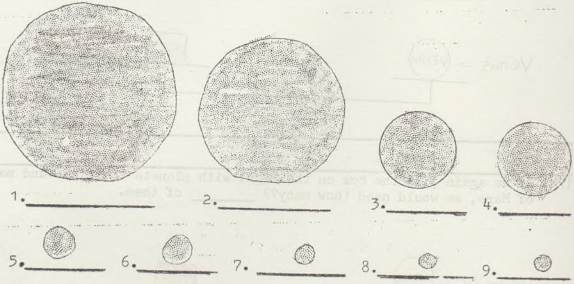
10

---

167. DATA FRAME ON RELATIVE SIZES OF PLANETS:

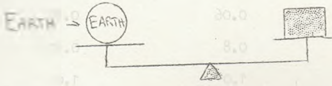
Planet	Diameter (in miles)	Mass (in Earth masses)	Surface Gravity (Gravity of Earth = 1.00)
Mercury	3,025	0.06	0.38
Venus	7,526	0.8	0.90
Earth	7,927	1.0	1.00
Mars	4,218	0.1	0.38
Jupiter	88,700	318.0	2.64
Saturn	75,100	95.2	1.13
Uranus	29,200	14.6	1.07
Neptune	31,650	17.3	1.08
Pluto	3,500	0.1	0.60

168. The next several frames are based on information from the above data frame. First, if the series of circles below represent the relative sizes of all the planets (in descending order), they would be labelled in the following way:



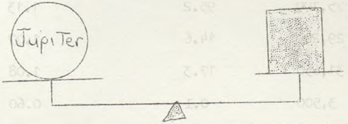
1. JUPITER; 2. SATURN; 3. NEPTUNE; 4. URANUS; 5. EARTH; 6. VENUS; 7. MARS; 8. PLUTO; 9. MERCURY

169. The scales on the diagram below are balanced if the box on the right contains (how many?) ________ planets the size and mass of Mars.



10

170. The scales are again balanced if the box on the right contains (how many?) ________ planets the size (and mass) of the Earth.

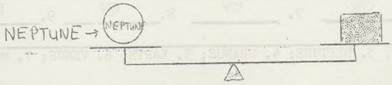


318

171. Again the scales are balanced if the box at the right contains (how many?) ________ planets the size and mass of Mars.

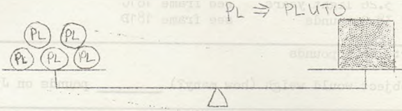
8

172. If we again fill the box on the right with planets the size (and mass) of Mars, we would need (how many?) ________ of them.



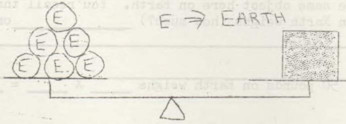
173

173. Once again, we are to fill the box at the right with planets the size (and mass)of Mars. We should need (how many?) ____ of them.



5

174. To balance the scales now, we need to fill the box at the right with (how many?) ______ planets the size (and mass) of Mercury.



100

175. You will notice, from the table in frame 167, that the surface gravity on the planet Venus is _____ times as much as it is here on Earth.

9/10 or 0.9

176. What this means is that a one pound object here on Earth would weigh (how many?) _____ pounds on Venus.

9/10 or 0.9

177. Someone weighing 100 pounds here on Earth would weigh (how many?) _____ pounds on Venus.

90

178. This same person would weigh (how many?) _____ pounds on Jupiter.

264

179. A person weighing 180 pounds on Venus would weigh (how many?) _____ pounds on Earth, and therefore (how many?) ______pounds on Jupiter.

200; 528

180. An object weighing 19 pounds on Mercury would weigh how much on Saturn?

(a) 56.5 pounds see frame 181A
(b) 50.0 pounds see frame 181B
(c) 3.26 light years see frame 181C
(d) 38.0 pounds see frame 181D

181A. Your answer: 56.5 pounds is correct.
This same object would weigh (how many?) _______ pounds on Jupiter.

---

132 Proceed, now, to frame 182

181B. Your answer: 50.0 pounds is incorrect.
You have part of the answer, however. Your answer is, in fact, the weight of the same object here on Earth. You recall that every pound here on Earth weighs (how much?) _____________ on Saturn.

1.13 pounds

181B2. Therefore, 50 pounds on Earth weighs _____ X _____ = _____ pounds on Saturn.

50; 1.13; 56.5

181B3. Go back, now, to frame 180 and select a better answer.

181C. Your answer: 3.26 light years is incorrect.
What you have given us is the number of light years in one parsec. This has nothing to do with the question that was asked, however. Take another look at your units. Then go back to frame 180 and try again(we recommend that you take a break first, however).

181D. Your answer: 38.0 pounds is incorrect.
Your answer equals the weight of an object on Mercury that weighs 100 pounds here on Earth. However the object we are considering weighs 19 pounds on Mercury. 19 = 38/____.

2

181D2. Therefore on Earth, this same object would weigh ____ / ____ = _____ pounds.

100; 2; 50

181D3. You know, from the data frame (167) that every pound here on Earth weighs (how much?) ___________ on Saturn.

1.13 pounds Proceed, now, to frame 181B2

---

182. It is now time to review this segment which has dealt, mostly, with phenomena in our solar system. Three units which we can use, conveniantly, to describe distances within our solar system are ________, ________ and ________.

LIGHT MINUTES; LIGHT HOURS; ASTRONOMICAL UNITS (A.U.s)

183. One light minute is equal to (defn.) ________, one light hour is equal to (defn.) ________, and one A.U. is equal to ________.

THE DISTANCE THAT LIGHT TRAVELS IN ONE MINUTE; THE DISTANCE THAT LIGHT TRAVELS IN ONE HOUR; THE AVERAGE DISTANCE FROM THE EARTH TO THE SUN

184. Three "laws" which we have talked about in this segment are known as ________, ________ and ________.

BODE'S LAW; NEWTON'S LAW OF UNIVERSAL GRAVITATION; KEPLER'S THIRD LAW

185. The mathematical statement of Bode's law is: ________.

$a = 0.4 + 0.3 \times 2^n$

186. The mathematical statement of Newton's law of Universal Gravitation is

________.

$$F_g = \frac{G \times M_1 \times M_2}{d^2}$$

187. The mathematical statement of Kepler's third law is:

________.

$$\frac{a^3}{p^2} = \frac{G}{4\pi^2}\left(M_1 + M_2\right)$$

188. Of these three laws, ________ and ________ are usefull scientific laws because they are based on ________ and have the power to ________.

NEWTON'S LAW OF UNIVERSAL GRAVITATION; KEPLER'S THIRD LAW; PHYSICAL PROPERTIES; PREDICT

189. One "solar mass" is equal to ________, and one "earth mass" is equal to ________.

THE MASS OF THE SUN; THE MASS OF THE EARTH

190. Concepts like ____ and ____ become unimportant in space.

dn; DOWN

191. You have come to the end of this segment of the program. If you have not taken a break since the beginning of this segment, we suggest that you do so now, before continuing on to frame 192.

192. You will recall that the Sun is just one example of a whole class of objects called ________.

STARS

193. Before we attempt to explain anything about such objects, however, it is going to be necessary for you to understand something known as Scientific Notation. This will not only help you to follow the material in this segment, but will facilitate your comprehension of concepts appearing later in the program which will also require a knowledge of ________ notation.

SCIENTIFIC

194. Scientific notation is simply a way of dealing with large numbers. In the first segment of this program (on Astronomical Distances), we mentioned that the nearest star to our solar system was 25,200,000,000,000 miles distant. The way that this difficulty was overcome, in that section of the program, was to invent new ______ for distance.

UNITS

195. Unfortunately, it is not always conveniant to invent new units for everything that we would like to measure in the universe. Hence, it becomes necessary to deal with large numbers directly. This thing called ________ helps us do this.

SCIENTIFIC NOTATION

196. You will recall, from various places earlier in the program, that if some number "k" is written with some other number"n" at the top right hand corner --ie.--"k^n", this means ________.

"n" "k"s MULTIPLIED TOGETHER or k X k X k X k X...(n times)

197. For example: 5^2 = ____.

25

198. 2^3 = ____.

8

199. 3^4 = ____.

81

200. $10^2 =$ _____.

100

201. $10^3 =$ ____; $10^4 =$ ____; and $10^5 =$ ____.

1,000; 10,000; 100,000

202. 10^n, of course, means ____________.

n 10's MULTIPLIED TOGETHER

203. It should be clear, from frames 200 and 201, that "n" in 10^n is also the number of ____ in your final answer.

0's

204. For example, a number like 10^{23} would be written as 1 followed by __________.

23 0's

205. It will now be necessary that you understand how numbers such as these are multiplied together and divided. Let us take an example: You can calculate, for instance, that 100 X 1,000 = ________.

100,000

206. Another way that we can write 100 is _____. Similarly, we can write 1,000 as _____ and 100,000 as _____.

10^2; 10^3; 10^5

207. Substituting these numbers into the multiplication problem which we considered in frame 205, gives us the expression: ____ X ____ = ____

10^2; 10^3; 10^5

208. Let us consider another example: 100 X 10,000 = _________.

1,000,000

209. Another way of writing this expression is: ____________.

$10^2 \times 10^4 = 10^6$

210. The numbers above and to the right of the 10's are called exponents. This way of writing numbers, in fact, is called exponential notation. The multiplication problems which you have considered (frames 205 - 209) should lead you to believe that, to multiply two numbers written in the same exponential notation*, all that you have to do is _____ their exponents.

ADD

211. For example, it now causes very little difficulty to do the following problem: $10^{23} \times 10^{47}$ = ____ (in exponential notation).

10^{70}

212. You will recall that this number "10^{70}" means ____________ or ____________.

70 10's MULTIPLIED TOGETHER; 1 FOLLOWED BY 70 0's

213. This technique for multiplication in exponential notation works for any number of numbers multiplied together. For example: $10^{13} \times 10^{7} \times 10^{15}$ = ____.

10^{35}

214. The method for dividing numbers written in ____________ notation is quite similar.

EXPONENTIAL

215. Let us consider some examples: $\frac{10,000}{100}$ = ________.

100

216. Another way of writing this expression is:

____________.

$\frac{10^4}{10^2} = 10^2$

217. $\frac{1,000,000}{1,000}$ =

__________.

1,000

218. Another way of writing this expression is

________.

$\frac{10^6}{10^3} = 10^3$

219. The rule for division for two numbers in the same ____________ notation is to ____________ their exponents.

220. You should now be able to do the following problem with little [redacted] [redacted] difficulty: $\frac{10^{62}}{10^{41}}$ = ________.

10^{21}

---

221. It is possible to combine the operations of multiplication and division in a very simple way: For example, what is the correct answer to the following problem?

$$\frac{10^{32} \times 10^{19} \times 10^{12}}{10^{10} \times 10^{29} \times 10^{3}} = ?$$

(a) 10^{63} see frame 222A
(b) 10^{10} see frame 222B
(c) 10^{42} see frame 222C
(d) 10^{21} see frame 222D
(e) I do not know how to do this problem see frame 222E

222A. Your answer: 10^{63} is incorrect.
The number which you have come up with represents only part of the answer. --ie.--$10^{63} = 10^{32} \times 10^{19} \times 10^{12}$. In other words, another way of writing $10^{32} \times 10^{19} \times 10^{12}$ is ____.

10^{63}

222A2. Similarly, another way of writing $10^{10} \times 10^{29} \times 10^{3}$ is ____.

10^{42}

222A3. This means that $\frac{10^{32} \times 10^{19} \times 10^{12}}{10^{10} \times 10^{29} \times 10^{3}}$, can be re-written as

____/____.

$10^{63}/10^{42}$

222A4. This problem can now be solved if you remember the rule for division in exponential notation which is to ______________ the exponents.

SUBTRACT

222A5. You should now be able to solve the problem in frame 221. Go back and try again.

222B. Your answer: 10^{10}
is incorrect.
Let us break up the problem into parts: You will recall that the rule for multiplication in exponential notation is to _____ the exponents.

ADD

222B2. Therefore, $10^{32} \times 10^{19} \times 10^{12} =$ _____.

10^{63}

222B3. Similarly, $10^{10} \times 10^{29} \times 10^{3} =$ _____.

10^{42}

222B4. This means that $\frac{10^{32} \times 10^{19} \times 10^{12}}{10^{10} \times 10^{29} \times 10^{3}} =$ _____ / _____.

$10^{63}/10^{42}$ Proceed, now, to frame 222A4.

222C. Your answer: 10^{42}
is incorrect.
The number which you have come up with represents only part of the answer.--ie.--$10^{10} \times 10^{29} \times 10^{3} = 10^{42}$. In other words, another way of writing $10^{10} \times 10^{29} \times 10^{3}$ is _____.

10^{42}

222C2. Similarly, another way of writing $10^{32} \times 10^{19} \times 10^{12}$ is _____.

