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## Volume 77 - Issue 4 - February, 1966

Rose Technic Staff

*Rose-Hulman Institute of Technology*

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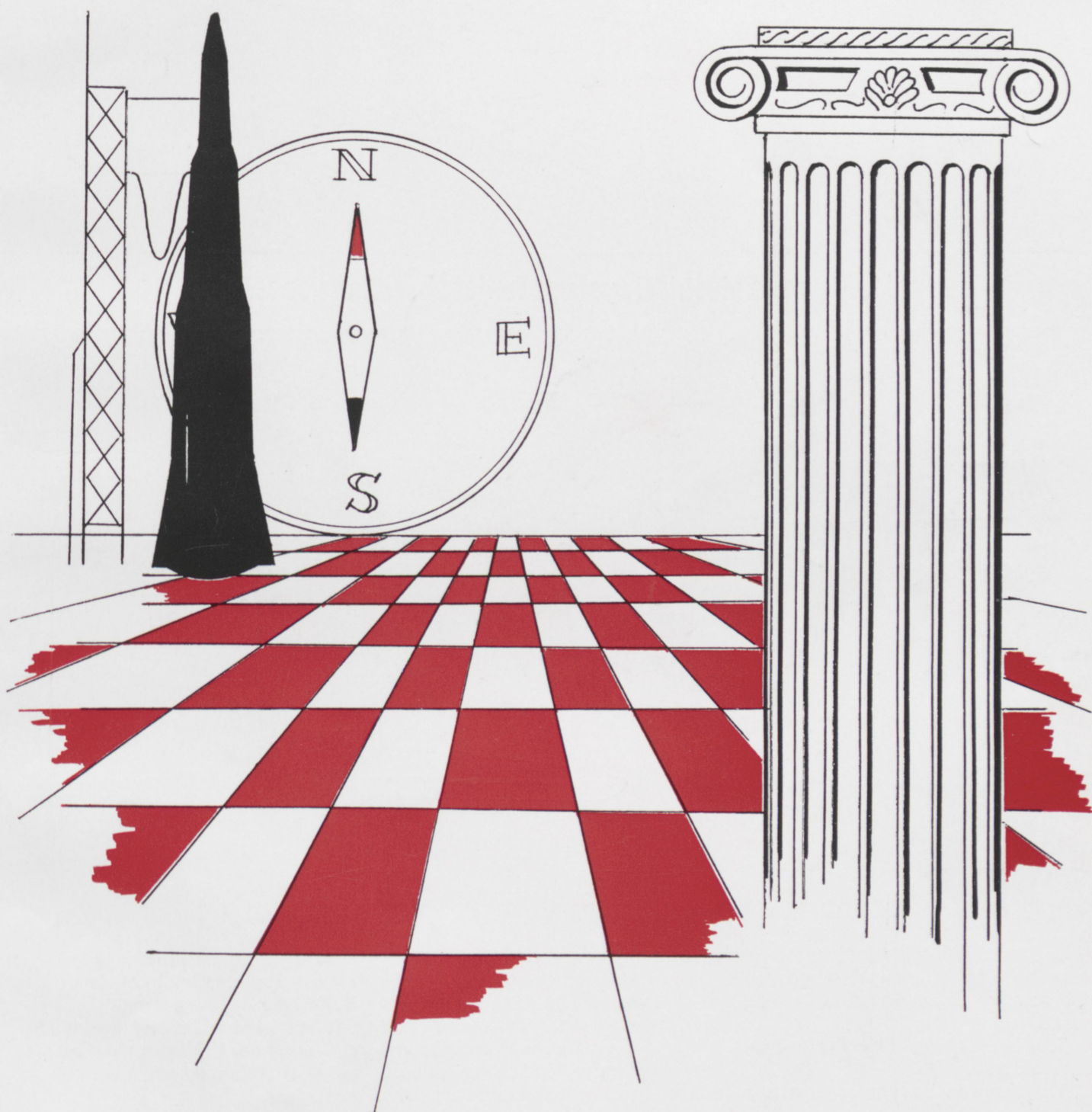
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# Rose Technic

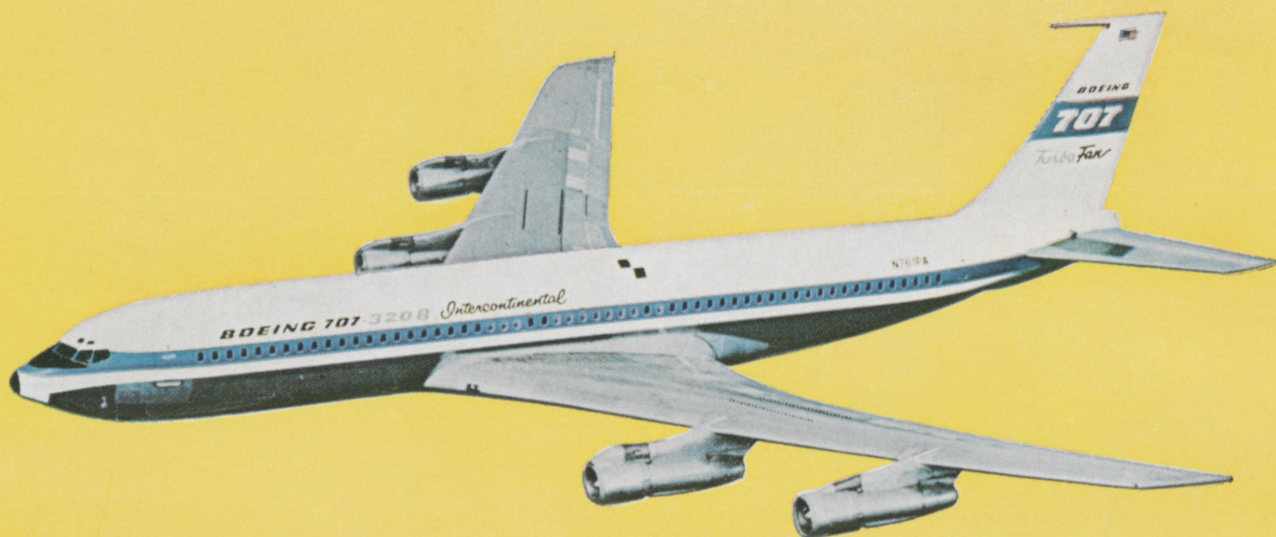
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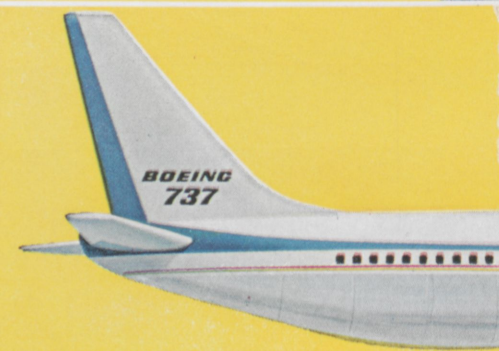
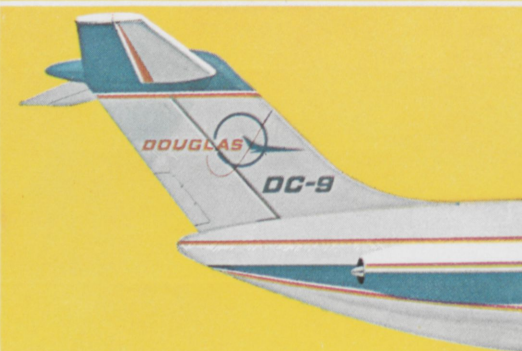
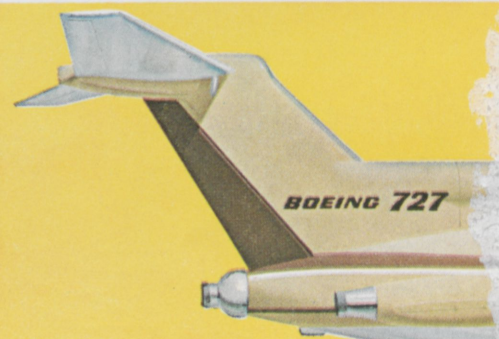
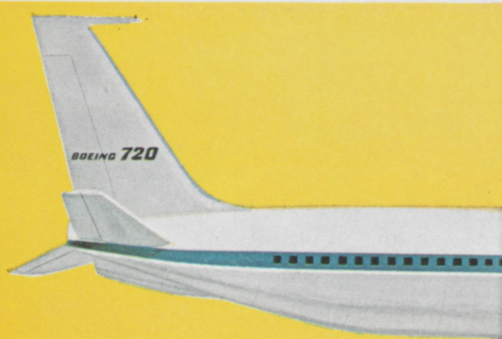


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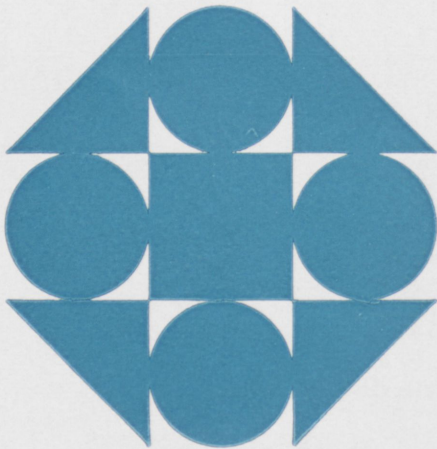
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## IN THIS ISSUE

### IN THIS ISSUE—

The feature article for this month is a comparative analysis of two civilizations. Written by Hugh Crome, a freshman, this article compares the growth and influence of technology in China and Rome. The cultures of these two countries are shown to have been greatly influenced by the scientific developments within the country. An interesting article, it is well worth the time needed to read it. The article begins on page 9.

The United States and the Soviet Union now face each other in outer space. They will undoubtedly be joined there by many other nations. The question we must begin to answer now is whether the concept of "might makes right" govern the use of outer space or, will there develop a code of ethics and laws between the space powers. Jay Sinex discusses this question in the thought provoking article "Law in Space," which starts on page 12.

Beginning on page 16 is an article with the odd title "The Euglena." In this article Gary Ransford gives an interesting and complete discussion of the Heisenberg Uncertainty Principle. The article will undoubtedly be interesting to Physics majors. Many others will also find it informative since Gary includes a philosophical justification in his paper.

## COVER NOTE

This month's cover is by Jeff Brugas. It is a graphical representation of our feature article, "Scientific Cultures of China and Rome."

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## The Dean's Corner

# CONVICTIONS

by Herman A. Moench,  
Dean of the Faculty

A peculiar kind of freedom pertains to life on a college campus. It is the freedom to experiment with "character." As a student you can try out or "try on for size" various guide lines for your conduct and your performance—particularly in your relations with the people around you. The day-to-day grind of a job and of family responsibilities has not yet closed in on most of you.

Nonconformity in dress and in manner can provide a relief from other constraints without implying any doubtful standards of conduct. At no later period will it be possible to experiment, to make mistakes, at such low cost. You've got bargain basement rates at this time in your life testing the old adage: "Good judgment comes from experience, and experience — that comes from bad judgment."

Even a highly disciplined young man with the advantages of a strong moral fabric in the home where he grew up still feels the urgent need to put the precepts offered by parents and teachers to a searching test. This is all to the good. But such testing should eventually lead to firm convictions—convictions about "people" and convictions about "things."