10^{63} Proceed, now, to frame 222A3

222D. Your answer: 10^{21}
is correct.
We will now go on to talk about how scientific notation is written. Scientific notation comes out of the type of notation we have just been talking about, which, as you will remember, is called _______________.

EXPONENTIAL NOTATION Proceed, now, to frame 223

222E. Your answer: I do not know how to do this problem is, of course, no answer at all. To solve your present difficulties, let us break up the problem into parts. You will recall that the rule for multiplication in exponential notation is to _____ the exponents.

ADD Proceed, now, to frame 222B2

---

223. It should be clear to you, now, that if 10^3 means "1" followed by ________, then 6×10^3 means ____________.

---

3 0's;6 FOLLOWED BY 3 0's

---

224. Also, 6.0×10^3 means ________________. Written out the "long way" this number is ________.

---

6 FOLLOWED BY 3 0's; 6,000

---

225. Similarly 6.1×10^3 is equal to _______ (written out the "long way").

6,100

---

226. In a similar fashion, 6.13×10^3 is equal to _______ (written the "long way").

6,130

---

227. Also, 6.132×10^3 is equal to _______ (written the "long way").

6132

---

228. You will notice, in the above frame, that multiplying by 10^3 has the effect of moving the decimal point in the number 6.132 over (how many?) ____ places to the (left/right) ________.

3; RIGHT

---

229. You will remember that multiplying by 10^3 is equivalent to multiplying by 10 (how many?) ____ times.

3

---

230. This leaves us to conclude that every time you multiply a number by 10, you move the decimal point in that number (how?) ____________.

---

1 PLACE TO THE RIGHT

---

231. For example, 9.37125×10^4 = ___________.

93712.5

---

232. Also 9.37125×10^5 = ____________.

937125

233. As well, 9.37125×10^6 = ____________.

9371250

234. In addition, 9.37125×10^{10} = ____________.

93712500000

235. If we now consider the number 9.37125×10^{23}, we know that it will be written as 9 followed by (how many?) ____ digits before the decimal point.

23

236. To find out how many 0's there will be in a number such as this, we simply subtract ____ (the number of digits after the 9 which are not 0) from 23. This gives us (how many?) ____ 0's.

5, 18

237. In other words, the number 9.37125×10^{23} is written as 937125 followed by (how many?) ____ 0's.

18

238. Similarly, the number 6.362×10^{42} is written as ______________.

6326 FOLLOWED BY 39 0's

239. You have reached the point where you should be able to understand what <u>Scientific Notation</u> is. A number is in scientific notation when it is written as some number that is greater than or equal to 1 and less than 10 multiplied by a 10 raised to some exponent. Another way of saying this, is: A number in scientific notation is written

as $k \times 10^n$ where "k" is a number greater than or equal to 1 and less than 10, and "n" is some exponent.

For example, the numbers 6.123×10^3 and 9.37125×10^{25} are both written in ____________________.

SCIENTIFIC NOTATION

240. Is the number 11.2×10^{12} written in Scientific notation?

(a) Yes — see frame 241A
(b) No — see frame 241B

241A. Your answer: Yes
is incorrect.
You will recall that a number in scientific notation should be written as $k \times 10^n$ where "k" is some number greater than or equal to ____, and less than _____.

1; 10

241A2. In the number 11.2×10^{12}, the number 11.2 is (greater/less) ________ than 10. Therefore, it is not in scientific notation.

GREATER

241A3. Go back, now, to frame 240 and choose the correct answer.

241B. Your answer: No
is correct.
You have realized that, in the number 11.2×10^{12}, 11.2 is greater than 10. Therefore, this number is not written in ______________ ______________.

SCIENTIFIC NOTATION Proceed, now, to frame 242

242. Is the number $.93 \times 10^{14}$ written in Scientific Notation?

(a) Yes see frame 243A
(b) No see frame 243B

243A. Your answer: Yes
is incorrect.
You will remember that a number in scientific notation is written as $k \times 10^n$, where "k" is less than ____ and greater than or equal to _____.

10; 1

243A2. You will notice that, in $.93 \times 10^{14}$, the number .93 is (greater/less) ____________ than ____. Therefore, this number can not be in Scientific Notation.

LESS; 1

243A3. Go back, now, to frame 242 and choose the correct answer.

243B. Your answer: No
is correct.
Is the number 6.236×10^2 written in Scientific notation?

(a) Yes see frame 244A
(b) No see frame 244B

244A. Your answer: Yes
is correct.
Finally, is the number 10.0×10^{42} written in Scientific notation?

(a) Yes see frame 245A
(b) No see frame 245B

244B. Your answer: No
is incorrect.
the number 6.326×10^2 certainly is in Scientific notation. The number 6.326 is less than 10 and greater than or equal to 1: and in 10^2, 2 is an acceptable exponent. If you are still confused on this point, go back to frame 239 and review Scientific notation in more detail. Otherwise, proceed to frame 243B and choose the correct answer.

245A. Your answer: Yes
is incorrect.
You have failed to understand the correct limits for "k" in the expression $k \times 10^n$. "k" is greater than or equal to 1, but less than 10. 10 can never be less than itself, therefore 10.0×10^{42} is not in scientific notation. If you are still confused on this point, go back to frame 239 and review scientific notation in more detail. Otherwise , proceed to frame 244A and select the correct answer.

245B. Your answer: No
is correct.
You have understood the correct limits for "k" in the expression $k \times 10^n$, in that you know that "k" is to be greater than or equal to ____ and less than ____.

1, 10 Proceed, now, to frame 246

---

246. Converting a number from the "long form" to Scientific notation is not difficult. All that you have to do is put a decimal point after the first digit in the number, count the number of digits to the right of the decimal point, and let that be the exponent "n" when you write 10^n. For example, the number 623000 can be converted to scientific notation if we put the decimal point between the digits 6 and 2. This leaves (how many?) ____ digits to the right of the decimal point.

5

---

247. Therefore, 623000, in scientific notation, is written as 6.23000 X ____.

10^5

---

248. The 3 0's after the decimal place are quite unnecessary, and, in fact, they can be left out. If we do this, our representation of 623000, in scientific notation, now looks like this: ________.

6.23×10^5

---

249. How would the number 93600 be written in Scientific notation?

(a) $.936 \times 10^5$ see frame 250A
(b) 9.36 see frame 250B
(c) 9.36×10^5 see frame 250C
(d) 9.36×10^4 see frame 250D
(e) I do not know see frame 250E

250A. Your answer: $.936 \times 10^5$
is incorrect.
The number .936 is less than 1, therefore, $.936 \times 10^5$ is not in Scientific notation. Go back to frame 249 and select a better answer.

250B. Your answer: 9.36
is incorrect.
You are missing something very important. In scientific notation you need a term consisting of 10 to some exponent. Go back to frame 249 and select a better answer.

250C. Your answer: 9.36×10^5
is incorrect.
You have the exponent wrong. Let us go back to the original number: 93600. The first step in changing this number into Scientific notation is, as you recall, to put the dedimal point after (which?) ________ digit.

THE FIRST

250C2. In other words, the decimal point is placed in between the digits ____ and ____.

9; 3

250C3. Next, we count all the digits to the right of the decimal point. There are (how many?) ____ of them.

4

250C4. This number (4) now becomes the value for ________ on 10^n.

THE EXPONENT or "n"

250C5. Hence this number, in scientific notation, is $9.3600 \times$ ____.

10^4

250C6. A simpler way of writing this is _____ X _____.

9.36 ; 10^4

250C7. Now go back to frame 249 and choose the correct answer.

250D. Your answer: 9.36 X 10^4
is correct.
Very Good!!!(For those of you who got this the first time). You should now be able to convert the number which we introduced at the beginning of this segment into Scientific notation. You will recall that the distance from our solar system to the next nearest star is about 25,200,000,000,000 miles. This number, in scientific notation is _______.

2.52 X 10^{13} Proceed, now, to frame 251

250E. Your answer: I do not know
Indicates one of two problems: Either you did not follow the developement in frames 246 - 248 closely enough, or you find yourself unable, for some reason, to formulate the correct answer to the question in frame 249. If your problem is the first of these, then go back to frame 246 and proceed from there. If not, continue on with the material in this frame: You will remember that the first step in changing a number (in this case 93600) into scientific notation is to put a decimal point after (which?) ____________ digit.

THE FIRST Proceed, now, to frame 250C2

251. The last topic that we will consider in talking about scientific notation, is the way in which numbers such as these are multiplied and divided. We will first consider the problem of multiplication:

Let us consider two numbers: 9.6 X 10^{10} and 2.4 X 10^{12}. You will notice, first of all, that both these numbers are in ____________ ____________.

SCIENTIFIC NOTATION

252. To multiply numbers together in Scientific Notation, you must multiply like parts of them together and then recombine the two results that you get to derive a final answer. As you know, numbers in Scientific notation are made up of two parts: One part (eg. 9.6) is written in decimal notation, the other (eg. 10^{10})is written in ____________ notation.

EXPONENTIAL

253. The multiplication which we are considering involves two steps. then. First, we multiply together the parts of the numbers which are in ______________ notation, then we multiply those parts which are in ______________ notation.

DECIMAL; EXPONENTIAL

254. If we are considering the problem $(9.6 \times 10^{10}) \times (2.4 \times 10^{12})$, we first multiply the decimal parts together --that is-- the numbers _____ and _____.

9.6; 2.4

255. When we do this (9.6×2.4), we come up with the number _____.

23.04

256. Next, we multiply the two exponential parts together --that is-- the numbers _____ and _____, remembering that the rule for multiplication in exponential notation is to ______________.

10^{10}; 10^{12}; ADD THE EXPONENTS

257. When we do this $(10^{10} \times 10^{12})$, we come up with the number _____.

10^{22}

258. If we now combine these two parts together, the result is the number _____ X _____.

23.04; 10^{22}

259.
You will notice however, that the number 23.04×10^{22} (is/is not) _____ in Scientific notation.

IS NOT

260. To correct this, we must move the decimal point in 23.04 so that it is now between the ____ and ____. The result is the number _____.
(which digits?)

2; 3; 2.304

261. Doing this has the same effect as dividing the number 23.04 by (how much?) _____.

10

262. To keep everything equal, however, we must multiply the exponential part (10^{22}) by (how much?) _____.

10

263. When we do this, the result is the number ______.

10^{23}

264. Our final answer, in scientific notation, then, is ____________.

2.304×10^{23}

265. What is the solution to the following problem (in scientific notation)?

$$(5.2 \times 10^{15}) \times (6.3 \times 10^{5}) = ?$$

(a) 3.276×10^{21} see frame 266A
(b) 327.6×10^{20} see frame 266B
(c) 32.76×10^{20} see frame 266C
(d) Darned if I know!?! see frame 266D

266A. Your answer: 3.276×10^{21}
is correct.
Your arithmetic has worked out quite well. We will now consider the problem of division in Scientific notation. Once again, we divide like parts of the numbers together and then recombine --that is-- we divide the two parts in ____________ notation, then the two parts in ____________ notation.

DECIMAL; EXPONENTIAL Proceed, now, to frame 267

266B. Your answer: 327.6×10^{20}
is incorrect.
Your answer indicates that you do not know how to multiply decimals. The problem of figuring out where the decimal point goes is, however, not difficult. You simply count the number of digits to the right of the decimal points in the two numbers that you are multiplying and let that be the number of digits to the right of the decimal point in your final answer. For example, consider the problem 6.12 X 7.3. In the number 6.12, there are (how many?) ___ digits to the right of the decimal point, and in the number 7.3 there are (how many?) ___ digits to the right of the decimal point.

2; 1

266B2. Altogether, then, there are (how many?) ___ digits to the right of the decimal points in these two numbers. Therefore, there will be (how many?) ___ digits to the right of the decimal point in the final answer.

3; 3

266B3. When we multiply 612 X 73, we get the number ________.

44676

266B4. Therefore, the result of 6.12 X 7.3 is the number ________.

44.676

266B5. Similarly, the result of 5.2 X 6.3 is the number ________.

32.76

266B6. Go back, now, to frame 265 and choose a better answer.

266C. Your answer: 32.76×10^{20}
is incorrect.
There is nothing wrong with the way in which you did the calculation; however you did forget to convert your answer to scientific notation. To do this, you must move the decimal point in 32.76 so that it is between the digits ____ and ____.

3;2

266C2. This has the effect of dividing the decimal part of your answer by ____.

10

266C3. To keep everything equal, then, you must multiply the exponential part by ____.

10

266C4. Your answer, in Scientific notation, then, is _____ X ____

3.276; 10^{21}

266C5. Go back, now, to frame 269 and select the correct answer.

266D. Your answer: Darned if I know!?!
indicates one to two things: Either you did not follow the developement from frame 251 closely enough, or you find yourself unable, for some reason, to calculate the correct answer. If your's is the first of these problems, go back to frame 251 and start the sequence again. Otherwise, continue on with the developement from this frame: You will recall that to multiply two numbers together, in scientific notation, it is necessary to multiply like parts of the numbers --that is--the ____________ part of one with that of the other, and the ____________ part of one with that of the other.

DECIMAL; EXPONENTIAL

266D2. In the problem $(5.2 \times 10^{15}) \times (6.3 \times 10^{5})$, for example, we multiply the two parts ____ and ____ together, then the two parts ____ and ____.

5.2; 6.3; 10^{15}; 10^{5}

266D3. When we do this (ie.--5.2 X 6.3, and 10^{15} X 10^{5}), we come up with the two results ______ and ______.

32.76; 10^{20}

266D4. Combining these gives us the number ______________.

32.76 X 10^{20}

266D5. To put this into scientific notation, we have to move the decimal point so that it is now between the digits ___ and ___.

3; 2 Proceed, now, to frame 266C2

267. As an example, let us take two numbers similar to those which we considered previously, and attempt the following problem:

$$\frac{2.4 \times 10^{15}}{9.6 \times 10^{10}}$$

If we first divide the decimal parts of both numbers, the result is 2.4/9.6 = ______.

.25

268. When we divide the exponential parts of both numbers (remembering that the rule for division in exponential notation is to ______________________), we come up with the result $10^{15}/10^{10}$= ______.

SUBTRACT THE EXPONENTS; 10^{5}

269. Combining these two results gives us the number _____ X _____.

.25; 10^{5}

270. Again, the number .25 X 10^{5} is not in Scientific notation. To put it into Scientific notation, we need to put the decimal point between the digits _____ and _____.

2; 5

271. This has the effect of multiplying the number .25 by _____.

10

272. To keep everything equal, we need to divide the exponential part by _____. The exponential part now becomes (what number?) _____.

10; 10^4

273. The answer, in Scientific notation, then, is ____ X ____.

2.5×10^4

274. What is the solution to the following problem (in scientific notation?)

$$\frac{1.3 \times 10^{50}}{2.6 \times 10^{21}} = ?$$

(a) 0.5×10^{29} see frame 275A
(b) 5.0×10^{70} see frame 275B
(c) 5.0×10^{28} see frame 275C
(d) One of the above. see frame 275D

275A. Your answer: 0.5×10^{29}
is incorrect.
There is nothing wrong with your calculation; however you have forgotten to convert your answer into Scientific notation. To do this, you must move the decimal point so that is is (where?) ____________.

AFTER THE FIVE

275A2. This has the effect of multiplying .5 by ____.

10

275A3. To keep things equal, we need to divide the exponential part of your answer by ____.

10

275A4. Your answer, in scientific notation, then, is ____ X ____.

5.0; 10^{28}

275A5. Go back, now, to frame 274 and select the correct answer.

275B. Your answer: 5.0×10^{70}
is incorrect.
You have forgotten how to divide in exponential notation. The rule for division in exponential notation is to (see frame 268) ____________.

SUBTRACT THE EXPONENTS

275B2. Go back, now, to frame 274 and select a better answer.

275C. Your answer: 5.0×10^{28} .
is correct.
You are to be commended for staying with the developement until this point. You will remember that we started this segment discussing objects called ______.

STARS Proceed, now, to frame 276

275D. Your answer: One of the above
is not incorrect; however it is obviously not explicit enough. It is fairly clear that you have become bored at this point. This is, as you might have guessed, another abort frame. We suggest that you set this book down for a while, and then, at some later time, continue on in the program starting from frame 274.

---

276. The nearest star to us which we call ________, is just one example out of this class of objects.

THE SUN

---

277. In the next several frames, we will attempt to acquaint you with some phenomena and a few facts that will help you to calculate how long we expect the sun to last. First, however, you will need to understand some units which we will use in this developement. The first unit which we will talk about is the centimeter. The centimeter (cm.) like the inch, is a measure of ____________.

LENGTH or, better -- DISTANCE

---

278. It takes, in fact, about 2½ centimeters to make up one inch. This means that an ordinary 12 inch ruler is about (how many?) ____ centimeters(cm.) long.

30

---

279. A distance of 300 cm., then, is about (how many?) _____ inches in length.

120

---

280. The second unit which we would like to introduce is the gram (g.). The gram, like the pound, is a unit of ___________.

WEIGHT, or better -- MASS

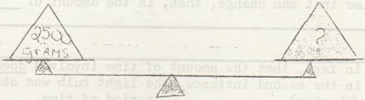
---

281. For example, there are about 500 grams(g.) in one pound. This means that a 10 pound object weighs about (how many?) ________ g.

5,000

---

282. The object at the right below would have to weigh (how many?) ____ pounds to balance the scales.



5

283. We have three more units to introduce: First, however, it will be necessary for you to be able to differentiate between two basic concepts: Energy and Power. You probably already have a good intuitive understanding of what Energy is. For example, a light bulb works by giving off ________.

ENERGY

284. Power, on the other hand, is defined as the rate of release of Energy. In fact, we can describe this relationship by using the following equation:

Power = Energy/Time

Another equation which we have considered earlier in the program, that is similar to this is: ______.

v = d/t

285. For example, suppose that you were able to measure the energy given off by a light bulb in some time period. Next, you take another light bulb and observe that it gives off the same amount of energy as the first, but during a shorter time period. How much Power is involved in this second instance?

(a) Less than was involved previously see frame 286A
(b) More than was involved previously see frame 286B
(c) The same amount that was involved previously see frame 286C
(d) There is not enough information available to answer this question see frame 286D

286A. Your answer: Less than was involved previously is incorrect.
We are considering the equation: Power = ______ / ______.

ENERGY; TIME

286A2. Something on the right hand side of this equation changes so that the amount of Power (on the left-hand side of the equation) changes. We know, from the question, that the amount of ________ released does not change.

ENERGY

286A3. The only thing left on the right hand side of the equation Power = Energy/Time that can change, then, is the amount of ________.

TIME

286A4. We know, in fact, that the amount of time involved does change, because, in the second instance, the light bulb was observed for a (longer/shorter) ____________ period of time.

SHORTER

286A5. Time appears as the bottom part of a fraction. Let us see what happens to a fraction as we decrease the value of its bottom part. For example, 3 is less than 4, however 1/3 is (greater/less) ________ than 1/4.

GREATER

286A6. Similarly, 2 is less than 3, however 5/2 is (greater/less) ________ than 5/3.

GREATER

286A7. Therefore, as you decrease the value of the bottom part of a fraction, the fraction, itself, becomes (larger/smaller) __________.

LARGER

286A8. Notice that Time is the bottom part of the fraction Energy/Time, the top part of which, as we have already discussed, does not change. In the example we are considering, the value for time (increases/decreases) ____________.

DECREASES

286A9. Therefore, the value of the fraction Energy/Time (increases/decreases) ______________.

INCREASES

286A10. You will recall that Energy/Time = ________.

POWER

286A11. Therefore, in the example we are considering, ________ increases.

POWER

286A12. Go back, now, to frame 285 and choose the correct answer.

286B. Your answer: More than was involved previously is correct.
You have realized that, in the equation Power = Energy/Time, as applied to our example, the value for Energy is staying the same, but the value for time is decreasing. The result of this is to increase the value for ____________.

POWER Proceed, now, to frame 287

286C. Your answer: The same amount that was involved previously is incorrect.
We are looking at the equation: Power = ________ / ________.

ENERGY; TIME Proceed, now, to frame 286A2

286D. Your answer: There is not enough information available to answer this question is incorrect.
We are looking at the equation: Power = ________ / ________.

ENERGY; TIME Proceed, now, to frame 286A2

---

287. One unit for energy is the Joule, another is the erg. The Joule and the Erg are both units of ____________.

ENERGY

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288. These units are related in the following way: 1 Joule = 10^7 Ergs. In other words, 5.3×10^7 ergs is equivalent to (how many?) ____ Joules.

5.3

---

289. 6.7×10^9 ergs equivalent to (how many?) _____ Joules.

670

---

290. 3.9 Joules is equivalent to (how many?) __________ ergs.

3.9×10^7

---

291. Units for Power are derived out of those for Energy. You will remember that Power and Energy are related to each other by the following equation: ____________________.

POWER = ENERGY/TIME

---

292. The unit for Power which we will consider is the watt. The watt is defined in the following way: 1 Watt = 1 Joule/second. In other words, 1 Watt = _____ ergs/second.

10^7

---

293. This means that a 60 watt light bulb releases (how many?) ____ Joules each second.

60

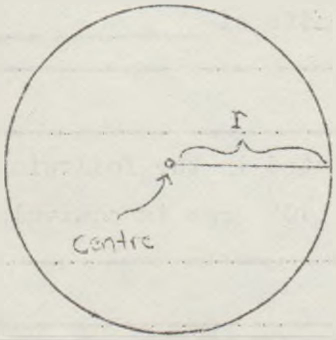
294. A 100 watt light bulb would release (how many?) ____ Joules each second.

100

295. It is clear, then, that a 100 watt light bulb would be (brighter/dimmer) ____________ than a 60 watt light bulb.

BRIGHTER

296. Two more things that we have to introduce, before beginning our developement on the lifetime of the Sun, are two equations: The first of these allows you to calculate the surface area of a sphere (or ball). To understand this, you will have to know what we mean by the radius of a sphere: The radius of a sphere is simply the distance between the centre of the sphere and its outside edge. For example, if the diagram below represents a slice taken through the centre of a sphere, the line drawn in (r) would represent the ______ of that sphere.



RADIUS

297. The formula for the surface area of a sphere, then, is this:

$$A = 4\pi r^2$$

where A represents Area
r represents radius
and π is a number approximately equal to ____.

3

298. For our purposes here, however, it will be conveniant to use a better approximation than this for "π". "π" is, in fact, closer to 3.1.

To illustrate how the formula $A = 4\pi r^2$ is used, we know, for instance, that a sphere of radius 3 inches would have a surface area of (how many?) ______ square inches.

111.6

299. The second equation that you will have to know attempts to relate Energy to Matter. This equation, developed by Albert Einstein, is the following:

$$E = mc^2$$

where E represents Energy, m represents mass, and c represents the speed of light.

To demonstrate how an equation such as this might be used, we will consider the following example: Given that the speed of light is 3×10^{10} cm./sec, if we were able to convert a 10 gram object into energy, the amount of energy that we would end up with would be equal to (how many?) ________ ergs.

9.0×10^{21}

---

300. This is a lot of energy!!! This is (how much?) ________ energy (in Joules), remembering that 1 Joule = 10^7 ergs.

9×10^{14} Joules

---

301. With this amount of Energy, we could keep (how many?) ________ 100 watt light bulbs burning for one second (remembering that 1 watt = 1 Joule/sec.).

9×10^{12}

---

302. In review of the material we have covered so far in preparation for the following developement, the centimeter is a unit of ________.

DISTANCE

---

303. The gram is a unit of ______.

MASS

---

304. Power is related to Energy by the following Equation: ________.

POWER = ENERGY/TIME

---

305. Two units for Energy are the ________, and the ________.

JOULE; ERG

---

306. A unit that is used to measure power is the ________.

WATT

---

307. 1 Watt = (how many?) ____ Joules/sec.
= (how many?) ____ ergs/sec.

1; 10^7

---

308. The equation for the surface area of a sphere is the following: ________.

$A = 4\pi r^2$

309. Einstein's equation, relating matter to energy, is the following: ________.

$E = mc^2$

310. In the next several frames, you will be manipulating several numbers in Scientific notation. If you are still uncertain about how numbers written in Scientific notation are multiplied together and divided, this would be a good time for you to review the contents of frames 265 and 274. If, on the other hand, you are ready to proceed, we must point out two things: First you should express all the answers that you calculate, in scientific notation. Secondly you should "round off" the decimal part of any answer that you get, to one decimal place. To illustrate how "rounding off" works, consider the number 3.14. This number is (closer to/farther from) ________ the number 3.1 than 3.2.

CLOSER TO

311. Hence, we can "round off" 3.14 (to one decimal place) by calling it the number ____.

3.1

312. Similarly, a number like 3.17 can be rounded off (to one decimal place) to the number ____.

3.2

313. For the sake of argument, we will consider a number like 4.25 to be closer to 4.3 than 4.2, hence, 4.25 can be rounded off (to one decimal place) to the number ____.

4.3

314. The purpose of the next several frames is to allow you to make some calculations regarding the power output of the Sun and to there-by determine how long we expect it to last. The first figure that you will need to know is this: 1 A.U. = 1.5×10^{13} cm. This, of course, means that the radius of the earth's orbit about the Sun is about (how many?) ________ centimeters long.