The perceptive student of the physical universe certainly cannot escape its inexorable lawfulness. As the known structure of physical science is illuminated step-by-step in the curricular sequence of courses, a growing body of "convictions" is established in the mind of the young engineer or scientist. This is the foundation of his indispensable body of specialized knowledge as a professional man.

Similarly, he will be developing the second essential ingredient of his professional stance—a spirit of service to others. This proceeds from convictions based on religious precepts, humanistic studies and participation in extracurricular activities, as well as his personal experience in helping others.

A third ingredient, loyalty to his own professional group, develops at a more mature level, as the student perceives that the body of knowledge grows only through generous sharing. The true professional is convinced that he should "gladly teach" his peers—disseminating the results of his creative work, his research, his insights, to all his associates. Their acceptance and approbation of his work, of his "convictions," can be the author's most durable satisfaction.

Most of us are reticent about expressing our deeply held beliefs. But all of us admire the mature man who, while tolerant and considerate of other views, organizes and runs his own life according to clear and tested convictions—beliefs that provide a solid anchor in times of stress.

Certainly the college years are a particularly good time to follow St. Paul's admonition: "Prove all things. Hold fast that which is good." Conflicting pressures bear down upon all of us on the Rose campus. A worthwhile goal for our academic community is to achieve an open society where no one needs to feel compelled to sacrifice his own deeply-held convictions.

*Herman A. Moench*



# Wine, Women And Happiness

Ask one hundred people what to them is the most important thing and you might get just as many different answers. Or, if those people happen to be guys from a small midwest engineering college, only two answers may be given: wine and women. Whatever the answer, the things named are practically always those things which bring the persons happiness. Here is found the real answer. The most important thing to us is happiness.

This is certainly not a great discovery. Anyone who has given it any thought has probably made the same conclusion. And, yet, the world is full of unhappy people. People who don't know what they really want. Look around you today. How many of us here are genuinely happy?

Life to the unhappy person is not unlike marriage to the Platonic husband. Neither is getting all he could. The happy person gets more out of life. More people like him and want to help him. And he is usually more successful in accomplishing his own goals.

When I refer to a happy person, I'm not making reference to those who go from day to day ignoring all

troubles and problems. I am speaking of the person who establishes his goals and then works toward them, facing troubles and solving problems as he goes. This is how we can become happy. We must decide what we really want and then go after it. Even though it may take a long time to accomplish our goals, we will be happier in knowing we are headed in the right direction.

One of our biggest problems is knowing what we really want. This problem usually stems from our not knowing who we really are. Much of our time is spent now experimenting in an attempt to discover our identity. So, in setting our goals, we must be aware of a tendency to set goals which are not our own but are those of the group we are immediately associated with. And the groups goals are often not the same as the ones we would establish as an individual well aware of who he really was.

In conclusion, to be happy, we must first discover our true identity. This may be accomplished by close and continued self analysis. Second, based on what we think will bring us happiness, we should establish both our short and long range goals. Third, we should set out to accomplish those goals. In doing these things we will build our happiness on a firm basis.

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# THE SCIENTIFIC CULTURES OF ROME AND CHINA

by HUGH CROME



Hugh Crome, a freshman, comes from Batavia, Illinois. He plays varsity basketball and is pledged to Theta Xi Fraternity.

All applied scientific notions came as a direct result of man's needs.

"Prehistoric man was the first creature to apply reason to the satisfaction of his everyday needs. Hence the history of science begins with the history of technology."<sup>1</sup>

Man had his first ideas about geology, zoology, botany, medicine, astronomy, and mathematics in prehistoric times. When man first conceived of sowing seed for himself, the science of agriculture was born. Mathematics started when man saw the necessity of having to count and record the number of animals in his herds and the number of stone implements he possessed.

Theoretical science and science that didn't have a necessary use developed out of magic, superstition, and religion. Magicians and priests started exploiting natural causes to enable themselves to keep on fooling the common people. The store of knowledge acquired during prehistoric times was passed on by priests and wizards, and until the invention of writing, word of mouth was the only means for passing on knowledge.

During prehistoric times China and Rome must have had much the same type of development in applied science. The only difference would come as a result of the differences of geography and psychological make-

up of the two different people. These two differences became the important reasons for the variation in the sciences of the two peoples, but early in the development of the Romans and Chinese their sciences must have been very similar.

## PASSIVISTS CONTROL CHINA

As time went on, however, the differences caused by geography and the respective cultures began to make a very significant gap in the two sciences. The Chinese had long been isolated from the West, and their culture developed independently of all contemporary cultures. The Chinese very early in their history became influenced by two groups of thinkers. These groups had extensive influence on the development of Chinese culture and especially on the Chinese science. These two groups were the activists and the passivists. The activists believed that all worthwhile objectives could only be obtained by active effort. The passivists felt strongly that all active effort was a waste of time, and all worthwhile objectives were to be found in the mind. The activists found firm footing in most parts of the world, but they were never able to gain much prestige in China.

The cause of the passivists was greatly helped by two very important groups. The followers of Confucius and the Taoists influenced the majority of the Chinese people into

the passivist camp. Confucius was the most important, and his ideas and beliefs are still considered and widely followed in the Far East today. Confucius believed wholly in the use of the mind for the greatest gain. He considered the essential virtues to be found in the rules of proper conduct.

The Taoists also had a very substantial influence on the Chinese people. Even though the Taoists did make some advances in the field of technology, they were still trying to strive for the simple life. The Taoists can be considered China's first philosophers and naturalists.

These two groups had an affect on life that was felt up until the middle of this century. The Chinese preferred, because of the thinking of these two groups, the "quiet, mannerly rule of tradition than the excitement of scientific growth."<sup>2</sup> The Chinese were content for a long time to use the ancient economic methods of their ancestors. They didn't like labor saving devices or other things necessary for economic advances because the passivists had them believing that it was better for everyone to work and have some economic security rather than have technology and some people getting rich while others were poor. This tendency can be seen throughout the history of China and her scientific advances. (Continued on page 10)



## ASTRONOMY THROUGH SUPERSTITION

The Chinese developed a very inventive culture. They made many important discoveries and inventions that are still important today. One of their biggest sciences was astronomy. Astronomy developed in China very much the same as it developed in other cultures. It was first used to predict the future, and then it gradually became an exact science. The first observations were to predict government fortunes. The astronomers were very important men as long as their predictions were fulfilled, but if their predictions failed their days of glory were over.

Through this study of the skies for the purpose of fortune-telling the Chinese developed a very good understanding of astronomy. They were able to accurately predict eclipses and the exact length of the cycles of the sun and moon. The Chinese developed a very accurate calendar based on the stars, and they had the courses of all the then known planets plotted. The Chinese astronomy became an exact science, but it did not develop any farther than any of the astronomies in other ancient civilizations.

### COSMOLOGICAL THEORY

The Chinese were advanced enough in their scientific thinking and inductive reasoning to have several cosmological theories. The oldest of these had the stars in a fixed hemisphere revolving around a square earth. Another theory said that the Universe was like a round egg with the earth, the yolk; and the stars, the shell. They thought about what was beyond the stars and came to the conclusion that no one would ever know. These theories were like most of the other cosmological theories of early civilizations. The tools which the Chinese had were not good enough to enable them to see the truth about the Universe.

### OTHER CHINESE TECHNOLOGICAL DISCOVERIES

The Chinese made some very notable discoveries in the field of tech-

nology. Some of their discoveries had an important effect on the world of that time. The Chinese came up with the first practical compass, and they discovered gunpowder. The invention of the compass came as a result of Chinese religion. The compass was first used to locate the ideal places for graves and temples. The Chinese developed the compass much further than this. The first European to travel to China took the idea of the compass back to Europe, and there it made its development that was to greatly help the science of navigation.

Gunpowder took much the same route as the compass. The Chinese first developed gunpowder as entertainment in rockets and fireworks. Later they did make primitive war rockets, but gunpowder never advanced beyond this point. The idea of gunpowder was spread from China by the Greeks and the Arabs. The Europeans once again developed a discovery of China into something that has had a terrific effect on the world.

### CHINESE TECHNOLOGY LACKED DEVELOPMENT

China never did develop a highly scientific society for several reasons. China was isolated from the rest of the civilized world by great distances of nearly impassable terrain. She was not able to see how the other cultures were developing. She developed her own style of thinking. The passivists killed all the beginnings of deductive thinking which is so necessary for the development of science. China was basically an agricultural nation and had no need to develop a technology which is the first step to applied science. The combination of these made ancient China a very unique country. She was a country of inventors who never developed their inventions.

"It would be wrong to aver that the Chinese lacked a scientific and rational view. They considered no phenomenon to be transcendent or inexplicable; to them man and society were objects of knowledge. If they

did produce mathematical arguments based on 'a priori' definitions, it merely shows that scientific ideas and methods are offspring of social climate and not merely of technical achievement."<sup>3</sup>

### ROME UNDER THE ETRUSCANS

The Roman civilization did not develop on its own. It was influenced by many outside sources. Rome first started to become a power while she was still under the rule and influence of the Etruscan kingdom. The Etruscans had no theoretical science at all. They were completely influenced by the power of religion. The Etruscans never made any distinction whatsoever between religious and everyday life, and they held fast to the idea that "the phenomenal world was the result of mystic forces from heaven or hell."<sup>4</sup> The Etruscans felt that everything happened by the will of God. This type of thinking was a tremendous hindrance to the development of science in the Etruscan culture.

Even though the Etruscans were very weak in science, they were very strong in many technological fields. The Etruscans gave Rome the background in the field which Rome is still admired and copied today—construction. The Etruscans were extremely strong in the basic ideas of construction and passed these ideas on to the Romans. Their influence developed Rome into one of the most technological civilizations of all time. The Romans took basic ideas of the Etruscans and combined these ideas with the designs of the Greeks. The combination of these two produced a technological culture that is only today being duplicated by our modern culture.

### CONCRETE AIDS IN ROMAN CONSTRUCTION

The Romans became very skilled in masonry, architecture, bridge designing and building, and the building of aqueducts. The Romans excelled in these technological arts because of several factors. The main  
(Continued on Page 35)





# CONSTRUCTION

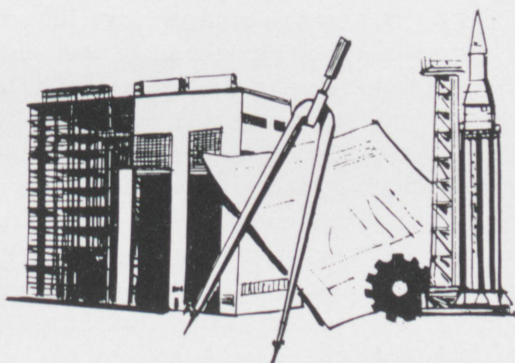
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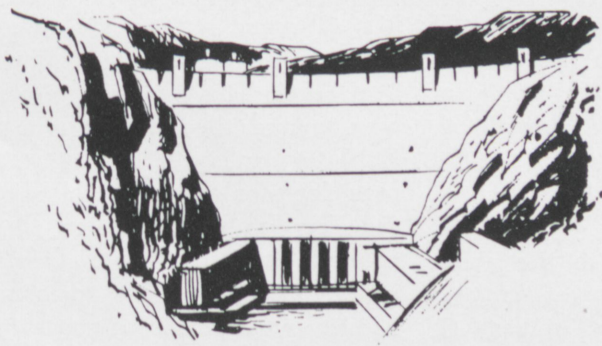
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# THE NEED FOR LAW IN SPACE

For many centuries, man has looked to the skies above wondering what they might contain. As man's knowledge and technology advanced, he was able to probe deeper and deeper into space and answer some of his questions. The invention of the telescope brought distant objects closer and also brought the answer to what space might contain. The development of complicated formulas gave a solution to why things in space behave as they do. Yet, man's quest for knowledge led him even further. Men invented expensive, complex machines to carry instruments and even man himself into space, in order that man might learn more about space.