1.5×10^{13}

315. At this distance, the power output of the Sun can be measured to be .14 watts per square centimeter of area. This means that, on the average, the measured power of the sun over an area of 1 square cm. on the Earth is (how much?) ________.

.14 watts

316. If we assume that the Sun releases the same amount of power in every direction, then it is possible to say that it releases .14 watts over every square centimeter of area at (how many?) ______ centimeters from the sun.

1.5×10^{13}

317. The problem of finding how many square centimeters are involved here is equivalent to considering the surface area of a sphere placed just inside the Earth's orbit, or, in other words, a sphere whose radius is (how many?) ______ centimeters.

1.5×10^{13}

318. To calculate the area of such a sphere, we must use the equation: ______.

$A = 4\pi r^2$

319. When we plug in this value (1.5×10^{13}) for "r", (remembering that π equals about 3.1) the result is (how many?) ______ square centimeters.

2.9×10^{27}

320. We know that the power output to each one of these 2.9×10^{27} centimeters is (how many?) ______ watts.

.14

321. Therefore, to calculate the total power output of the Sun, it is simply a matter of finding out how many watts are involved for every square centimeter we are considering, taken together. This calculation can be done by multiplying the two numbers ____(number of watts per square centimeter) X ______ (number of square centimeters).

.14; 2.9×10^{27}

322. When we do this, the result is the number ______.

4.1×10^{26}

323. This number (4.1×10^{26}) is the total ______ output of the Sun in (what units?) ______.

POWER; WATTS

324. You will recall that 1 watt = (how many?) _____ ergs/sec .

10^7

---

325. Therefore, 4.1×10^{26} watts = ____________ X ____ ergs/sec.

4.1×10^{26}; 10^7

---

326. When we do the calculation outlined in the obove frame, we come up with the number ____________.

4.1×10^{33}

---

327. This number (4.1×10^{33}) is, as you will recall, the number of __________ in (how many?) ____________ watts.

ERGS/SEC. ; 4.1×10^{26}

---

328. This means that the Sun's energy output per second is (how much?) ____________________.

4.1×10^{33} ergs.

---

329. The Sun "works" by convering matter to energy. Thus, if we know how much energy is released by the Sun every second, we should be able to find out how much matter is converted to energy in this process. To do this, we must use the following equation which attempts to relate matter to energy: __________.

$E = mc^2$

---

330. We know the values for two of the letters in this equation already. These are the letters ____ and ____.

E; c

---

331. E = (how much?) ______________, and c = (how many?) ____________ cm./sec.

(see frame 299)

4.1×10^{33} ergs; 3.0×10^{10}

---

332. The only letter that we do not know the value of, then, is (which one?) ____.

---

m

---

333. However, we can calculate the value for "m" by knowing those for "E" and "c". First, however, we must re-arrange the equation $E = mc^2$ so that "m" stands by itself on one side. At this point in the program you should be able to re-arrange an equation of this sort. If you are still somewhat uncertain about this, however, we suggest that you go back and review frames 11B to 11B5 to recall how we developed d = v X t from v = d/t, before continuing on from this frame. Otherwise, you should be able to manipulate the equation $E = mc^2$ to get the equation: m = ____.

E/c^2

---

334. Using the values for E and c that we have already talked about, we can calculate that m = __________ / __________ grams.

4.1×10^{33}; 9.0×10^{20}

---

335. When we complete the calculation outlined in frame 334, we find that the value for "m" becomes (how much?) ______________.

4.6×10^{12} grams

---

336. What this means is that (how many?) __________ grams (of matter) are converted to Energy in the Sun every second.

4.6×10^{12}

---

337. 4.6×10^{12} grams is equal to about 5 million tons. Remember that 5 million tons represents the amount of ________ converted to ________ in the Sun (how often?) ________________.

MATTER; ENERGY; EVERY SECOND

---

338. We know, from Kepler's Third Law, that the mass of the Sun is equal to about 2.0×10^{33} grams. About .7 percent of this mass is available to be converted to energy. What this means is that, for every 100 grams of matter in the Sun, .7 grams can be converted to energy. 2.0×10^{33} = __________ X 100, (10^2)

2.0×10^{31}

---

339. Therefore, the amount of matter in the Sun that can be converted to energy is equal to .7 X __________ grams.

2.0×10^{31}

---

340. When we complete this calculation, we come up with the number __________.

1.4×10^{31}

341. This number (1.4×10^{31}) is, as you will recall, the amount of ______ ______________________________.

MATTER IN THE SUN THAT CAN BE CONVERTED TO ENERGY

342. If we assume that, when this "fuel" is used up, the Sun's lifetime is over, then we should be able to calculate about how long this particular star will last. We know, for instance, that (how many?) ______ ______ grams of matter are converted to energy in the Sun every second.

4.6×10^{12}

343. We also know that (how many?) __________ grams of matter are available in the Sun, to be converted.

1.4×10^{31}

344. Therefore, we should expect that the Sun will last __________ / __________ seconds.

1.4×10^{31}; 4.6×10^{12}

345. When we complete this calculation, we come up with the number __________.

3.0×10^{18}

346. This number (3.0×10^{18}) is, as you recall, the length of time that ______________________________ in (what units?) ____________.

WE EXPECT THE SUN TO LAST; SECONDS

347. We can convert this figure for seconds into one for years, knowing that there are 3.2×10^{7} seconds in one year. Therefore 1 second =(1/ __________) years.

3.2×10^{7}

348. Therefore 3.0×10^{18} seconds = (__________ / __________) years.

3.0×10^{18}; 3.2×10^{7}

349. When we do the above calculation, the result is the number __________.

9.4×10^{10}

350. This number (9.4×10^{10}) represents the length of time that we expect the Sun to last in (what units?) ________.

YEARS

351. Does the fact that the Sun may "burn out" after this time period worry you at all?

(a) Yes — see frame 352A
(b) No — see frame 352B
(c) Only at night — see frame 352C

352A. Your answer: Yes
may very well indicate a very genuine concern for humanity on your part. However it should be pointed out that there are other factors which threaten to shorten man's existance on this planet to much less than 9.4×10^{10} years. You would be well advised to redirect your concern to some of these factors. Go back to frame 351 and pretend that you are a little less concerned about this problem.

352B. Your answer: No
is quite realistic, if we remember how long a time period 9.4×10^{10} years actually is. We are now going to proceed to discuss matters relating to the brightness of stars. We have already considered the power output of one star (the Sun). Stars vary, however, in the amount of power that they put out. It should be obvious that the more power a star puts out, the (brighter/fainter) ________ that star will tend to be, at some distance.

BRIGHTER — Proceed, now, to frame 353

352C. Your answer: Only at night
might have some interesting philosophical implications; however it probably indicates a state of exhaustion on your part. This is an abort frame. If you have not done so recently, we suggest that you put the book down momentarily and take a break. When you feel ready to make a more coherent attack on these programmed materials, we suggest that you proceed from frame 351.

353. In Astronomy, the brightness of things is talked about in terms of something called Magnitude. To talk about the relative brightness of things in Astronomy, it is conveniant to use the term ________.

MAGNITUDE

354. Magnitudes are represented by a series of numbers: The greater the value of the number, the less the brightness of the object in question. For example, a star of magnitude 4 is (brighter/fainter) ________ than a star of magnitude 3.

FAINTER

355. A star of Magnitude 0 is (brighter/fainter) ______________ than a star of magnitude 2.

BRIGHTER

---

356. A negative number, like -2, is (greater/less) ____________ than 0.

LESS

---

357. Hence an object of magnitude -2 is (brighter/fainter) ____________ than one of magnitude 0.

BRIGHTER

---

358. An object of magnitude 1 would be (brighter/fainter) ____________ than one of magnitude -2.

FAINTER

---

359. To give you some idea of how bright objects are, whose magnitudes are represented by numbers like these, the faintest stars which you are able to see (on a dark clear night) are around magnitude 6. The brightest stars are around magnitude 0. The magnitude of the Sun is about -27. A star of magnitude 2 is (how many?) ___ magnitudes brighter than the faintest stars visable to the unaided eye, (how many?) ___ magnitudes fainter than the brightest stars, and (how many?) ___ magnitudes fainter than the Sun .

4; 2; 29

---

360. The telescope at Mount Palomar can photograph stars of magnitude 23. This is (how many?) ____ magnitudes fainter than the faintest stars visable to the unaided eye.

17

---

361. You will recall that, the brighter a star appears, at some distance, the (greater/less) ____________ its power output will tend to be.

GREATER

---

362. Hence, the greater the number representing the magnitude of a star, at some distance, the (greater/less) ___________ the power output of that star will tend to be.

LESS

---

363. Suppose, now, that all stars are the same colour and that you are out observing them under the night sky. You see a star, the magnitude of which you estimate to be equal to 1. The estimated magnitude of a second star is equal to 2. Is the power output of the first star greater than that of the second?

(a) Yes see frame 364A
(b) No see frame 364B
(c) Not necessarily see frame 364C

364A. Your answer: Yes
is incorrect.
Your answer assumes that both stars in question are about the same distance from you . It is quite possible that this is not the case. You know, in an intuitive way, that, as you increase the distance between yourself and a bright object, the object appears to become (brighter/fainter)_________________.

FAINTER

364A2. Hence, a star could very well be quite bright in itself --ie.--its power output is (great/small) _______--however this same star might, to us, appear to be quite faint, because it is __________.

GREAT; DISTANT or FAR AWAY

364A3. Hence, information on magnitudes of stars, by itself, tells un nothing about their power outputs, because different stars are differ-_________________ from us.

DISTANCES

364A4. Go back, now, to frame 363 and select a better answer.

364B. Your answer: No
is incorrect.
It is possible that you are confused by the fact that, although the power output of the first star is not necessarily greater than that of the second, it is still possible that this is the case. Return to frame 363 and select a better answer.

364C. Your answer: Not necessarily
is correct.
You have realized that the two stars in frame 363 may be at different distances from us, hence information regarding their magnitudes can not, by itself, allow us to say anything about their relative power outputs. The fact that we are talking about the brightness of stars as they appear to us suggests the term: Apparent Magnitude--the brightness of an object as it appears to us. It should be clear that the ______________________ of a star is affected by distance as well as power output.

APPARENT MAGNITUDE Proceed, now, to frame 365

365. In other words, the farther away a particular star is the (higher/lower) ____________ will be the number representing its apparent magnitude.

HIGHER

366. Suppose that the two stars mentioned in frame 363 actually had the same power output. From this, we would be able to conclude that the star whose apparent magnitude was 1 was actually (closer to/farther from) ________________ us than the star whose apparent magnitude was 2.

CLOSER TO

367. To talk about magnitudes of stars, in a way that refers, more closely, to their actual power output, we must use a different term: Absolute Magnitude. From the absolute magnitude of a star, it is possible to say something about its power output. Hence, absolute magnitude is based on how bright an object (eg. — a star) would appear at some fixed ______________.

DISTANCE

368. The distance that is used is 10 parsecs or (how many?) ____ light years (hint: see frame 59).

32.6

369. So, then, ____________________ is defined as the apparent magnitude a star would have, viewed from a distance of 10 parsecs.

ABSOLUTE MAGNITUDE

370. Hence, if we know the apparent and absolute magnitude of a star, it would be possible to calculate the _____________ from here to that star.

DISTANCE

371. For example, if two stars having the same absolute magnitude were observed to have different apparent magnitudes, we would be justified in concluding that the two stars are at different ___________ from us.

DISTANCES

372. Numerical calculations for distances, knowing absolute and apparent magnitudes are possible, using an equation. This equation allows us to calculate the distance to a particular star, by knowing two facts about that star: Its _____________________ and its ____________________.

APPARENT MAGNITUDE; ABSOLUTE MAGNITUDE

373. The equation that we use is the following: $r = 10^{\left(\frac{m - M + 5}{5}\right)}$

where "m" represents Apparent Magnitude
"M" represents Absolute Magnitude
and "r" represents distance (in parsecs)

It is important that you realize that $\left(\frac{m - M + 5}{5}\right)$ is an exponent.

For example, suppose that a star exists whose absolute magnitude is 2, and whose apparent magnitude is 7. The value for m, then, is ____ and that for M is ____.

7; 2

374. Therefore, the expression $\left(\frac{m - M + 5}{5}\right)$ takes on the value ____.

2

375. Going back to frame 373, we can now calculate that "r" is equal to 10 raised to the exponent ____.

2

376. Hence, "r" takes on the value ______.

100

377. What this means is that the star in question is (how far?) ____________ away.

100 PARSECS

378. So far, we have talked about exponents in a very intuitive way: You know, for instance, that

10^{11} means ____________________________.

11 10's MULTIPLIED TOGETHER

379.