During the same period of time, in a totally unrelated manner, man was carrying out the evolution of another process. Having learned of his environment and his fellow humans, man began to develop a system of laws so that he could live in relative peace and harmony with his fellow man. Just as civilizations and knowledge change, man had to adjust his laws and codes to keep in step with the other changes. This leads us to one of the major questions of today: How will the laws of today be affected by the exploration of space and future space travel? Also, will it be necessary to draft a set of laws for space and space travel? The remainder of this article will attempt to answer these questions.

One of the major problems in

drafting any set of rules or laws is the protection of the little man, in this case the smaller nation. The more affluent nations, mainly the United States and Russia, have no difficulty financing space exploration and space travel. However, the less affluent nations might be awhile joining the "space race." "Most nations agree on looking at space as the new frontier for exploration, and they expect to join the exploring someday themselves. To keep the early arrivals from writing their own frontier code, they are willing to set some basic rules."<sup>1</sup> This points out that the small nation wishes to have the same rights as the large nation with respect to sovereignty, that is the right to claim planets or other outer space bodies as property belonging to their government. The difficulty here lies in the fact that the space exploring nations view sovereignty as the right of first come, first serve. However, the nations that are not in the class of first come feel that the rights of sovereignty should be regulated. Consequently, one can easily see the necessity for laws or legislation in this case.

However, contrary to the above mentioned views on sovereignty is the view expressed by Andrew G. Haley in his book, *SPACE LAW AND GOVERNMENT*, is that "one of the basic doctrines to be established now upon which the law of space must be built is that any natural object in space is not subject

to any earthly jurisdiction or sovereignty. No single nation may justifiably assert a paramount claim to any other heavenly body or portion of outer space."<sup>2</sup> Thus, there is a need for laws to determine the extent of sovereignty or to determine sovereignty unlawful.

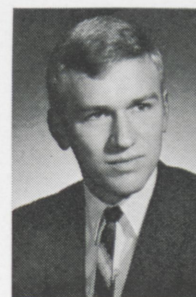
Next, imagine, at some date in the not so distant future, two space vehicles of two different nations on a space flight to the moon. Perhaps, while approaching the moon for landing, the two vehicles collide causing damage to the vehicles and injury to the passengers. "The potential harm is demonstrated by the inability even of manned aircraft, after many years of experience and experimentation, completely to curtail the incidence of air mishaps. It is unrealistic, therefore, to assume the missile and space industry is equipped to bring about perfection during its infancy."<sup>3</sup> So this possibility is not beyond reality. The difficulty here in the determination of who is held liable. This example points the way toward the necessity of more legislation or laws. Since there is no precedent for a case of this nature, the law must determine if the nation, government, or the individual is liable. The question of liability would also encompass damage to property or injury to individuals due to a misfired space vehicle or damage caused by an emergency landing.

An even greater danger to human life than that mentioned above is



by JAY SINEX

Jay Sinex is a junior Ch.E. from North Central High School in Indianapolis. Although he is married, Jay is still active in his fraternity, Sigma Nu, as well as in R-Men's Club and on the Institute Inklings staff.



the possibility of a space vehicle bringing back to earth some unknown bacteria. Such bacteria could contaminate the entire world and endanger the life of every living thing. "The danger to man himself derives in part from the fact that he has evolved his specific defenses against terrestrial bacteria and might be therefore less capable of coping with exobiotic organisms. The obvious course is the establishment of international legal norms to control our interplanetary communications."<sup>4</sup>

Since the study of disease and bacteria is related to medicine, there is also a necessity for laws pertaining to the medicine of outer space.

#### VEHICLE REGULATION

Another problem caused by space exploration is the lack of any kind of regulation with respect to the space vehicle itself. "Today, the USA and USSR have sent dozens of vehicles onto the unpaved, unrestricted highways of outer space, and again a system of lawless anarchy is developing. Abuses in radio usage; unreported vehicles performing undisclosed functions at undisclosed distances from earth; unrecorded launchings; secret payloads; and many other space practices are completely unrestrained to date. Somewhere the nations of the earth must begin a common system of regulation, and licensing."<sup>5</sup> Consequently, the necessity for laws pertaining to the regulation of space vehicles is present.

The formation of such laws would present still another problem. It would be very difficult to imagine an outer space police force boarding a space vehicle to search for illegal cargo. Consequently, space travel presents the problem of drafting laws, and these laws would present the very difficult problem of enforcement.

#### PRESENT ACTION

Since space travel is not of the future, but is in existence today, the necessity of laws for space is a problem of today and not of the future. Consequently, there are organizations in existence today with the aim of drafting laws to cope with the problems mentioned above, and many other which are too numerous to mention here. However, are these organizations acting fast enough to keep ahead of the race for space?

"After a long period of little progress in settling some of the technical and legal aspects of space, the jog jam has been broken."<sup>6</sup> As with any activity pertaining to an international problem, legislation and laws are slow in coming. One of the most influential organizations on the regulation of space activity is the United Nations Committee on the Peaceful Use of Outer Space, which was established December 13, 1958.

This organization has approved many resolutions, one of which was "... a resolution that was agreed on before hand by the U.S. and Russia. The resolution states that no nation can claim sovereignty over

the moon and planets; that states are liable for damage their space vehicles cause; that an astronaut who makes an emergency landing will be promptly repatriated along with whatever remains of his space ship."<sup>7</sup> However, "an international organization, in its most elemental form, is only one step removed from an international conference. It merely represents the decision of several governments to deal with a mutual problem together rather than separately. None of these organizations can enact legislation, levy taxes, raise armies, or enforce laws.

While an international organization can make decisions about the structure and functioning of its secretariat and can assess member governments for annual dues, any member government that has serious objections to these arrangements can always, as a last resort, withdraw."<sup>8</sup> There are many other smaller organizations which face the same problem. The agreements drawn up by the international organizations are not binding on the individual governments. Consequently, in actuality, no laws, as such, can be drawn up by international organizations.

In conclusion, in order to keep ahead of the problems that can result from space travel (as mentioned first) the problems of legislation and enforcement must be solved first. With the rapid development of space technology, some international pit-falls must be bridged first and soon.





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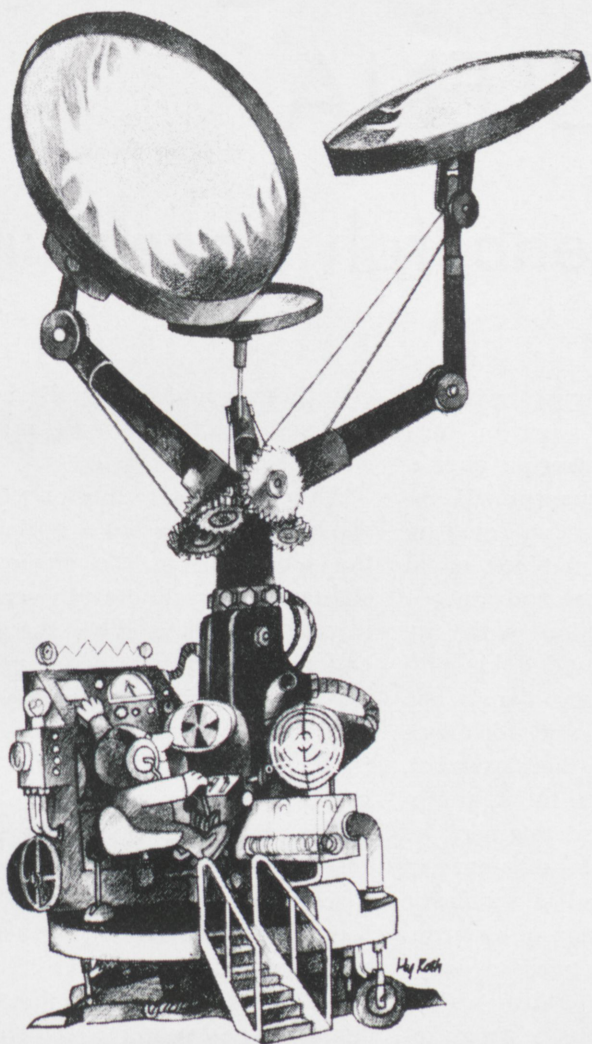
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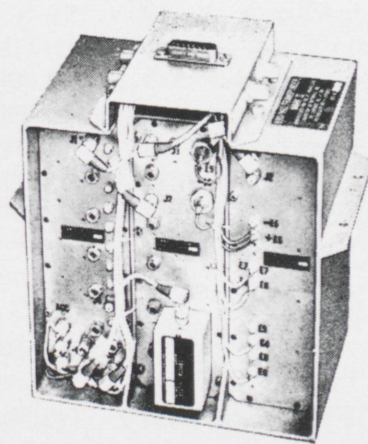
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# THE EUGLENA

## Heisenbergh Uncertainty

### PHILOSOPHICAL JUSTIFICATION

The uncertainty relations enunciated by Heisenberg in 1927 form the basis for Quantum Theory. By introducing these into both the wave theory of matter and the matrix theory of matter, the basic difference between these two modern theories and the older Newtonian approach is realized, i.e., the quantization of certain characteristic quantities in a system, e.g., angular momentum and energy.

But before I discuss the mathematical formulation of the uncertainty relations, I believe that philosophical justification for these would be in order, since physics actually goes under the odious title of Natural Philosophy. It is the goal of Newtonian science to make all truths objective, i.e., to make all laws such that they are invariant, not only in all reference systems, but to all observers. To do this all laws must be made such that they contain no reference to any observer, and to make all experimental verification such that it includes no influence from the experimentalist. In systems which the founders of the old school of Natural Philosophy had to consider the problem of which I have spoken was present, but its influence was so small as to be quite easily excluded by simply overlooking it.

However, the situation on a scale in which the quantities are comparable to the influence of the experimentalist requires a more detailed analysis. No longer can the effects of the measuring devices on the system be ignored. To register a reading on any measuring device,

the system must interact with it. The experimentalist must in turn interact with the measuring device.

The founders of Quantum Mechanics were not the first to come up with the realization that one could not separate the object and view it without any interaction with the viewer. Descartes founded his philosophy on a similar idea. The famous beginning point for Cartesian philosophy is the statement, "cognito ergo sum;" I think, therefore I am. From this statement he elaborates to prove the existence of God on the usual lead of scholastic philosophy. But the crux of his argument came when he tried to prove the existence of the world by stating that God had given him a strong inclination to think that the world existed, and God would not purposely deceive him. His concept of the connection of God-World-I has inherent in it the fact that one must cognize the existence of something before it exists for him. Therefore, this person must interact with the something before he registers its existence.<sup>1</sup>

Laurels cannot, however, be placed upon the head of Descartes for such a prodigious discovery. In the same breath with which he uttered these concepts, he introduced the concepts of "res cogitans" and "res extensa." These became the basis for what is known as the Cartesian division of reality. Instead of the approach suggested to one by the unification in the first Cartesian statements, science at that time divided the world, excluding any influence of the observer in it and tried to study phenomena on the basis of "res extensa."<sup>2</sup> Likewise, the person-

al influence invoked in the concept of "res cogitans" was primarily channeled off into religion.

Although this division of the world did not present a difficulty to the physicists in the seventeenth, eighteenth and nineteenth centuries, it was still present. When the investigations finally pushed into the "grass roots" of natural philosophy, this difficulty was uncovered.<sup>3</sup>

### PARTICLES AND WAVE PACKETS

The ability for de Broglie to represent a particle as a wave packet threw serious doubts onto some of the old, well-established concepts of the treatment of masses by Newton. An example is the specification of the exact position of a particle if the particle can be represented by a wave packet. It can be found by simple analysis that the group velocity of the wave packet which represents the particle is just equal to the classical velocity which it has. This fact and the supposition that to effectively describe a particle the wave must have some connection with it point to the assumption that the wave packet and the particle are to an extent coincident, i.e., the particle is confined to the physical extent of the wave packet.

Now if the assumption is made that a wave packet, or particle, is moving down the x-axis with a group velocity  $v$ , the wave packet will have a spread  $\Delta x$  in it, in which the particle will be confined. Now suppose the wave packet is made up of a superposition of sinusoids of varying wavelengths  $\Delta \lambda$ . This wave packet will spread out as time passes and it can be seen that there will therefore be a different group velo-



# Principle

The author of this article is Gary Ransford. He is a native of Clinton, Indiana, but is married now and presently resides in Terre Haute. Gary is a Physics major and is in his senior year at Rose. He is also a member of the American Institute of Physics.



city associated with it. Calling group velocity uncertainty  $\Delta v$ , from de Broglie's relation,

$$\lambda = \frac{h}{p} \quad \text{the group velocity is given by,}$$

$$\lambda = \frac{h}{mv} \quad m\lambda = \frac{h}{v} \quad \text{or} \quad v = \frac{h}{m\lambda}$$

Since there are wavelengths in the packet of wavelength  $\lambda + \Delta\lambda$ ,  $\Delta\lambda$  can be calculated as

$$\Delta v = \frac{h}{m\lambda^2} \Delta\lambda \quad (a)$$

Going back now to the  $\Delta x$  term, it can be seen that there should be

$$n = \frac{\Delta x}{\lambda} \quad \text{crests or troughs in}$$

the wave packet's extent. Now outside the packet all the waves must cancel by interference. This can occur only if there exists some wavelengths which can crowd  $n+1$  wavelengths into the given region. This gives the relation,

$$\frac{\Delta x}{\lambda - \Delta\lambda} \geq n + 1$$

From the preceding equations

$$\Delta\lambda \geq \frac{\lambda^2}{\Delta x} \quad (\beta)$$

can be derived.

Substitution of into (a) gives

$$\Delta p_x \Delta x \geq h$$

This is a quite crude derivation of the uncertainty principle but it can be done with generalized coordinates equally as well. This method is obtained from the mathematical scheme of quantum theory.

If  $\bar{q}$  is defined as the average coordinate value for the position of a particle, the expression for is written as

$$\bar{q} = \int q' |S(q')|^2 dq'$$

$\Delta q$  can now be defined as

$$(\Delta q)^2 = 2 \int (q' - \bar{q})^2 |S(q')|^2 dq'$$

where in each case  $s(q')$  is a probability amplitude.

Likewise, for the momentum of a particle

$$\bar{p} = \int p' |T(p')|^2 dp'$$

where  $T(p')$  is the probability amplitude for the momentum. Also, the definition of  $\Delta p$  follows:

$$(\Delta p)^2 = 2 \int (p' - \bar{p})^2 |T(p')|^2 dp'$$

The relationship between the two probabilities amplitudes can be written as

$$T(p') = \int S(q')$$

$$R(q'p') dq'$$

$$S(q') = \int T(p') R^+(q'p') dp'$$

where  $R(q'p')$  is the matrix of the transformation from a Hilbert space where  $q$  is a diagonal matrix to a space where  $p$  is the diagonal matrix. From the matrix formulation of quantum mechanics there is the relation,

$$\int p(q'q'') R(q''p') dq'' =$$

$$\int R(q'p'') p(p''p') dp''$$

which is equivalent to:

$$\frac{h}{2\pi i} \frac{\partial}{\partial q'} R(q'p') = p' R(q'p')$$

The solution to this equation gives

$$R = c e^{\frac{2\pi i}{h} p' q'}$$

If we normalize this,  $c$  turns out to be equal to  $\frac{1}{\sqrt{h}}$

To facilitate easier handling, a change in notation can be made as follows:  $x = q' - \bar{q}$ ,  $y = p' - \bar{p}$

$$S(x) = S(q') e^{\frac{2\pi i}{h} p' q'}$$

$$t(y) = T(p')$$

$$e^{-\frac{2\pi i}{h} \bar{q} (p' - \bar{p})}$$

The equations above for the position and momentum and their changes now become

$$(\Delta q)^2 = 2 \int x^2 |S(x)|^2 dx$$

$$(\Delta p)^2 = 2 \int y^2 |t(y)|^2 dy$$

Likewise the interconnection equations above become

$$t(y) = \frac{1}{\sqrt{h}} \int S(x)$$

$$e^{\frac{2\pi i}{h} xy} dx$$

$$S(x) = \frac{1}{\sqrt{h}} \int t(y) e^{-\frac{2\pi i}{h} xy} dy$$

The expression for  $\Delta p$  may be transformed into an expression containing  $\Delta q$  by

$$\frac{1}{2} (\Delta p)^2 = \frac{1}{\sqrt{h}} \int y^2 t^+(y) dy$$

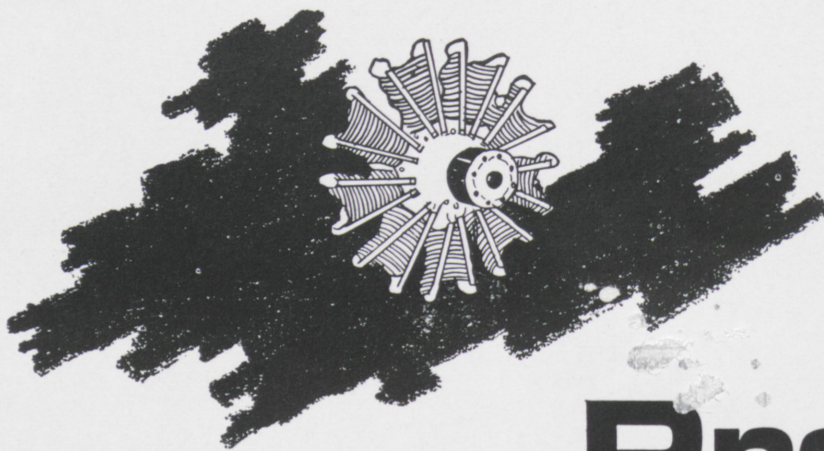
$$S(x) e^{\frac{2\pi i}{h} xy} dx$$

$$= \frac{1}{\sqrt{h}} \int t^+(y) dy$$

(Continued on page 26)

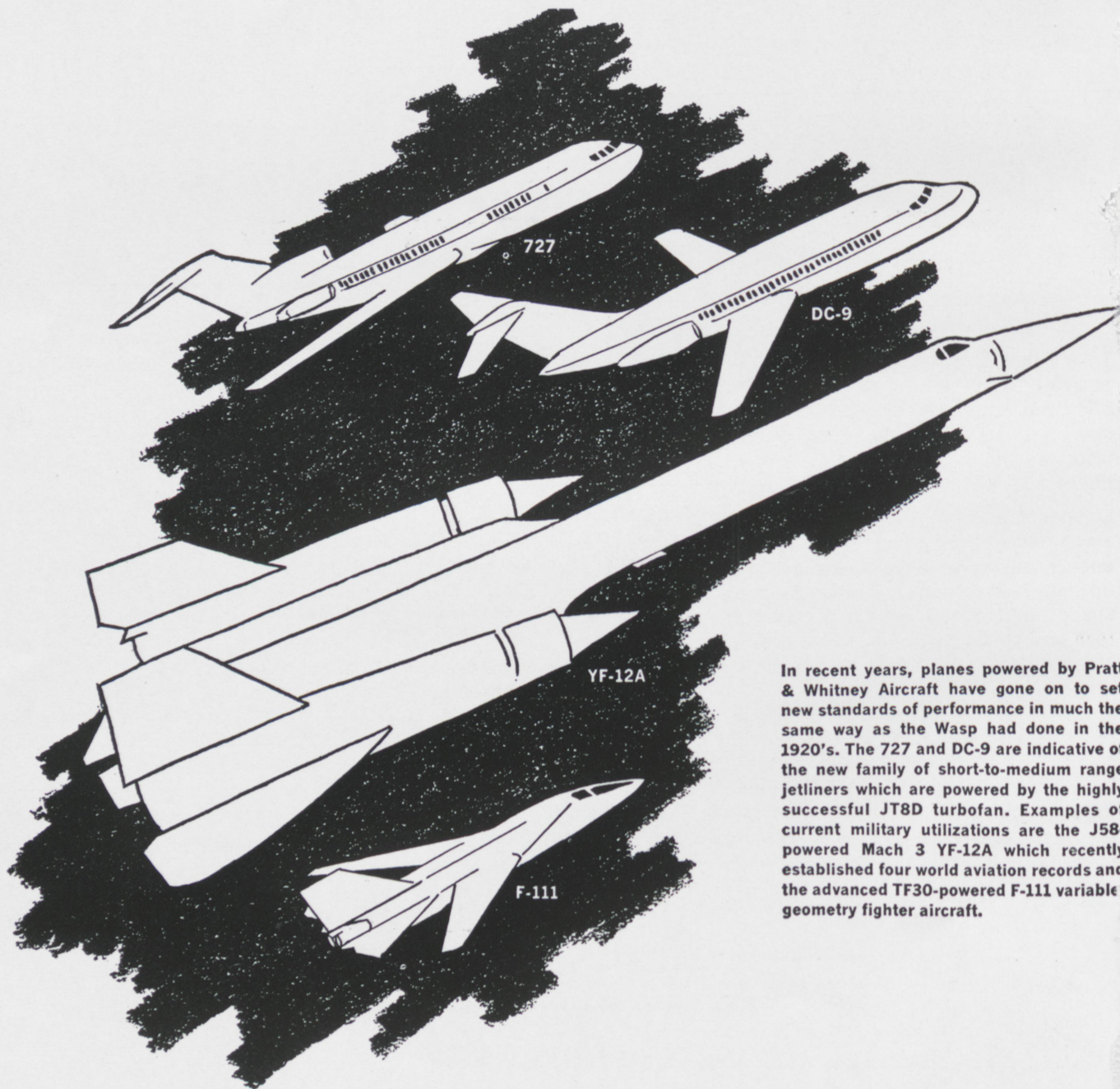


# Past



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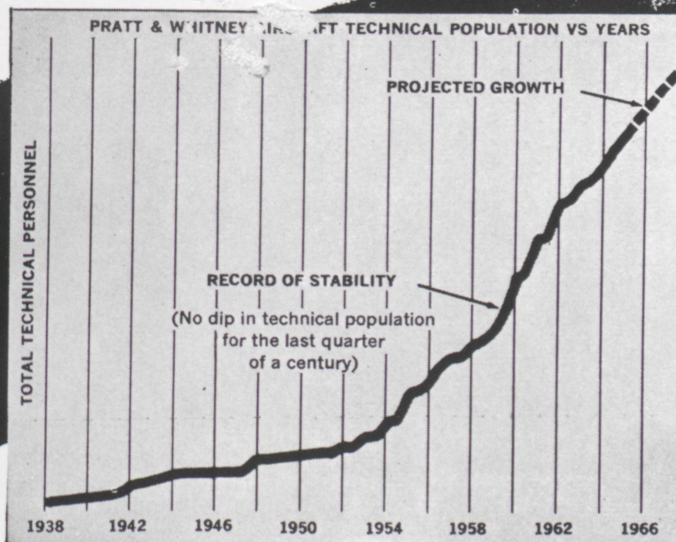
# Present



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# Quantum Electronics

## Part II

by Dr. H. A. Sabbagh

Part II in this three part series deals with quantization of the electromagnetic and acoustical field.