A number like $10^{\frac{1}{2}}$ seems to be meaningless, in this context. However, a number like $10^{\frac{1}{2}}$ does have an actual numerical value, although it is beyond the scope of this program to discuss how such values are derived. Exponents like $\frac{1}{2}$ are fractions, hence they are called fractional exponents. To do meaningfull calculations with the equation for distance which we have introduced, it will be necessary for you to know how to work with fractional exponents. These exponents are usually expressed in decimal notation. For example, the decimal representation of $\frac{1}{2}$ is _____.

0.5

380. Hence, $10^{\frac{1}{2}}$ can be written as ____.

$10^{.5}$

381. $10^{2/5}$ can be written as _____.

$10^{.4}$

382. DATA FRAME ON FRACTIONAL EXPONENTS:

$$10^{.1} = 1.2$$

$$10^{.2} = 1.6$$

$$10^{.3} = 2.0$$

$$10^{.4} = 2.5$$

$$10^{.5} = 3.2$$

$$10^{.6} = 4.0$$

$$10^{.7} = 5.0$$

$$10^{.8} = 6.3$$

$$10^{.9} = 8.0$$

The above list contains some examples of fractional exponents of the number 10 and the approximate values of these numbers. You will find these usefull in the next several frames.

---

383. To determine values for numbers with fractional exponents, using information from the above data frame, is a simple procedure: To illustrate this, consider the example: $10^{1/3}$. The fraction 1/3 written as a decimal, rounded off to one decimal place, is ____.

.3

---

384. Therefore $10^{1/3}$ can be written as ____ (approximately).

$10^{.3}$

---

385. The value for $10^{.3}$, from the data frame (382) is ____.

2.0

---

386. The procedure, then, is quite simple: You simply convert the fractional exponent to a decimal, rounded off to one decimal place, and look up the value for 10 raised to that exponent in data frame 382. For example, $10^{5/8}$ = ____.

4.0

---

387. Let us consider an example using the equation for distance relating to Absolute and Apparent magnitude which is, as you recall, r = ____

$10^{\left(\frac{m - M + 5}{5}\right)}$

388. The brightest star in the night sky, Sirius, has an apparent magnitude of -1.4 and an obsolute magnitude of 1.5. Therefore, in this case, $\left(\frac{m - M + 5}{5}\right)$ = ___ / ___.

2.1; 5

389. 2.1/5 = ___ (rounded off to one decimal place).

.4

390. From the table, in data frame 382, you know that $10^{.4}$ = ___.

2.5

391. Therefore, we know that Sirius is (how far?) ___________ away.

2.5 Parsecs

392. The distance from here to Sirius is, therefore, (how many?) ______ light years.

8.15

393. Dealing with fractional exponents greater than 1 like $10^{3.2}$, for example, presents no problem. All that you need to do is split the number up and deal with it in two parts, for example, $10^{3.2} = 10^3$ X ___. (Hint: You remember that the rule for multiplication in exponential notation is to add the exponents).

$10^{.2}$

394. 10^3, written the "long way" is _____, and $10^{.2}$ = _____(see frame 382)

1,000; 1.6

395. Therefore, $10^{3.2}$ = ___ X ____ .

1,000; 1.6

396. When we do the above multiplication, the result is the number _____.

1,600

397. 1,600 is written, exponentially, as ____.

$10^{3.2}$

---

398. Let us consider another example: Polaris, the north star, has an apparent magnitude of 2.0 and an absolute magnitude of -4.6. What is its distance from us in light years?

(a) 2.3 light years — see frame 399A
(b) 7.5 light years — see frame 399B
(c) 652 light years — see frame 399C
(d) 200 light years — see frame 399D
(e) I do not know what to do with a negative exponent. — see frame 399E

399A. Your answer: 2.3 light years
is incorrect.
The number in your answer represents the value of the exponent we are using, ie.—the value of the expression $\left(\frac{m - M + 5}{5}\right)$ when you plug in the correct numbers for absolute and apparent magnitude. This number, however, is only an exponent. It is part of the equation r = ________ (see frame 373).

$10^{\left(\frac{m - M + 5}{5}\right)}$

399A2. "r" represents the distance to the star in question in (what units?) ________.

PARSECS

399A3. The exponent on the ten, in this case, is ____.

2.3

399A4. The value for $10^{2.3}$ is calculated by splitting $10^{2.3}$ into two parts:

$10^{2.3} = 10^{2} \times$ ____.

$10^{.3}$

399A5. 10^{2} = ____ (written the "long way"), and $10^{.3}$ = ____ (see frame 392).

100; 2.0

399A6. So, then, 10^2 X $10^{.3}$ = _____.

200

399A7. This number (200) represents ______________________.

THE DISTANCE TO POLARIS IN PARSECS

399A8. To convert this to a distance in light years, it is necessary to know that 1 parsec = (how many?) ______ light years (see frame 59).

3.26

399A9. Therefore, Polaris is _____ X 3.26 light yrs. away from us.

200

399A10. Go back, now, to frame 398 and choose a better answer.

399B. Your answer: 7.5 light years
is incorrect.
This answer indicates that you have not handled the exponent correctly. You will recall that the equation for distance, using absolute and apparent magnitude is r =

_______________.

$$10^{\left(\frac{m - M + 5}{5}\right)}$$

399B2. Polaris has an apparent magnitude of 2.0 and an absolute magnitude of -4.6. Therefore, in this instance, m = _____ and M = _____.

2.0; -4.6

399B3. When we plug in these values for "m" and "M", the expression $\left(\frac{m - M + 5}{5}\right)$ becomes equal to _____.

2.3 Proceed, now, to frame 399A2

399C. Your answer: 652 light years
is correct.
This is a commendable effort on your part. As you already know, the "mascot" for the project that produced this book is the star Zubenelgenubi. The apparent magnitude of this star is 2.8, and its absolute magnitude is 1.2. From this, we can conclude that Zubenelgenubi is (how far?) ___________ away (in parsecs).

---

20 PARSECS Proceed, now, to frame 400

399D. Your answer: 200 light years
is incorrect.
The number in your answer represents the distance to Polaris in parsecs. To convert this to a distance in light years, we must remember that 1 parsec = (how many?) _____ light years (see frame 59.)

3.26 Proceed, now, to frame 399A9

399E. Your answer: I do not know what to do with a negative exponent. is, of course, inadequate. If you did the question correctly, you should not have come up with a negative exponent. It is possible that you have the values for "m" and "M" mixed up. You will remember, from frame 373, that "m" represents _______________ and "M" represents _______________.

APPARENT MAGNITUDE; ABSOLUTE MAGNITUDE

399E2. The star Polaris has an absolute magnitude of -4.6 and an apparent magnitude of 2.0. Therefore "m" = _____ and "M" = _____.

2.0; -4.6

399E3. When we substitute these numbers into the expression $\left(\frac{m - M + 5}{5}\right)$,

we get _____ - (_____) + 5 on the top part of the fraction.

2.0; -4.6

399E4 . When two "-" signs occur together, they can be replaced by a "+" sign. Hence, 2.0 - (-4.6) + 5 = _____ + 5

6.6

399E5. Hence the value of $\left(\frac{m - M + 5}{5}\right)$ is now equal to _____.

2.3

399E6. Go back, now, to frame 398 and select a better answer.

---

400. As another example, consider this: The absolute magnitude of the Sun is approximately 4.8, and the faintest magnitude visable to the unaided eye is about 6. How far could you go out into space (in parsecs) and still see "home" (ie.--the Sun).

(a) 16 parsecs — see frame 401A
(b) 1.2 parsecs — see frame 401B
(c) 6.3 parsecs — see frame 401C
(d) I am puzzled — see frame 401D

401A. Your answer: 16 parsecs
is correct

You have indicated that you understand how to use the equation:
$r = 10^{\left(\frac{m - M + 5}{5}\right)}$ and that you know what apparent and absolute magnitude are. We are now going on to discuss matters related to the temperatures of stars. Temperature is another factor that helps to determine the magnitude of stars. Temperature, therefore, is related to the ______________ of stars.

BRIGHTNESS Proceed, now, to frame 402

401B. Your answer: 1.2 parsecs
is incorrect.
The number in your answer represents the solution to the expression $\left(\frac{m - M + 5}{5}\right)$ when the correct values for "m" and "M" are put in.
However, you will recall that the equation for distance is this:
r =

______________.

$10^{\left(\frac{m - M + 5}{5}\right)}$

401B2. So, then, the number 1.2 is the ______________ on the 10.

EXPONENT

401B3. You should now be able to calculate the correct answer. If you do not feel that you can do this, you would be well advised to review the question in frame 398. If not, return to frame 400 and select a better answer.

401C. Your answer: 6.3 parsecs
is incorrect.
You have mixed up the values for "m" and "M". This indicates that you probably do not understand the question. You are given, first of all, the absolute magnitude of the Sun which is (see frame 400)
_____.

4.8

401C2. This means that the value of "M", in this case, is _____.

4.8

401C3. The question asks how far from the sun you would have to be for it to <u>appear</u> to be of magnitude 6. In other words, what is asked for, then, is the distance at which the Sun would have to be to have an apparent magnitude of (how much?) _____.

6

401C4. Hence, the value for "m" is, in this case, equal to (what number?) _____.

6

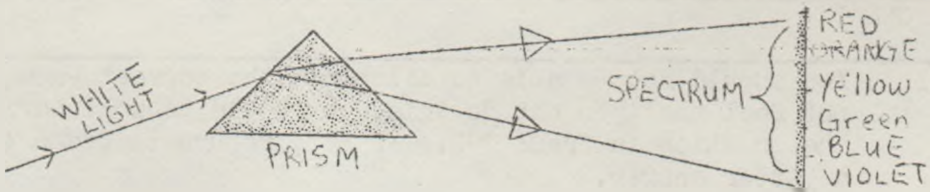
401C5. All that we do now is substitute these values for "m" and "M" into the equation r = __________.

$10^{\left(\frac{m - M + 5}{5}\right)}$ Proceed, now, to frame 401B3

401D. Your answer: I'm puzzled
is, of course, inadequate.
It is obvious that you do not understand the question. First of all, you are informed that the absolute magnitude of the Sun is (see frame 400) _____.

4.8 Proceed, now, to frame 401C2

402. To understand matters relating to the temperatures of stars, it is important that you understand something about light. Consider the following experiment: The passing of white light through a prism results in a band of different colours (see diagram below).



This experiment suggests that white light is, in fact, "made up" of different __________.

COLOURS

403. This observation is, in fact, quite correct: There are, in fact, different "kinds" of light. Our eyes can detect different kinds of light by seeing different __________.

COLOURS

404. Colours of objects which emit light are related to their temperatures --ie.--light sources of different temperatures emit different colours of light. Assuming that stars are different temperatures, do you now think that the assumption that we made in frame 363 (that all stars are the same colour) is correct?
(a) Yes see frame 405A
(b) No see frame 405B
(c) Only if stars are the same colour. see frame 405C

405A. Your answer: Yes
is incorrect.
We have already pointed out that stars have different outside temperatures and that colour varies with temperature. Hence, it is reasonable to assume that stars are different ________.

COLOURS

405A2. Go back, now, and choose a better answer (frame 404).

405B. Your answer: No
is correct.
Stars, by virtue of the fact that they have different "outside" temperatures, are different colours, These colours generally vary along the spectrum from the red end to the blue end. "Reddish" colours indicate lower temperatures. Conversely, "bluish" colours indicate ________ temperatures.

HIGHER Proceed, now, to frame 406

405C. Your answer: Only if stars are the same colour
indicates that you are obviously not thinking clearly. This, in fact, would be a good time for you to take a break if it has been a long time since you have done so. This, as you probably recognize, is another abort frame. Please take a break, then resume your work in the program starting from frame 404.

406. The progression of colours, as temperature increases, is generally as follows: Red → Yellow → White → Blue. In other words, the "outside" temperature of the Sun (a yellowish star) is (greater/less) ________ than that of a bluish coloured star, and (greater/less) ________ than that of a reddish coloured star.

LESS; GREATER

407. Looking out at the night sky, all stars appear to be white. However we know that this is not really the case, because stars have different ________ and are, therefore, different colours.

"OUTSIDE" TEMPERATURES

408. The fact that stars appear to be white in the night sky is more a property of the human eye than of the stars themselves. You know from your own experience, for instance, that, as dusk approaches, your ability to see colour (increases/decreases) ________.

DECREASES

409. Therefore, the human eye does not see colour well when there is (much/little) ________ light to see.

LITTLE

410. In Astronomy, colours of stars are described in terms of something called <u>spectral class</u>. It should be clear that spectral class also describes the ________ of stars.

TEMPERATURES

411. Different spectral classes are distinguished by naming them using different letters of the alphabet. The following spectral classes will be of concern to us here: O; B; A; F; G; K; M. These are listed in order from the more "bluish" stars(O) to the more "reddish" stars (M). For example, a star of spectral class K would be (more/less) _________ bluish than reddish.