### 1. Introduction

The early work in quantum mechanics dealt with particle phenomena. Everything would have been fine except that people (and later on we also will be people in this sense) had to calculate interaction phenomena between particles and fields. This meant that in order to treat the complete system of particles and fields consistently one had to quantize the fields.

In this part of the series we will show how the electromagnetic and acoustic fields may be cast into a quantum mechanical framework. We will use the results in our next paper in order to demonstrate how light and sound may interact to perform parametric amplification and/or frequency conversion. At this point a review of part I may be in order.

### 2. Quantizing the Electromagnetic Field

We start out classically by imagining the E-M field to be contained within a cavity of arbitrary shape with perfectly conducting boundary walls. The interior of the cavity contains material of dielectric constant  $\epsilon$  and magnetic permeability  $\mu$ . The field vectors  $\vec{E}(\vec{r}, t)$ ,  $\vec{H}(\vec{r}, t)$  satisfy Maxwell's equations and the appropriate boundary conditions: (2-1)

$$(a) \nabla \times \vec{E}(\vec{r}, t) = -\mu \frac{\partial \vec{H}(\vec{r}, t)}{\partial t}$$

$$(b) \nabla \times \vec{H}(\vec{r}, t) = \epsilon \frac{\partial \vec{E}(\vec{r}, t)}{\partial t}$$

(c)  $E_{\text{tan}} = 0$ ,  $H_{\text{normal}} = 0$  on S, the boundary of the cavity. From (2-1) we obtain the wave equations (2-2)

$$(a) \nabla \times \nabla \times \vec{E}(\vec{r}, t) = -\mu \frac{\partial^2 \vec{E}(\vec{r}, t)}{\partial t^2}$$

$$(b) \nabla \times \nabla \times \vec{H}(\vec{r}, t) = -\mu \epsilon \frac{\partial^2 \vec{H}(\vec{r}, t)}{\partial t^2}$$

Assuming product solutions  $\vec{E}(\vec{r}, t) = \vec{E}(\vec{r})p(t)$ ,  $\vec{H}(\vec{r}, t) = \vec{H}(\vec{r})q(t)$ , (2-2) is equivalent to (2-3)

$$(a) \nabla \times \nabla \times \vec{E}(\vec{r}) = k^2 \vec{E}(\vec{r})$$

$$(b) \nabla \times \nabla \times \vec{H}(\vec{r}) = k^2 \vec{H}(\vec{r})$$

$$(c) \frac{d^2 p(t)}{dt^2} = -\frac{k^2}{\mu \epsilon} p(t) = -w^2 p(t)$$

$$(d) \frac{d^2 q(t)}{dt^2} = -\frac{k^2}{\mu \epsilon} q(t) = -w^2 q(t)$$

Equations (2-3) (a) and (b) constitute an eigenvalue problem for the vectors  $\vec{E}(\vec{r})$  and  $\vec{H}(\vec{r})$ .  $k^2$  is the eigenvalue parameter.

Because  $\vec{E}$  and  $\vec{H}$  are subjected to the boundary conditions (2-1) (c), it follows that there are a discrete set of eigenvalues,  $k^2 n$ ,  $n=1, 2, 3, \dots$  and associated eigenvector-functions  $\vec{E}_n(\vec{r})$ ,  $\vec{H}_n(\vec{r})$ .\* It can be shown, also, that any function of  $(\vec{r}, t)$  can be expanded in a series of these eigenfunctions, or modes. The expansion coefficients are the p and q functions which also form a discrete set.

We can, and therefore will, assume that the  $\vec{E}_n$  and  $\vec{H}_n$  are orthonormalized in the sense that (2-4) (a), (b)

$$\int_V \vec{E}_l(\vec{r}) \cdot \vec{E}_l(\vec{r}) dV = 1$$

$$\int_V \vec{H}_l(\vec{r}) \cdot \vec{H}_l(\vec{r}) dV = 1$$

$$l=1, 2, 3, \dots$$

$$\int_V \vec{E}_l(\vec{r}) \cdot \vec{E}_m(\vec{r}) dV = 0$$

$$\int_V \vec{H}_l(\vec{r}) \cdot \vec{H}_m(\vec{r}) dV = 0$$

$$\text{if } l \neq m;$$

V is the volume of the cavity.

The expansion of  $\vec{E}(\vec{r}, t)$  and  $\vec{H}(\vec{r}, t)$  is (2-5) (a) and (b)

$$\vec{E}(\vec{r}, t) = \sum_{l=1}^{\infty} \frac{1}{\sqrt{\epsilon}} p_l(t) \vec{E}_l(\vec{r})$$

$$\vec{H}(\vec{r}, t) = \sum_{l=1}^{\infty} \frac{1}{\sqrt{\mu}} w_l q_l(t) \vec{H}_l(\vec{r})$$

where, of course,  $w_l = \frac{k_l}{\sqrt{\mu \epsilon}}$

is the frequency of vibration of the l-th mode. Equation (2-5) is a generalized form of Fourier series in which the independent variables are r, t.

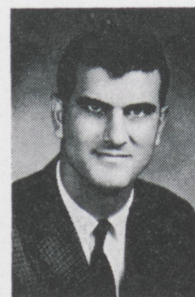
The Hamiltonian, H, for the E-M field is simply the net stored energy. (2-6)

$$\mathcal{H}_{E-M} = \frac{\mu}{2} \int_V \vec{H}(\vec{r}, t) \cdot \vec{H}(\vec{r}, t) dV + \frac{\epsilon}{2} \int_V \vec{E}(\vec{r}, t) \cdot \vec{E}(\vec{r}, t) dV$$

which, when (2-5) and (2-4) are used, becomes (2-7)

$$\mathcal{H}_{E-M} = \sum_{l=1}^{\infty} \frac{1}{2} [p_l^2(t) + w_l^2 q_l^2(t)]$$

(Continued on Page 24)



Dr. Sabbagh was born in Lafayette, Indiana, and lived there until graduation from Purdue University in 1958. In 1961 he returned to Purdue and received his doctorate in Electrical Engineering in 1964.



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## QUANTUM

(Continued from Page 22)

Observe that for each 1 the term

$$\frac{1}{2} p_1^2(t) + \frac{w_1^2}{2} q_1^2(t)$$

corresponds to the energy of a harmonic oscillator (or an L-C tank circuit) whose frequency is  $w_1$ . We have shown, therefore, the formal equivalence of the cavity E-M field to a system of harmonic oscillators, each oscillating at a different frequency.

For each 1 we introduce two new variables  $a_1^+(t)$  and  $a_1(t)$  (everything is still classical, no operators yet): (2-8) (a) and (b)

$$q_1(t) = \left(\frac{h}{2w_1}\right)^{\frac{1}{2}} [a_1^+(t) + a_1(t)]$$

$$p_1(t) = i\left(\frac{h}{2w_1}\right)^{\frac{1}{2}} [a_1^+(t) - a_1(t)]$$

A little bit of algebra puts (2-7) into the form (2-9)

$$H_{E-M} = \sum_{l=1}^{\infty} \frac{hw_l}{2} (a_l a_l^+ + a_l^+ a_l)$$

Now we are ready to quantize the E-M field. In order to do this we associate quantum mechanical operators  $A_1^+ A_1$  with the classical variables  $a_1^+, a_1$ , respectively.

$A_1^+, A_1$  are adjoints of each other and are taken to satisfy the commutation relations (2-10) (a) (b)

$$[A_l, A_m] = [A_l^+, A_m^+] = 0 \quad (\text{operator})$$

for any  $l, m$

$$[A_l, A_m^+] = 0 \quad \text{if } l \neq m$$

(operator)

$$= I \quad \text{if } l = m$$

(identity operator)

The Hamilton operator corresponding to (2-9) becomes (2-11)

$$H_{E-M} = \sum_{l=1}^{\infty} \frac{hw_l}{2} (A_l A_l^+ + A_l^+ A_l)$$

$$\text{Because } A_l A_l^+ - A_l^+ A_l = I$$

(2-11) can be brought into the form

$$(2-12) \quad H_{E-M} = \sum_{l=1}^{\infty} \frac{hw_l}{2} (2A_l^+ A_l + I) = \sum_{l=1}^{\infty} hw_l A_l^+ A_l$$

where, in the second equality, we have suppressed the operator term  $\frac{1}{2} \sum_{l=1}^{\infty} hw_l I$  because it represents only reference level for energy measurements.

The equations of motion for the operator  $A_1^+, A_1$  in the Heisenberg representation are (2-13)

$$\begin{aligned} \frac{dA_1}{dt} &= \frac{1}{i\hbar} (A_1 H - H A_1) \\ &= \frac{1}{i\hbar} (A_1 \sum_{n=1}^{\infty} hw_n A_n^+ A_n - \sum_{n=1}^{\infty} hw_n A_n^+ A_n A_1) \\ &= -i w_1 A_1 \end{aligned}$$

$$\frac{dA_1^+}{dt} = \frac{1}{i\hbar} (A_1^+ H - H A_1^+)$$

where (2-10) was used.

The solutions of (2-13) are (2-14) (a) and (b)

$$\begin{aligned} (a) \quad A_1 &= A_{10} e^{-i w_1 t} \\ (b) \quad A_1^+ &= A_{10}^+ e^{i w_1 t} \end{aligned}$$

where  $A_{10}, A_{10}^+$  are "arbitrary constant" operators, independent of time and satisfying (2-10). The term  $e^{\pm i w_1 t}$  is, of course, a complex parameter depending of time and not an operator.

From (2-14) we have

$$A_1^+ A_1 = A_{10}^+ A_{10}$$

which shows that even though

$$A_1^+ \text{ and } A_1$$

individually depend on time as in (2-14), their product does not. If we substitute this result into (2-12) we get (2-15)

$$H_{E-M} = \sum_{l=1}^{\infty} \frac{hw_l}{2} A_{l0}^+ A_{l0}$$

Hence (2-15)

$$\langle H_{E-M} X | X \rangle = \sum_{l=1}^{\infty} \frac{hw_l}{2} \langle A_{l0}^+ A_{l0} X | X \rangle$$

which has an interesting interpretation if  $x$  is an (abstract) eigenvector of the operator  $A_{l0}^+ A_{l0}$ .

We proceed now to investigate the eigenvalue problem (2-16)

$$A_{l0}^+ A_{l0} X_k = \lambda_k X_k$$

where  $x_k$  is the  $k$ -th eigenvector and  $\lambda_k$  is the corresponding eigenvalue.

First we prove that  $\lambda_k > 0$ ,  $k=0, 1, 2, \dots$ . From (2-16) we get (2-17)

$$\langle A_{l0}^+ A_{l0} X_k | X_k \rangle = \lambda_k \langle X_k | X_k \rangle$$

and, by using the definition of the adjoint operator, (2-18)

$$\langle A_{l0} X_k | A_{l0} X_k \rangle = \lambda_k \langle X_k | X_k \rangle$$

Because the norms of the vectors

$A_{l0} X_k$  and  $x_k$  are non-negative for each  $k$ , we conclude that  $\lambda_k > 0$ .

Next we will show that if  $x_k$  is an eigenvector of  $A_{l0}^+ A_{l0}$ ,

$$\text{then so also is } A_{l0}^+ X_k$$

The result follows because

$$\begin{aligned} A_{l0}^+ A_{l0} (A_{l0}^+ X_k) &= \\ A_{l0}^+ (A_{l0}^+ A_{l0} + I) X_k &= \\ (\lambda_k + 1) A_{l0}^+ X_k \end{aligned}$$

where we have assumed that

$$A_{l0}^+ A_{l0} X_k = \lambda_k X_k \quad \text{and used}$$

(2-10) (b). Hence,  $A_{l0}^+ X_k$  is an eigenvector of the operator  $A_{l0}^+ A_{l0}$

and its eigenvalue is  $\lambda_k + 1$ . By an identical argument we can show that

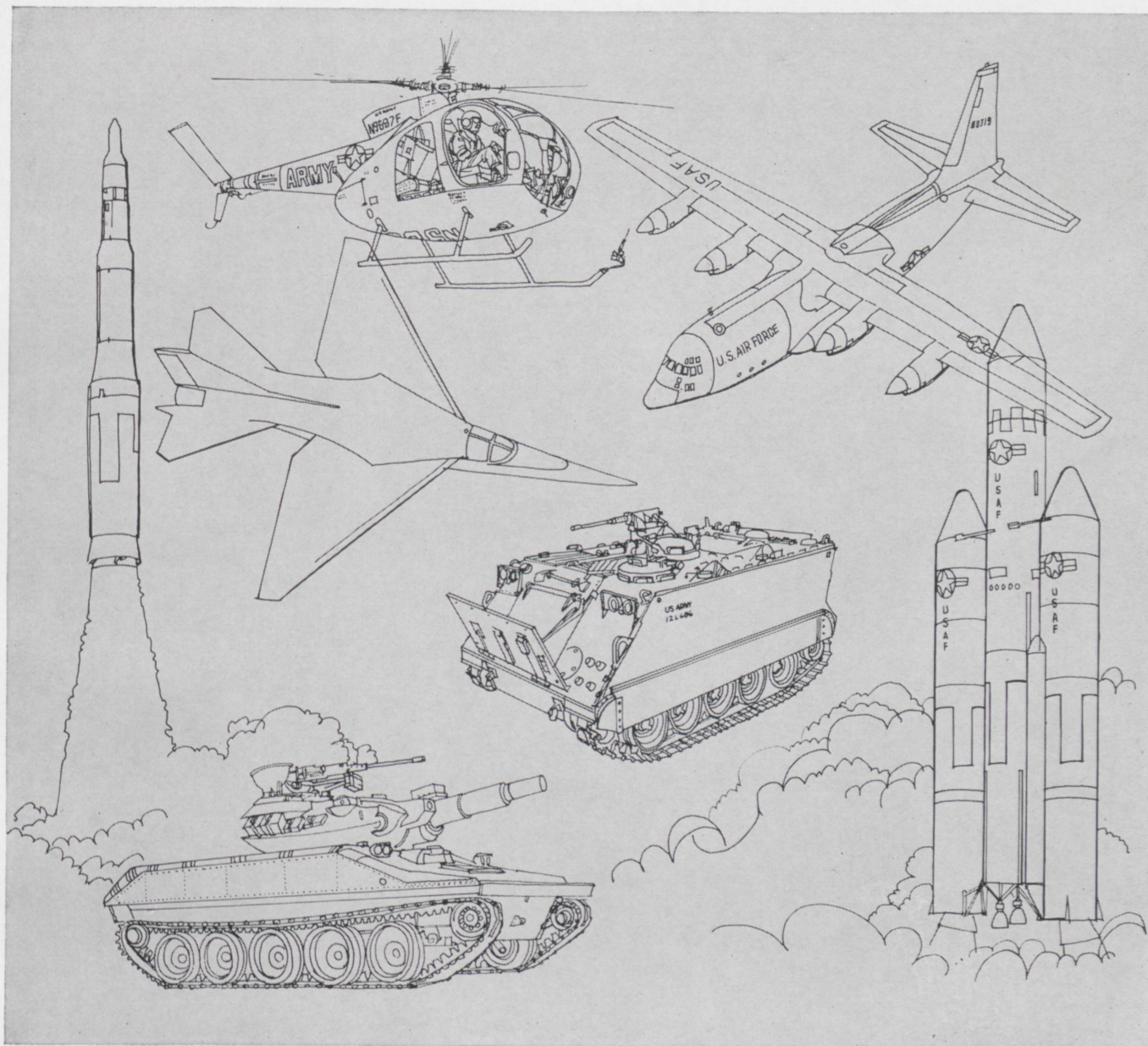
$$A_{l0} X_k \quad \text{is an eigenvector of}$$

$$A_{l0}^+ A_{l0}$$

with eigenvalue  $\lambda - 1$ .  $A_{l0}^+$  is called the raising operator because it raised an eigenvalue by unity, while

(Continued on Page 30)





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## EUGLENA

(Continued from Page 17)

$$\begin{aligned}
 & S(x) \left( \frac{h}{2\pi i} \frac{d}{dx} \right)^2 \\
 & e^{\frac{2\pi i}{h} xy} dx \\
 & = \frac{1}{\sqrt{h}} \left( \frac{h}{2\pi i} \right)^2 \int t^+(y) dy \\
 & \int \frac{d^2 S}{dx^2} e^{\frac{2\pi i}{h} xy} dx \\
 & = \left( \frac{h}{2\pi i} \right)^2 \int S^+(x) \\
 & \frac{d^2 S}{dx^2} dx \Rightarrow \\
 & \frac{1}{2} (\Delta p)^2 = \frac{h^2}{4\pi} \int \left| \frac{dS}{dx} \right|^2 dx
 \end{aligned}$$

The formula which can be used is

$$\begin{aligned}
 \left| \frac{dS}{dx} \right|^2 & \geq \frac{1}{(\Delta q)^2} |S(x)|^2 \\
 - \frac{d}{dx} \left( \frac{x}{(\Delta q)^2} |S(x)|^2 \right) \\
 - \frac{x^2}{(\Delta q)^4} |S(x)|^2
 \end{aligned}$$

This comes from re-arranging

$$\left| \frac{x}{(\Delta q)^2} S(x) + \frac{dS}{dx} \right|^2 \geq 0$$

which obviously holds true because of the square of the absolute value being always positive or zero. This gives

$$\begin{aligned}
 \frac{1}{2} (\Delta p)^2 & \geq \frac{1}{2} \frac{h^2}{4\pi^2} \frac{1}{(\Delta q)^2} \\
 \text{or} \\
 \Delta p \Delta q & \geq \frac{h}{2\pi}
 \end{aligned}$$

There can be other forms of the uncertainty principle. For example, in the case of angular momentum there exists the relation,

$$\Delta \theta \Delta L_{\theta} \geq h$$

Still another form of the uncertainty principle includes the variables of time and energy. Starting from the Planck hypothesis and re-arranging

$$\text{them; } \nu = \frac{E}{h} \text{ which gives}$$

$$\nu = \frac{\Delta E}{h}$$

From the theory of Fourier analysis, a simple relation between the frequency and time comes out

$$\Delta \nu \Delta t \geq \frac{1}{2\pi}$$

Upon substitution in the above the conclusion is arrived at that

$$\Delta E \Delta t \geq \frac{h}{2\pi}$$

The third section will be devoted to a discussion of the entrance into each of the two main quantum theories of Heisenberg's Uncertainty Principle. As was stated before, this principle forms the basis of Quantum Theory.

In matrix theory the Heisenberg Principle takes the form of the commutation laws. Before discussing further the actual statement of these laws I will define the term commutation. If  $r_1$  and  $s_1$  are two matrices they are said to commute if the order in which they are multiplied together does not affect the answer of the multiplication. In mathematical symbols, commutation occurs when,

$$r_1 s_1 - s_1 r_1 = 0$$

In general, commutation does not occur in matrices. There are a few cases in which it does, but these are exceptions rather than the rule.

In the early development of quantum matrix theory, Dirac enunciated the generalized commutation rules for conjugate quantities like position and momentum. He found that the  $r$ th solution matrix  $q_r$  commutes with the non-conjugate solution matrices  $q$  and  $p$  but it does not commute with the conjugate momentum matrix  $p_r$ . Then the commutation rules read

$$(\alpha) \quad q_r q_s - q_s q_r = 0$$

$$(s=r, s \neq r)$$

$$(\beta) \quad p_r p_s - p_s p_r = 0$$

$$(s=r, s \neq r)$$

$$(\gamma) \quad p_r q_s - q_s p_r = 0$$

$$(s \neq r)$$

$$(\delta) \quad p_r q_r - q_r p_r = \frac{h}{2\pi i} \cdot 1$$

where 1 represents the unit matrix.<sup>8</sup> These rules hold for all conjugate quantities, such as energy and time, not just the momentum and position terms. This can be seen to be a statement of the Uncertainty Principle.<sup>9</sup>

In the Wave Theory of Schrodinger, where the particles themselves are represented as wave packets, the uncertainty relations come about when one tries to define the classical quantities of position and momentum for the packet. To do this the packet somehow must be connected with the particle whose characteristics are to be represented. This is done, as in the earlier section, by assuming that the particle is situated at some point inside the confines of the wave packet. Then this gives an uncertainty in the position of the particle  $\Delta x$  which was shown in the previous section to be

$$\text{equal to} \quad \Delta x \geq \frac{\lambda^2}{\Delta \lambda}$$

From a different source the momentum was shown to have an uncertainty of  $\Delta x \Delta p_x \geq h$ . This gives which is the statement of the uncertainty principle for wave mechanics.