LESS

412. A conveniant mneumonic device for remembering these spectral classes is to fit the letters into a sentence, such as:"O Be A Fine Girl, Kiss Me."; remembering that the sequence:O; B; A; F; G; K; M, goes from (what colour?) _________ stars to (what colour?) _________ stars.

BLUISH; REDDISH

413. The sentence: "O be a fine girl, kiss me." is a good memory aid for recalling the spectral classes of stars which are represented by the following sequence of letters: ___________________.

O, B, A, F, G, K, M

414. A mneumonic device for remembering spectral classes is the sentence: "________________________________."This gives us the sequence of letters: _______________ which represent spectral classes of stars from (what colour?) ___________ stars to (what colour?) _______________ stars in that order.

OH BE A FINE GIRL, KISS ME; O, B, A, F, G, K, M; BLUISH; REDDISH

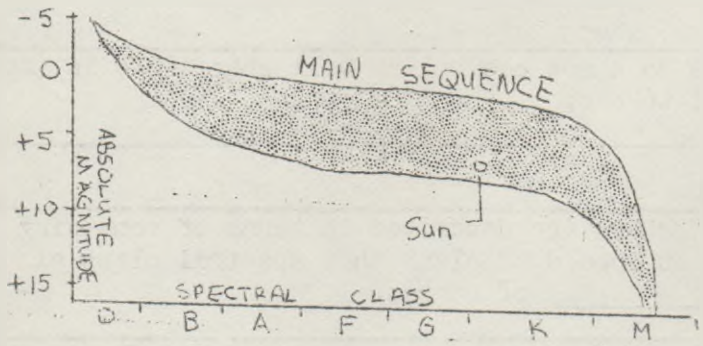
415. Information concerning the colours of stars also tells us something about their _______________________.

"OUTSIDE" TEMPERATURES

416. We have now come to the point where we can talk about a relationship that exists between spectral class and magnitude. Magnitude, as you recall, is a way of talking about the ___________________ of stars.

BRIGHTNESS

417. A graph describing this relationship appears below:



Spectral Classes
—
Absolute Brightness Graph

417(cont...) .

When the values (for absolute magnitude and spectral class) for most stars are plotted, they fall into the region described by the shaded area. This area is known as the main sequence (the position of the Sun on the main sequence is shown on the diagram). What this relationship means is that the more "reddish" a star is, the (brighter/fainter) ____________ it will tend to be.

FAINTER

---

418. You will also remember that spectral class describes temperatures of stars in that the "outside" temperatures of "bluish" stars are (higher/lower) _____________ than those of "reddish" stars.

HIGHER

---

419. Therefore, the relationship depicted in frame 417 can also be stated in another way by saying that, the higher the "outside" temperature of a star, the (greater/less) ___________ will tend to be its brightness.

GREATER

---

420. Before we review the concepts that we have covered in this section on stars, it is important that we discuss one more feature of stars: their masses. You will recall that we are able to determine the mass of the nearest star to us (the Sun) by using (see frame 338) ________ ___________________.

KEPLER'S THIRD LAW

---

421. Kepler's third law is stated mathematically, in the following way:

___________________.

$$\frac{a^3}{p^2} = \frac{G}{4\pi^2}\left(M_1 + M_2\right)$$

---

422. In the above equation, "a" represents _____________, "p" represents _____________, "G" represents _____________ and "M_1" and "M_2" represent _________________.

DISTANCE; PERIOD; THE GRAVITATIONAL CONSTANT; THE MASSES OF TWO BODIES

---

423. In the expression for Kepler's third law, the letters ____, ____, ____, and ____ represent variables --ie.--numbers that change with the examples we are considering.

---

a; p; M_1; M_2

---

424. In the case of the one example which we have already considered (the Sun), we are able to observe the motions of planets associated with it. In the case of any particular planet, we know its distance from the Sun --ie.--the value for the variable ____, and the length of time it takes to orbit the Sun once --ie.-- the value for the variable ____.

---

a; p

---

425. From knowing values for these two variables, it is possible to calculate those for the other two: ie.--____ and ____.

M_1 ; M_2

---

426. That is to say, it is possible to say something about the masses of the Sun and one of its planets, by knowing the ____________ between them and the __________ associated with their motions.

DISTANCE; PERIOD

---

427. Unfortunately, we do not, at present, have the facilities to observe planets around other stars (if, indeed, they do exist). However, estimates concerning the masses of some of them are still possible using the same tool that we used to make this kind of estimate for the Sun: That is, we again use ______________________________.

KEPLER'S THIRD LAW

---

428. Most of the stars whose masses we can estimate in this way, are part of binary systems. A binary system is an instance where two stars exist in close proximity to one another, in such a way that the gravitational attraction between them can be studied. In a way similar to the one which we used to calculate the mass of the Sun, we can determine the masses of stars in a binary system by knowing the ______________ between them and the ______________ associated with their regular motions with respect to one another.

DISTANCE; PERIOD

---

429. It should be obvious that the regular motions observed for two stars in a binary system is a result of ______________________ attraction between them.

GRAVITATIONAL

---

430. That is, for a binary system, we know the values for the variables ____ and ____ in the Kepler's third law equation (which is ____________)

From this, we can calculate the values for the variables ____ and ____.

---

a; p; $\frac{a^3}{p^2} = \frac{G}{4\pi^2}\left(M_1 + M_2\right)$; M_1; M_2

---

431. Most of the stars whose masses have been calculated in this way, fall within the range: .1 to 100 solar masses, where 1 solar mass is is equal to ______________________.

THE MASS OF THE SUN

---

432. From this we can conclude that the Sun is a (small/middle/large) __________ sized star, where mass is concerned.

SMALL

---

433. It is now time to review some of the concepts that we have learned in this segment which has dealt mostly with objects called ________.

STARS.

---

434. One example of a star (the one with which we are most familiar) is called ________.

SUN

---

435. It is possible to make a rough calculation regarding how long we expect the Sun to last by knowing its _______________.

POWER OUTPUT

---

436. The centimeter (cm.) is a unit of _____________.

DISTANCE

---

437. The gram (g.) is a unit of _________.

MASS

---

438. The equation relating Power to Energy is as follows: ___________.

POWER = ENERGY/TIME

---

439. Two units for Energy are the _________ and the _________.

JOULE; ERG

---

440. One unit for Power is the _____.

WATT

---

441. 1 Watt = (how many?) _____Joules/sec.
= (how many?) _____Ergs/sec.

1; 10^7

---

442. The equation for the surface area of a sphere is the following: __________.

$A = 4\pi r^2$

443. Einstein's equation relating matter to Energy is as follows: ______.

$E = mc^2$

444. A number, in scientific notation, is written as: $k \times 10^n$, where "n" represents ______________, and "k" represents ______________.

THE VALUE OF SOME EXPONENT; A NUMBER GREATER THAN OR EQUAL TO 1 AND LESS THAN 10

445. In Astronomy, the brightness of things is talked about in terms of something called ____________.

MAGNITUDE

446. Two kinds of magnitude are __________ and __________.

APPARENT MAGNITUDE; ABSOLUTE MAGNITUDE

447. Apparent magnitude refers to ______________ while absolute magnitude is defined as ______________.

THE BRIGHTNESS OF OBJECTS AS THEY APPEAR TO US; THE APPARENT MAGNITUDE AN OBJECT WOULD HAVE AT A DISTANCE OF 10 PARSECS

448. An equation which allows us to calculate distances, knowing absolute and apparent magnitude, is the following:

__________.

$$r = 10^{\left(\frac{m - M + 5}{5}\right)}$$

449. In the above equation, "m" represents __________, "M" represents __________, and "r" represents __________.

APPARENT MAGNITUDE; ABSOLUTE MAGNITUDE; DISTANCE (IN PARSECS)

450. For stars, colour is related to ______________.

"OUTSIDE" TEMPERATURE

451. The more "blue" a star is the (greater/less) ______ will be its outside temperature, while the more "red" a star is, the (greater/less) ______ will be this temperature.

GREATER; LESS

452. Stars are classified this way in terms of something called ________ ________.

SPECTRAL CLASS

---

453. Seven spectral classes from the blue to the red end of the spectrum can be listed consecutively as follows: ____________________.

O, B, A, F, G, K, M

---

454. The higher the "outside" temperature of a star, the more (red/blue) _____ the star will tend to be, and the (brighter/fainter)__________ the star will tend to appear.

BLUE; BRIGHTER

---

455. The masses of some stars can be calculated by using ______________.

KEPLER'S THIRD LAW

---

456. Most of the stars whose masses we can calculate in this way are part of ______________________.

BINARY SYSTEMS

---

457. You have completed this section of the program on stars. If you have not taken a break recently, we suggest that you do so before continuing on in the program.

---

458. This final segment of the program will be a relatively short one. Its aim is to help you come to some understanding of the structure of the Universe as we know it. Hopefully it will also allow you to review some of the concepts you have learned previously. One type of object that helps to make up the Universe is something we have already discussed in some detail. These light emitting sources are called _____.

STARS

---

459. Stars are organized into huge "islands" in space known as Galaxies. These galaxies are then separated by great distances. A __________ then, is simply a very large collection of stars.

GALAXY

---

460. The Sun is situated in one of these vast collections of stars called the Milky Way galaxy. Our galaxy (which is shaped like a disk or "plane") contains approximately 200 billion stars. In scientific notation, we would express this as (how many?) ______________ stars.

2.0×10^{11}

---

461. This is quite a large number. In fact it has often been remarked that there are more stars in our galaxy than there have been people who have ever lived on the face of this planet. Numbers such as this are extremely hard to visualize. To help you out in this respect, we are going to develop a few models of the galaxy based on things with which you are familiar in your every day life. At this point, we would like you to go back to frame 61 and do the question presented there. When you are sure that you have the correct answer, continue on with the material in frame 462.

---

462. You will remember, from frame 61, that the number of solar system diameters between our Sun and the nearest star is (how many?) ______.

3,160

---

463. If we were now to construct a model of our own region of space, with the diameter of our solar system being represented by a distance of 1 inch, then the next nearest star, on this scale, would be (how many?) ________ inches away.

3,160

---

464. In other words, on this scale, the next nearest star is (how many?) ______ yards (rounded off to one decimal place) away.(1 yard = 36 inches)

87.8

---

465. This is almost the length of a football field. In other words, the nearest star to our system is almost as distant as the length of a football field, on a scale that would have the diameter of the solar system represented by a distance of ________.

---

1 INCH

---

466. If we assume that the diameter of the Sun is 1/100 A.U.s , how large would it be, on the same scale (remembering that the diameter of our solar system is 80 A.U.s, and that this diameter is represented by a distance of one inch.)?

(a) 1/80	inch.	see frame 467A
(b) 1/8,000	inch.	see frame 467B
(c) 1/100	inch.	see frame 467C
(d) I do not know.		see frame 467D

467A. Your answer: 1/80 inch.
is incorrect.
This answer would only be right if the diameter of the Sun was 1 A.U. That is, if the diameter of the solar system (80 A.U.s) is represented by 1 inch, a distance of 1 A.U. would be represented by 1/____ of this distance, or (how many?) ______ inches.

80; 1/80

467A2. However the diameter of the Sun is only 1/100 A.U., where 1 A.U. is represented on our scale, you will recall, as (how many?) ____ inches.

1/80

467A3. That is to say, the diameter of the Sun, on our scale, would be represented by 1/100 X _____ = _____ inches.

1/80; 1/8,000

467A4. Go back, now, to frame 466 and choose the correct answer.

467B. Your answer: 1/8,000 inch.
is correct.
You realize immediately that a diameter such as this would be much too small to be perceptable, so let us try something else: Let us represent the size of the Sun by a grain of sand. The kind of sand we are working with is of such a size that 20 grains of it, lined up side by side, in a straight line, would measure 1 inch in length. That is, the length of one grain of sand is (how many?) _____ inches.

1/20 Proceed, now, to frame 468

467C. Your answer: 1/100 inch.
is incorrect.
Your answer would only be right if the diameter of the solar system was 1 A.U. In this case, the Sun, being 1/100 A.U. in diameter, and the diameter of the solar system being represented by one inch, the diameter of the Sun would be represented by (how many?) _____ inches.

1/100

467C2. However the diameter of the solar system is 80 A.U.s . That is, if the diameter of the solar system is to be represented by 1 inch, then a distance of 1 A.U. would be represented by 1/ ____ of this distance or (how many?) _____ inches.

80; 1/80 Proceed, now, to frame 467A2

467D. Your answer: I do not know
is, of course, insufficient.
Let us develop the correct answer: We are representing the diameter of the solar system (a distance of 80 A.U.s) by a distance of one inch. On this scale, a distance of 1 A.U. would be represented by 1/ ____ of this distance or (how many?) _____ inches.

80; 1/80 Proceed, now, to frame 467A2.