## RESULTS AND CONFLICTS

It would be a gross understatement to infer that the effect of the enunciation of the uncertainty principle by Heisenberg on philosophical development was tremendous. It was catastrophic! As was stated before, natural science took as its basis the ability to perform the Cartesian division. Science attacked the problem of explaining the world under the impression that the "res extensa" concept was valid in every case. They tried to separate themselves from the world and view the occurrences objectively, interacting in no way with the system.

Heisenberg has pointed out one of the basic difficulties involved in the Cartesian division of the world. He points to the fact that because of the definition of "res extensa" the animals would have to be categorized there, i.e., their actions and the processes of their lives can be explained



by application of the laws of physics and chemistry. This implies that they are nothing more than ultra-complex "machines" of a sort. Since parallelism between experiences of the mind and body, the mind must also follow these laws of physics and chemistry. This brings up the question of "free will."<sup>10</sup>

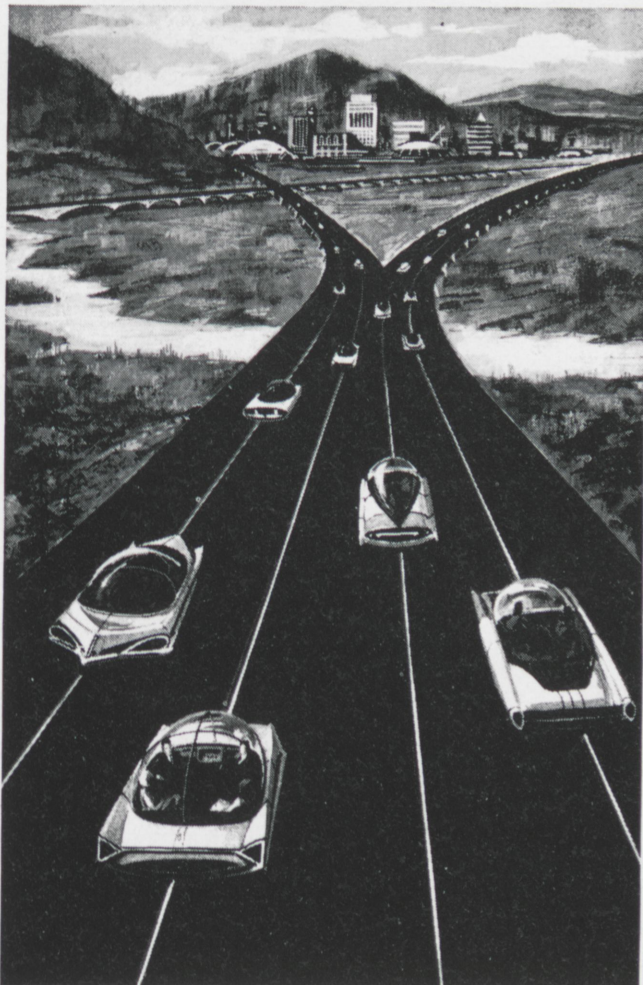
As was pointed out before, however, the Cartesian division did seem to be adequate for the explanation of natural phenomena in Newton's time. The reason for this can easily be seen. If, in the statement of the uncertainty principle, we allow the value of  $h$ , Planck's quantum of action to shrink to zero, we find that the quantum mechanical predictions are exactly the same as those of Newtonian science at that point. The same effect can be realized if the quantities involved in the uncertainty relation are many orders of magnitude larger than Planck's constant. This was the entire domain in which classical physics was operating so it was quite easy to overlook such a small uncertainty.

Riding along with this concept of uncertainty is the concept of indeterminacy. Newtonian science is an exact science, or vigorously deterministic, because any quantity can be calculated or, in theory, measured accurately to as many decimal places as desired. The uncertainty principle, however, refutes this argument by disallowing the simultaneous measurement to arbitrary accuracy of conjugated quantities. This brought on the concept of probability, and with it a storm of protests from very eminent scientists. Albert Einstein led this protest, expressing his objection by stating "God does not play dice."<sup>11</sup> However, this probability is a direct consequence of the uncertainty principle. So, if one accepts the principle then one must also accept the probability derived directly from it.

One possible explanation for the Einstein objection would be that Einstein is confused as to what the uncertainty principle applies. It may be true that "God does not play dice". However, this concept refers

to the actual state of a system under scouting. On the other hand, the uncertainty principle refers to our knowledge of the state of the system. It can be taken for granted that these are two distinct entities which become coincident (if the term may be loosely applied here) only when an actual measurement is performed and an observation is made. Therefore, "God" may do anything and the uncertainty principle will apply to our knowledge of the system.

Many interesting philosophical problems are uncovered in the discussion of such a principle. Some of the most flashing are the concept of reality, direct measurements and indirect measurements, incompleteness of definitions in our classical language for use in explanations of reality, etc. However, the discussion of these would be involved and would pertain very little to the direct consequences of the uncertainty principle, although with little trouble they can be shown to have their roots in this relation.



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# SPORTS

## *Un-illustrated*

### BASKETBALL TEAM'S NEW YORK TRIP

by JOHN MUTCHNER



by ESPENLAUB

One of the many sights seen by the basketball team.

On Monday, December 13, the Rose Poly basketball team left campus at 5:30 P.M. enroute to New York for three basketball games.

On Monday evening we drove to just north of Columbus, O. where we stayed all night. On Tuesday we drove up to Buffalo, N.Y. and went over to see Niagara Falls. From there we continued on to Batavia, N.Y. on the New York Expressway where we stayed all night and worked out at the local YMCA. On Wednesday we drove on to Troy, New York where we played Rensselaer Poly that evening. We lost

81 to 75 and did not play badly considering we had not practiced, other than a little the night before, for seven days and had driven approximately 1000 miles to get there. The next day we drove down to New York City and stayed at the U.S. Marine Academy in Kingspoint. We were scheduled originally to play the Merchant Marine Academy but they had to cancel due to a conference tournament commitment. They did, however, honor their original guarantee. We certainly enjoyed having the opportunity to see a military academy in operation. We played New York Tech that evening on the Merchant Marine Academy floor. We defeated New York Tech by 20 points and played what was by far the best game we had played all year. They were an exceptionally big team with a 6-8" center and 6-6" and 6-5" forwards. Their record at the time we played them was four wins and one loss.

On Friday, after having moved to a Manhattan hotel, we went back over to Brooklyn and played Brooklyn Poly. Even though we outscored Brooklyn Poly by four field goals we managed to lose to them by four points.

We spent the rest of the weekend generally seeing the city. Almost all of the boys took the downtown Manhattan tour, visited the United Nations building and the Statue of Liberty, went to the top of the Empire State Building, took a ride on the Staton Island Ferry, and generally had an all-around good time just wandering around Times Square. More than half the team saw the musical "Hello Dolly" Saturday evening.

On Sunday morning we left New York and drove down to Philadelphia where we stopped off at Independence Hall and saw the Liberty Bell and other historical sights around that area. From there we came on home via the Pennsylvania Turnpike and arrived back in Terre Haute on Tuesday evening.

It was a wonderful trip and while we won only one ball game the other two games were close and were lost to fine schools. The boys had a wonderful time and saw a lot of things which many of them had not had an opportunity to see before. It is my sincere desire on trips of this type that we take advantage of every possible educational opportunity.



## QUANTUM

(Continued from Page 24)

$A_{10}$  is called the *lowering operator* because it lowers an eigenvalue by unity.

Next let  $x_0$  be the eigenvector corresponding to the eigenvalue  $\lambda_0=0$  (this is the smallest possible eigenvalue of  $A_{10}^+ A_{10}$ ). We are going

to show that  $A_{10} x_0 = 0$ . The proof uses (2-18), because if  $\lambda_0=0$  is substituted into the right-hand side then  $\langle A_{10} x_0 | A_{10} x_0 \rangle = 0$ . But the only vector whose norm is zero is 0. Thus

$$A_{10} x_0 = 0$$

The  $k$ -th eigenvector is given

by  $(A_{10}^+)^k x_0 = x_k$ . The corresponding eigenvalue is  $\lambda_k=k$ ,  $k=0, 1, 2, \dots$ ,

because  $A_{10}^+$  applied  $k$  times to  $x_0$  adds the integer  $k$  to  $\lambda_0$  ( $=0$ ) in order to get  $\lambda_k=k+\lambda_0=k$ . We have just proved a very important result: the eigenvalues of  $A_{10}^+ A_{10}$  are integers or zero.

So far we have discussed each mode separately. An eigenstate of the E-M field considering all modes together may be written as

$$x_{k_1 k_2 \dots k_\infty}$$

This abstract vector satisfies (2-19) (a) (b) and (n)

$$A_{10}^+ A_{10} x_{k_1 \dots k_\infty}$$

$$= k_1 x_{k_1 \dots k_\infty}$$

$$A_{20}^+ A_{20} x_{k_1 \dots k_\infty}$$

$$= k_2 x_{k_1 \dots k_\infty}$$

$$A_{n0}^+ A_{n0}$$

$$A_{n0}^+ A_{n0} x_{k_1 \dots k_\infty}$$

$$= k_n x_{k_1 \dots k_\infty}$$

where all the  $k$ 's are zero or a positive integer. Because of this last

fact we say that  $x_{k_1 \dots k_\infty}$  represents a state of the E-M field in which there are  $k_1$  photons in mode 1,  $k_2$  in mode 2, etc. It is easy to verify that eigenvalue of  $H_{E-M}$  corresponding to

$$x_{k_1 \dots k_\infty} \text{ is } \sum_{l=1}^{\infty} h w_l k_l.$$

Because the eigenstates can always be taken to the orthonormal, we have, upon substitution of (2-19) into (2-15), (2-20)

$$\langle H_{E-M} x_{k_1 \dots k_\infty} | x_{k_1 \dots k_\infty} \rangle = \sum_{l=1}^{\infty} h w_l k_l.$$

The interpretation of (2-20) is that each photon in mode 1 has energy  $h w_1$ . Thus we have a statement of the energy of the E-M field in terms of discrete quanta, the photons, of energy  $h w$ .

### 3. Quantizing the Acoustic Field

The ideas used in quantizing the acoustic field are identical to those just presented. We first assume a homogenous, isotropic elastic medium of mass density  $\rho$ , length  $L$ , and stiffness modulus (a combination of shear and bulk moduli)  $T$ . Let the deviation of an element of the medium, initially located at  $x$ , be  $q(x, t)$  (we assume one-dimensional wave motion, only).

The Hamiltonian for acoustic wave propagation is (3-1)

$$H_{\text{acoustic}}$$

$$= A \int_0^L \left[ \frac{\rho}{2} \left( \frac{\partial q}{\partial t} \right)^2 + \frac{T}{2} \left( \frac{\partial q}{\partial x} \right)^2 \right] dx$$

where  $A$  is the cross-sectional area of the acoustic wave normal to  $x$ . Note that (3-1) is the net energy (kinetic and potential) contained within the volume occupied by the medium.

We expand  $q(x, t)$  in a Fourier series (3-2)

$$q(x, t) = \frac{1}{(AL)^{1/2}} \sum_{k=-\infty}^{\infty} Q_k(t) e^{ikx}$$

When (3-2) is substituted into (3-1), we obtain (3-3)

$$H_{\text{acoustic}} = \sum_{k=-\infty}^{\infty} \left( \frac{\rho}{2} \dot{Q}_k \dot{Q}_{-k} + \frac{T}{2} k^2 Q_k Q_{-k} \right)$$

The dot over a quantity stands for the time derivative of that quantity.