468. In our new model, then, the diameter of the Sun is represented by a distance of (how many?) ____ inches.

1/20

469. You will recall that the actual diameter of the Sun is (how many?) _____ A.U.s.

1/100

---

470. What this means, then, is that, in our model, a distance of 1/100 A.U.s is represented by (how many?) _____ inches.

1/20

---

471. On this same scale, a distance of 1 A.U. would be represented by (how many?) _____ times as much as this(ie.--the distance in the previous frame), or (how many?) _____ inches.

100; 5

---

472. As you will recall, the solar system is (how many?) _____ A.U.s in diameter.

80

---

473. So, then, the diameter of the solar system, on this scale, would be represented by _____ X _____ = _____ inches.

80; 5; 400

---

474. This means that, if the Sun's size were to be represented by a grain of sand (ie.--the diameter of the Sun is represented by a distance of 1/20 inches) then the solar system would be (how many?) _____ yards. (rounded off to one decimal place) across. (1 yard = 36 inches)

11.1

---

475. You will recall, from frame 61, that the number of Astronomical units in one light year is (how many?) _________ and that the nearest star to our system is (how many?) _____ light years distant.

63,200; 4

---

476. This allows you to conclude, then, that the distance from here to the nearest star outside our solar system is _________ X _____ = _________ A.U.s .

63,200; 4; 252,800

---

477. On our scale (where the size of the Sun is represented by a grain of sand 1/20 inches across) a distance of 1 A.U. is represented by (how many?) _____ inches.

5

---

478. A distance of 252,800 A.U.s then, would be represented by _______ X _____ = ___________ inches.

252,800; 5; 1,264,000

479. In other words, on the scale which we are using, the distance to the nearest star outside our own solar system would be (how many?) ______ miles (rounded off to one decimal place) in length. (1 mile = 63,360 inches)

19.9

480. At this point, we are going back and consider, once again, the number of stars in our galaxy which, as you will recall (see frame 460) is (how many?) ____________.

200 Billion or 2.0×10^{11}

481. Let us assume that the average diameter of these stars is equal to that of the Sun --ie.--this average diameter is (how many?) ______ A.U.s in length.

1/100

482. On the scale we have been working with, then, the stars in our galaxy would be represented by grains of sand each of which would be (how many?) ______ inches in length.

1/20

483. To demonstrate how large a number like 2.0×10^{11} is, we are going to attempt to pack all of the grains of sand that represent stars in our galaxy, into one pile. The size of this pile will, hopefully, provide you with some conception of the meaning of a number like 2.0×10^{11} which, as you remember, represents ____________ ____________.

THE NUMBER OF STARS IN THE MILKY WAY GALAXY

484. If we assume that each of the grains of sand that we are using to represent a star in our galaxy, is roughly cube-shaped, then each side of the grain of sand will measure (how much ?) ____________ in length.

1/20 INCHES

485. The volume of a cube (ie.--the amount of space it occupies) can be calculated by multiplying its length times its width times its height. In the example we are considering, length, width, and height are all equal to (how mcuh?) ____________.

1/20 INCHES

486. Hence, the volume of one grain of sand is given by the expression: _____ X _____ X _____ cubic inches.

1/20; 1/20; 1/20

487. When the above multiplication is performed, the result is the number: _________.

1/8,000

488. This number (1/8,000) represents the _________ of one grain of sand in (what units?) __________________.

VOLUME; CUBIC INCHES

489. From this, we can conclude that 2.0×10^{11} grains packed together in one pile would have a volume of ___________ X _________ cubic inches.

2.0×10^{11}; 1/8,000

490. When we perform the multiplication indicated in the previous frame, we come up with the fraction: ___________ / _________.

2.0×10^{11}; 8,000

491. The bottom part of this fraction can be written, in scientific notation, as _________.

8.0×10^3

492. This fraction, then, can now be written as _________ / _________.

2.0×10^{11}; 8.0×10^3

493. If we now divide the top part of this fraction by the bottom part, the result (in scientific notation) is the number __________.

2.5×10^7

494. This number (2.5×10^7), represents the _________ in (what units?) __________________ of (how many?) _________ grains of sand packed together in one pile.

VOLUME; CUBIC INCHES; 2.0×10^{11}

495. Let us suppose that we wish to pile this amount of sand on a lot 100 feet long by 25 feet wide. The dimensions of this lot, in inches, are: (how many?) ______ inches long by (how many?) ____ inches wide.

1200; 300

496. We know that the volume of sand that we are going to pile on this lot will be equal to (how much?) ____________________.

2.5 X 10^7 CUBIC INCHES

497. Therefore, in the expression Volume = Length X Width X Height, we know the values for the variables ________, ________ and ________.

VOLUME; LENGTH; WIDTH

498. When we substitute these numbers into the equation above, for volume, the result is the expression: (how many?) ________ cubic inches = (How many?) ________ inches X (how many?) ________ inches X ________.

2.5 X 10^7; 1200; 300; HEIGHT

499. The numbers 1200 and 300 are written, in scientific notation, as ________ and ________ respectively.

1.2 X 10^3; 3.0 X 10^2

500. The result of the multiplication of those two numbers is the number ________.(in scientific notation)

3.6 X 10^5

501. Our expression for Volume, then, can now be written as: (how many?) ________ cubic inches = (how many?) ________ square inches X ________.

2.5 X 10^7; 3.6 X 10^5; HEIGHT

502. To determine an expression for the variable HEIGHT, we must divide each side of the above equation by (how much?) ________________.

3.6 X 10^5 SQUARE INCHES

503. When this is done, it is now possible to express the equation as HEIGHT = ________ / ________.

2.5 X 10^7 CUBIC INCHES; 3.6 X 10^5 SQUARE INCHES

504. When we perform the division indicated in the above frame, the result is the number ________(in scientific notation with the decimal portion rounded off to one decimal place).

6.9×10^1

---

505. This number (69) is the ________ in (what units?) ________ of a box-shaped pile of sand on a lot whose dimensions are (how many?) ______ feet long, by (how many?) ______ feet wide, where each grain of sand represents ________________________.

HEIGHT; INCHES; 100; 25; A STAR IN THE MILKY WAY GALAXY

---

506. The height in the above frame (69 inches) is equal to (how many?) _____ feet (rounded off to one decimal place).

5.8

---

507. In other words, if we were to represent each star in our galaxy by a grain of sand (how many?) ____ inches long, we could pack all of this sand into a pile of dimensions: (how long?) ________, by (how wide?) ________, by (how high?) ________.

1/20; 100 FEET; 25 FEET; 5.8 FEET

---

508. Stars are not packed together like this, in our galaxy, however. You will recall that the distance between the Sun and the nearest star to to it, on this same scale (ie.--where stars are represented by grains of sand) is (how long?) _________(see frame 479).

19.9 MILES

---

509. The length of the galaxy is about 100,000 light years. This can be expressed, in scientific notation, as (how many?) ________ light years.

1.0×10^5

---

510. You will recall, from earlier in this segment (see frame 475) that 1 light year = (how many?) ________ A.U.s .

63,200

---

511. This number (63,200) can be expressed, in scientific notation, as ________ (with the decimal part of it rounded off to one decimal place).

6.3×10^4

---

512. We can now calculate the distance, in A.U.s, from one end of the Milky Way Galaxy to the other: This is given by the expression: ________ X ________ A.U.s .

6.3×10^4; 1.0×10^5

513. When we do the multiplication indicated above, the result is the number ___________(in scientific notation).

6.3×10^9

514. This number (6.3×10^9) represents the _______ of the Milky Way Galaxy in (what units?) ____________________.

LENGTH; ASTRONOMICAL UNITS (A.U.s)

515. You will recall, from earlier in this segment (see frame 471) that a distance of 1 A.U. on the scale we are using, is equal to (how much?) ____________.

5 INCHES

516. Therefore, on this same scale, a distance of 6.3×10^9 A.U.s would be represented by _________ X ____ = _________ inches (in Scientific notation, with the decimal portion rounded off to one decimal place).

6.3×10^9; 5; 3.2×10^{10}

517. You will recall (see frame 479) that 1 mile is equal to (how many?) _________ inches.

63360

518. This number can be expressed, in scientific notation, with the decimal portion of it rounded off to one decimal place, as (how many?) ___________ inches.

6.3×10^4

519. Remembering that the diameter of our model of the Galaxy, in inches, is (how much?) _________, you should be able to calculate that this same diameter, in miles, will be _________ / _________ miles.

3.2×10^{10}; 3.2×10^{10}; 6.3×10^4

520. When the division, indicated in the above frame, is performed, the result is the number _________ (in scientific notation, with the decimal portion rounded off to one decimal place).

5.1×10^5

521. This number (510,000) represents the ________________ where individual stars are represented by grains of sand (how much?) ________________ in length.

THE DIAMETER OF A MODEL OF THE MILKY WAY GALAXY IN MILES; 1/20 INCHES

522. 510,000 miles is approximately equal to the diameter of the Moon's orbit around the Earth. Our model of the Galaxy, then, (would/would not) ________________ be very practical to construct.

WOULD NOT

523. For the next few frames, we are going to discuss the contents of galaxies. You are already familiar with one of the contents --these light emitting sources are called __________.

STARS

524. Sometimes, stars cluster together into groups within our galaxy. The term applied to such collections of stars is derived from the fact that the stars ____________ together.

CLUSTER

525. Collections like this are, in fact, called ____________.

CLUSTERS

526. When clusters appear within the plane of the galaxy, they are called, for obvious reasons, "Galactic ______________".

CLUSTERS

527. Galactic clusters are usually quite irregular in shape. If, for example, you look through a tel escope at a cluster that has what you conclude to be a definite spherical shape, you can be reasonably certain that you are not looking at a ________________________.

GALACTIC CLUSTER

528. Clusters that are spherical in shape (which are also part of our galaxy) usually reside outside the plane of the galaxy. Since clusters like these consist of stars which are associated with each other in a globular (from the word "globe") arrangement, they are called ________________________.

GLOBULAR CLUSTERS

529. Globular clusters differ from Galactic clusters in that Galactic clusters are __________________ in shape.

IRREGULAR

530. Globular clusters are, however, ____________ or ____________ in shape.

SPHERICAL; GLOBULAR

531. Another difference is that ______________________ exist outside the plane of the galaxy, whereas ______________________ exist within the Galactic plane.

GLOBULAR CLUSTERS; GALACTIC CLUSTERS

532. In the night sky, it is sometimes possible to see a band of light which is called the "Milky Way". This band of light represents the part of our galaxy that is visable to us from our position in it. "Milky Way" is also the name of ______________________.

THE GALAXY IN WHICH WE LIVE

533. If a friend now informs you that he has located a cluster in the Milky Way with his telescope, more often than not, he would have found a ______________________.

GALACTIC CLUSTER

534. If, in fact, your friend has found a galactic cluster, you can expect when you look into his telescope, to see a collection of stars with a(n) ________________ shape.

IRREGULAR

535. If, on the other hand, your friend locates a cluster whose shape is spherical, it is extremely likely that he has found a ____________ ____________.

GLOBULAR CLUSTER

536. Other contents of galaxies are gas clouds. These are called Nebulae. (Nebulae is the plural of Nebula.) A nebula, then, is simply a ____ __________ in space.

GAS CLOUD

537. As a simplification, there are three main types of nebulae, each defined in terms of what they do with light: One type of nebula emits (or "sends out") light. It is called an emission nebula. Another kind of nebula reflects light. This kind of nebula would be called a ________ nebula.

REFLECTION

538. A third kind of Nebula absorbs light. We would call this kind of nebula an ______________________.

ABSORPTION NEBULA

539. Of these three types of nebulae, the kinds that we can see light coming from are ________________ and ________________.

EMISSION NEBULAE; REFLECTION NEBULAE

540. These kinds of Nebulae would be visable in this way because they either ________ or ________ light.

EMIT; REFLECT

541. On the other hand, ____________________ would not send light directly to our eyes, because they ________ light.

ABSORPTION NEBULAE; ABSORB

542. From Earth, we can see only a small fraction of the stars in our own galaxy. One reason to explain the fact that we can not see the rest of these stars, is that the light from them becomes ________ in ________________________.

ABSORBED; ABSORPTION NEBULAE

543. In review, our galaxy consists of ______, some of which collect together into groups called ____________, and gas clouds called ____________.

STARS; CLUSTERS; NEBULAE

544. Two types of clusters are called ______________ and ________________.

GALACTIC CLUSTERS; GLOBULAR CLUSTERS

545. Galactic clusters tend to exist (where?) ______________ and are __________ in shape, whereas Globular clusters tend to exist (where?) ________________________ and are ________ in shape.

WITHIN THE PLANE OF THE GALAXY; IRREGULAR; OUTSIDE THE PLANE OF THE GALAXY; SPHERICAL

546. Three types of Nebulae are called ______________, ______________ and ________________.

EMISSION NEBULAE; REFLECTION NEBULAE; ABSORPTION NEBULAE

547. These types are defined in terms of what the nebulae do with ______.

LIGHT

548. An emission nebula, for example, ________ light, a reflection nebula ________ light, and an absorption nebula ________ light.

EMITS; REFLECTS; ABSORBS

549. "Milky Way" is the name given to which of the following?

(a) A cluster within our galaxy	see frame 550A
(b) A nebula that emits light	see frame 550B
(c) A Galaxy	see frame 550C
(d) A band of light in the night sky	see frame 550D
(e) Both (c) and (d)	see frame 550E
(f) A chocolate bar	see frame 550F

550A. Your answer: A cluster within our galaxy
is incorrect.
You have obviously worked too quickly through the section on clusters. Go back and do the sequence from frame 523 to 535 again. Then proceed to frame 549 and select a better answer.

550B. Your answer: A nebula that emits light
is incorrect.
You have obviously worked too quickly through the section on nebulae. Go back and do the sequence from frame 536 to 542 again. Also, you would be well advised to review the contents of frame 532. After you have done this, proceed to frame 549 and select a better answer.

550C. Your answer: A Galaxy
is incomplete.
If you do not know why, go back and review the contents of frame 532. Otherwise proceed to frame 549 and select a better answer.

550D. Your answer: A band of light in the night sky
is incomplete.
If you do not know why, go back and review the contents of frame 532. Otherwise, proceed to frame 549 and select a better answer.

550E. Your answer: both (c) and (d)
is correct.
We will now go on to talk about other galaxies. You will remember that a galaxy is simply a ______________________.

VERY LARGE COLLECTION OF STARS Proceed, now, to frame 551

551. The Galaxy in which we live is known as the ________________.

MILKY WAY GALAXY Proceed, now, to frame 552

550F. Your answer: a chocolate bar
is not incorrect, but it is quite out of context. This is the last abort frame that appears in this book. If you feel it to be appropriate, you may take a break at this point before continuing on through the "home stretch" of this program.

552. We are aware of about a billion other Galaxies as well. The nearest major galaxy to our's —- called the Andromeda galaxy, is about 2.1 $X\ 10^6$ light years away. You will recall that, on the scale that we have been using (where a star is represented by a grain of sand 1/20 inches across) a distance of 1 A.U. was represented by (how much?) ____________ (see frame 471).

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5 INCHES

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553. Knowing this fact, along with the facts that: 1 light year = $6.3\ X\ 10^4$ A.U.s; and 1 mile = $6.3\ X\ 10^4$ inches; how far away would the Andromeda galaxy be on our scale (in miles)?

(a) $1.1\ X\ 10^7$ miles see frame 554A
(b) $1.3\ X\ 10^{11}$ miles see frame 554B
(c) $6.5\ X\ 10^{11}$ miles see frame 554C
(d) I do not know see frame 554D

554A. Your answer: $1.1\ X\ 10^7$ miles is correct.
If the decimal part of your answer is different from this by one tenth, do not be concerned: You are correct as well; you have just done the operations in a slightly different order. The distance you have calculated is about 1/4 the distance from Earth to the planet Mars when both planets and the Sun are in a straight line (with the Earth in the middle). In other words, if we were to construct a model of our part of space on the scale we have been using, the ____________________ would fit just inside the orbit of the Moon about the Earth; and the ____________________ would be as far away as 1/4 the distance to the orbit of Mars.

MILKY WAY GALAXY; ANDROMEDA GALAXY Proceed, now, to frame 555.

554B. Your answer: $1.3\ X\ 10^{11}$ miles is incorrect.
You have part of the answer, however. What you have calculated is the distance to the Andromeda Galaxy in A.U.s (calculated by multiplying $2.1\ X\ 10^6$ times $6.3\ X\ 10^4$). You will recall, however, that, on our scale, a distance of 1 A.U. is represented by a distance of ____________.

---

5 INCHES

554B2. Therefore, on our model, the distance to Andromeda would be represented by a distance of ____ X _________ = _________inches,

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5; $1.3\ X\ 10^{11}$; $6.5\ X\ 10^{11}$

554B3. This distance can be converted into one in miles, remembering that 1 mile = (how many?) __________ inches (see frame 553).

6.3×10^4

554B4. Therefore, the distance to Andromeda, on our model, is __________ divided by __________ = __________ miles (in scientific notation with the decimal part rounded off to one decimal place).

6.5×10^{11}; 6.3×10^4; 1.0×10^7

554B5. If the question we have considered was done in a slightly different way, the decimal part of the answer could differ by one tenth. Either answer, however, can be considered to be correct. In either case, this number represents ______________________________.

THE DISTANCE TO ANDROMEDA (IN MILES) ON OUR MODEL

554B6. Go back, now, to frame 553 and choose the correct answer.

554C. Your answer: 6.5×10^{11} miles
is incorrect.
You have part of the answer, however: What you have calculated is the distance, in inches, to Andromeda, on our model. This can be converted to a distance, in miles, remembering that 1 mile = (how many?) __________ inches (see frame 553).

6.3×10^4 Proceed, now, to frame 554B4

554D. Your answer: I do not know
is, of course, inadequate.
Let us construct the correct answer: The distance to Andromeda is 2.1×10^6 light years. You will recall that 1 light year is equal to (how many?) __________ A.U.s (see frame 553).

6.3×10^4

554D2. Therefore, the distance from here to Andromeda, in Astronomical Units is __________ X __________ = __________.(in scientific notation, with the decimal portion rounded off to one decimal place.)

2.1×10^6; 6.3×10^4; 1.3×10^{11}

554D3. You will recall that, on our scale, a distance of 1 A.U. is represented by a distance of __________.

---

5 INCHES Proceed, now, to frame 554B2

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555. The limit to how far out in the Universe we can "see" is, at present, about 12 billion light years. Everything within this distance constitutes what is known as the "observable universe". The "observable universe" extends outward to a distance of (how far?) ____________ (in scientific notation).

1.2×10^{10} LIGHT YEARS

---

556. How far away, then, would the "edge" of the "observable universe" be, on our scale (in miles)?

(a) 3.8×10^{15} miles — see frame 557A
(b) 6.0×10^{10} miles — see frame 557B
(c) 7.6×10^{14} miles — see frame 557C
(d) I do not know — see frame 557D

557A. Your answer: 3.8×10^{15} miles is incorrect.
You have part of the answer, however. What you have calculated is the distance, in inches, to the "edge" of the "observable universe" on our model. This can be converted to a distance, in miles, remembering that 1 mile = (how many?) __________ inches (see frame 553).

6.3×10^4

557A2. Therefore, the distance to the "edge" of the "observable universe" on our model is __________ / __________ = __________ miles. (in scientific notation with the decimal part rounded off to one decimal place.)

3.8×10^{15}; 6.3×10^4; 6.0×10^{10}

557A3. This number (6.0×10^{10}) represents ______________________________ ______________________________.

THE DISTANCE TO THE "EDGE" OF THE "OBSERVABLE UNIVERSE", IN MILES, ON OUR MODEL

557A4. Go back, now, to frame 556 and choose the correct answer.

557B. Your answer: 6.0×10^{10} miles is correct.
This is quite a large distance. It represents almost 8 times the diameter of the solar system. In other words, if we were to construct a model of the "observable universe" on the scale we have been using, the __________ would fit just inside the orbit of the Moon about the Earth; __________________ would be at 1/4 the distance to the orbit of Mars; and the __________________________ would be 8 solar system diameters away.

MILKY WAY GALAXY; ANDROMEDA GALAXY; "EDGE" OF THE "OBSERVABLE UNIVERSE"
Proceed, now, to frame 558

557C. Your answer: 7.6×10^{14} miles
is incorrect.
You have part of the answer, however. What you have calculated is the distance to the "edge" of the "observable universe" in Astronomical Units (calculated by multiplying 1.2×10^{10} times 6.3×10^{4}).
You will recall, however, that, on our scale, a distance of 1 A.U. is represented by a distance of __________.

---

5 INCHES

557C2. Therefore, on our model, the distance to the "edge" of the "observable universe" would be represented by a distance of ____ X ________ = ________ inches (in scientific notation, with the decimal portion rounded off to one decimal place).

5; 7.6×10^{14}; 3.8×10^{15}

557C3. This can be converted to a distance in miles remembering that 1 mile = (how many?) ________ inches (see frame 553).

6.3×10^{4} Proceed, now, to frame 557A2

557D. Your answer: I do not know
is, of course, inadequate.
Let us construct the correct answer: The distance to the "edge" of the "observable universe" is 1.2×10^{10} light years. You will recall that 1 light year = (how many?) ________ A.U.s (see frame 553).

6.3×10^{4}

557D2. Therefore, the distance, from here to the "edge" of the "observable universe", in Astronomical Units, is ________ X ________ = ________ (in scientific notation with the decimal portion rounded off to one decimal place).

1.2×10^{10}; 6.3×10^{4}; 7.6×10^{14}

557D3. You will recall that, on our scale, a distance of 1 A.U. is represented by a distance of __________.

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5 INCHES Proceed, now, to frame 557C2

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558. So far, we have attempted, in this book, to acquaint you with some principles of Modern Astronomy. This has been done for the purpose of furthering your knowledge of the Universe, as we know it. On the basis of what you have learned, up to this point, which of the following conclusions, in your opinion, can be accepted?

(a) The Universe is Finite (with end) — see frame 559A
(b) The Universe is Infinite (without end) — see frame 559B
(c) The Universe constitutes a molecule of water inside a huge goldfish bowl — see frame 559C
(d) I do not know — see frame 559D

559A. Your answer: The Universe is Finite
is incorrect.
At no point does any of the information we have presented in these pages lead to the conclusion you have drawn. Go back to frame 558 and select a better answer.

559B. Your answer: The Universe is Infinite
is incorrect.
At no point does any of the information we have presented in these pages lead to the conclusion you have drawn. Go back to frame 558 and select a better answer.

559C. Your answer: The Universe constitutes a molecule of water inside a huge goldfish bowl.
Ha, ha, ha, ha, ha, ha!!!! Hee-hee-hee, Ho, ho, ha, ha, ha, he-he!! Ho-ho-ho-ho, chuckle, chuckle, chuckle!!!!! Snort! Ha-ha-ha-ha!!! Chortle,-chuckle, he, he, he, ho-ho, ha-ha-ha-ha!!! Chortle-chortle!! He-he-he-he-he, Ho, ho, ho, Ha-ha-ha-ha-ha!!!!! Snort!! Chuckle, Chuckle, Ho-ho-ho-ho, Ha, ha, ha, ha, ha, Chuckle-chortle, ha, ha...

The above is a very implicit way of indicating that the conclusion you have drawn does not follow from any premises which we are familiar with. Go back to frame 558 and select a better answer.

559D. Your answer: I do not know
is correct !!!
You have realized that the question "Does there have to be an end to the Universe?" does not have an answer at present, particularly on the basis of information presented in this book. Unfortunately, there still exist many people who believe that they can answer this question and others like it (with as little information). The authors of this book think that it is quite possible for things to be infinite; however, for the convenience of everyone concerned, the authors, after much deliberation, formally declare this book to be FINITE....

Notes:

1. Miles per hour means miles/hour or miles divided by hours.

2. By the "same exponential notation" we mean numbers that are written as the same base to some exponent. For example, the numbers 5^2 and 5^6 are in the "same exponential notation". In this example, the base is the number 5.

3. Implicit in our rule for division in exponential (notation) is the fact that the exponent of the number you are dividing by is subtracted from that of the number you are dividing into. For example $\frac{5^6}{5^2} = 5^{(6-2)} = 5^4$.

4. It is assumed that the conversion of hydrogen to helium is the only energy producing process that will ever take place in the Sun. This is a good assumption for our purposes; however it is not believed to be correct.

5. It is assumed that all available hydrogen will be consumed in this process. This is not believed to be correct. However the simplicity of this assumption makes this segment much less confusing.

For further information................

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BOOKS and MAGAZINES

All About Telescopes,
by Sam Brown,
Edmund Scientific Co.,
paperback.

Astronomy with Binoculars,
by James Muirden,
Faber Editions,
paperback.

A Field Guide To The Stars and Planets,
by Donald Menzel,
Houghton Menzel Company,
hardcover.

Modern Astronomy,
c/o 18 Fairhaven Drive,
Buffalo, N.Y. 14225, U.S.A.
published bimonthly.

the Observer's Book of Astronomy,
by Patrick Moore,
Frederick Warne & Co., hardcover.

(R.A.S.C.) the Observer's Handbook,
publ. annually by the R.A.S.C.
paperback.

Red Giants and White Dwarfs,
by Robert Jastrow,
A Signet Book,
paperback.

The Sky Observer's Guide,
by Mayall and Wyckoff,
A Golden Handbook Guide,
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