Proceeding as before, we define new variables (still classical),

$$b_k^+, b_{-k} \text{ by: (3-4) (a) and (b)}$$

$$\dot{Q}_k = i(h w_k / 2p)^{1/2} (b_k^+ - b_{-k})$$

$$Q_k = \frac{1}{|k|} (h w_k / 2T)^{1/2} (b_k^+ + b_{-k})$$

where  $w_k = (T/P)^{1/2} |k|$  is the frequency of vibration of the  $k$ -th acoustic mode.

Equation (3-4) when substituted into (3-3) yields (3-5)

$$H_{\text{acoustic}} = \frac{1}{2} \sum_{k=-\infty}^{\infty} h w_k (b_{-k}^- b_k^+ + b_k^+ b_{-k}^-)$$

We quantize the acoustic field at this point by assigning quantum mechanical operators  $B_k$  and  $B_k^+$  to their respective classical variables. As before, these operators satisfy (3-6)

$$[B_k, B_k^+] = I, \quad k=0, \pm 1, \pm 2, \dots$$

Hence, the Hamiltonian operator for the acoustic fields is (after dropping the energy reference level operator as before) (3-7)

$$H_{\text{acoustic (operator)}}$$

$$= \sum_{k=-\infty}^{\infty} h w_k B_k^+ B_k.$$

The formal resemblance of (3-7) and (2-12) is obvious. Everything said about the E-M field from (2-12) on holds for the acoustic field. The quantized acoustic waves are called *phonons*. When the E-M field interacts with the acoustic field we think, picturesquely, in terms of photon-phonon collisions or interactions. This will be the subject of our next paper.



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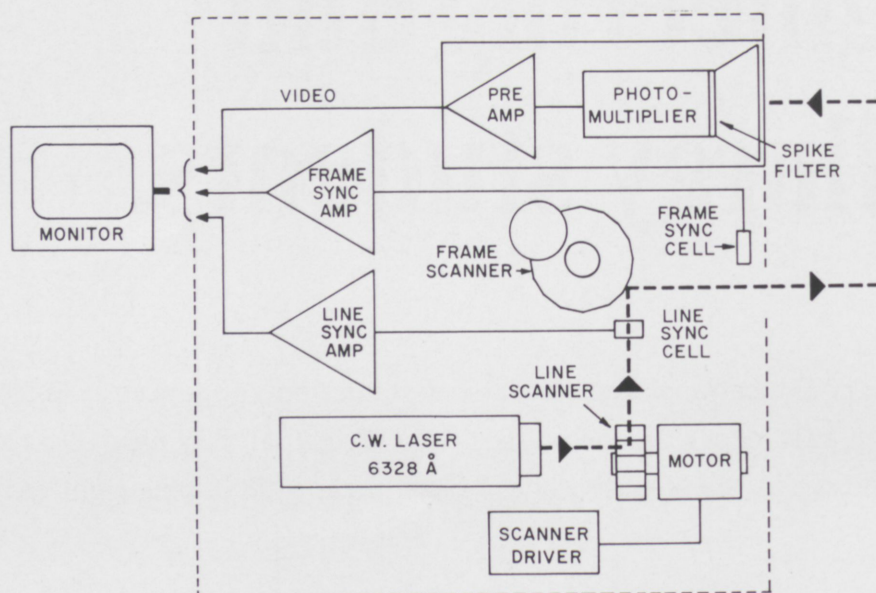


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## SHOOTING IN THE DARK

edited by FRANK NIGH



Laser TV Block Diagram

Beware all followers of Buck Rogers, Flash Gordon, and Dick Tracy, scientific ingenuity is advancing on Diet Smith. None of the serials to date have suggested a television camera system that functions with no apparent illumination. Thus Perkin-Elmer may be one step ahead of the comics.

Scanning by rapidly moving narrow lines of red laser light, subjects even in complete darkness appear on the TV monitor as sharp and clear as in daylight. Unlike conventional TV cameras, this system uses no image orthicon tube; instead, it uses a laser light transmitter and a reflected-energy receiver. For protection, the intensity of the laser beam is well below the level which might endanger the vision of human subjects.

In the present system, the light beam from a continuous wave laser

is deflected by a pair of rotating mirrors so as to completely scan the subject in a series of continuous lines once every sixtieth of a second. The energy reflected from the target is sensed by a photomultiplier and used to intensity modulate the cathode ray tube in a television monitor whose electron beam is scanning in synchronism with the transmitted laser beam.

The model shown in the picture is a helium-neon unit with approximately 15 milliwatts output in a one milliradian beam at 6,328 angstroms. The beam from this laser is reflected off a folding mirror to the line scanner. This scanner consists of a 16-sided 1.5" diameter polygon prism mounted integral with the scanner motor rotor. This motor drives the line scanner at approximately 60,000 rpm or 16,000 scans per second. Following the line scanner the beam

strikes the 24-sided frame scanner running at 150 rpm or 60 frames per second. The beam reflected off the frame scanner continues on toward the target. In combination, the line and frame scanners cause the target to be scanned at rates similar to commercial television (15,750 lines/sec; 60 frames/sec). The one milliradian beam results in resolution similar to that of commercial television.

A portion of the laser energy reflected from the target is detected by photomultiplier with the photocathode. A spectral filter located in front of the photocathode rejects 99% of the background light. Following the photomultiplier, a preamplifier raises the signal to a level sufficient to drive the video amplifier of a commercial television set. The deflector circuits on the television monitor are

(Continued on Page 34)





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## R & D

(Continued from Page 32)

synchronized with the scanning laser beam by means of photocells placed in the scanning beams.

Performance and range capability of all forms of this system could be tremendously enhanced by utilizing the new argon green-beam lasers, which provide output powers of several watts and other wavelengths also could be employed.

One potential use is that of an all-weather landing aid for aircraft. The device could be used as a direct vision video "radar" effective from an altitude of several hundred feet. Runways or helicopter landing spots can be readily marked off with reflective paints or tapes. These would give energy returns to the laser receiver with several hundred times the intensity of the surrounding terrain. Such an aid could be especially valuable for remote military outposts jungle or other dense areas. For instance, helicopter landings could be quickly indicated by ground crews using portable markers.

Laser TV has potential as a means of covert surveillance for law enforcement agencies. The laser beam's fast scan speed and low intensity combine to make it virtually invisible. With a properly tailored system it would be possible to observe persons at distances in excess of a mile.

In the field of science, a number of applications such as studies of the nocturnal habits of animals may be feasible. Versions of this type of system also could have possibilities as a lunar or planetary landing aid for spacecraft.

The possibility that an imaginative reader may find more marvels in scientific achievements than in the adventures of his favorite good-guy shows that applications are quickly following up unpredecended ideas. Maybe one day the sky will no longer be the limit and gravity will no longer be the restraining force on man, but together they will be man's guideline and source of energy.

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## CULTURES

(Continued from Page 10)

one of these factors was the excellence in building materials. The Romans made some very important discoveries in construction. They made and used the first good quality concrete. This concrete enabled the Romans to do extensive building of big structures. Without concrete the famous arches and vaults of the Romans would have been almost impossible to build. On a whole, Roman building had its success based on the fine quality of the concrete used and the strong, technical concepts of building that had been passed on by the Etruscans.

### GREEK CONTRIBUTION

In fields other than technology, Rome was influenced by the culture of Greece. Rome took all its ideas of theoretical science from the Greeks and never did develop their own basis for theoretical science. The Romans were so much influenced by the Greeks that details about Roman science would be a carbon copy of the scientific achievements of Greece. Rome, however, when she took these Greek ideas lost something in the translation. The Romans lost all the beauty of the Greek thinkers and didn't appreciate the full value of what this science had to say to them. The Romans had "conquered the Greek world, but they had already lost the most precious part of its heritage."<sup>5</sup>

The Greek philosophy never quite overcame the Etruscan mixture of science and religion. The superstitions of the Etruscans were constantly present during the entire time of the Roman civilization. The combination of the Greek thought and the Etruscan superstition seemed to stop all advances in science that Rome might have been able to make. The Romans at no time distinguished themselves in mathematics and mechanical sciences. They borrowed all their ideas from the Greeks and all their skills from the Etruscans. The Romans did not despise pure science, but they were content

with the knowledge of the Greeks and the Etruscans. There was no such thing as Roman science. Rome just took over the different sciences and used them to make themselves rich and conquer lands.

### COMPARISON

The Chinese and Roman sciences were as different as night and day. The Chinese did not have an exceptionally scientific culture, but they did not remain content to let other civilizations develop science for them as the Romans allowed the Greeks to do. The main reasons for this basic difference in the two civilizations are their geographical locations and the psychological make-up of their people. The Chinese were isolated from the lands to the west and developed a culture different from any other in the world. China was tremendously influenced by this factor and the teachings of the passivist thinkers. The Romans came into power with science and culture already developed for them. Rome "made no advance in science and no improvements in industry, but she enriched the world with a commerce moving over secure seas, and a network of enduring roads that became the arteries of a lusty life."<sup>6</sup>

From these two civilizations the conclusion can be drawn that man is influenced by his environment and what type of outside influences are present. The Chinese were basically agricultural and were isolated. Their development was different from that of all other cultures in the world. The Romans were influenced tremendously from the outside by the Greeks and the Etruscans, and they were a highly commercialized nation. Rome became a highly technical society while China became agriculturally oriented.

<sup>1</sup>Reni Taton, *Ancient and Medieval Science*, (New York, 1965), p. 1.

<sup>2</sup>Reni Taton, *Ancient and Medieval Science*, (New York, 1965), p. 781.

<sup>3</sup>Reni Taton, *Ancient and Medieval Science*, (New York, 1965), p. 177.

<sup>4</sup>Reni Taton, *Ancient and Medieval Science*, (New York, 1965), p. 305.

<sup>5</sup>Will Durant, *Caesar and Christ*, (New York, 1944), p. 311.

<sup>6</sup>Will Durant, *Caesar and Christ*, (New York), p. 671.

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# DATE RATER

Stolen by Chuck Risch, Jr. M.E.

From the Minnesota 'Technolog', who got it from the Georgia Tech 'Rambler' by way of the Iowa 'Transit', comes this unique Date Rater. This has been circulating in the college magazine humor pool for some time. Noting its practical applications we felt it should be brought to the attention of the students at Rose. This chart will solve the age-old problem of finding a good date. Just ask her for the required measurements (if she's not willing to give them to you, bring her in to the Technic office and we'll be glad to measure her for you) and plug into the equations.

Note that this chart also rates dates for their working ability, a real asset after you decide to get married and enter graduate school.

(1) Compute these values: NR, NP, NB, using the table of average values below to make sure you are in the ball park.

NP =

Ring Size X Head Diameter (in.)

X No. Teeth

Shoe Size X Wrist (in.) X

Grip (lbs.) X No. Chins

No. Chins X 33,000

Weight—80-180 lbs.

Head Diameter—6-8 in.

Height—58-72 in. Ring Size—5-8

Waist—20-42 in.

No. of Teeth—20-35

Hips—26-42 in.

No. of Chins—1 (single)

Bust—26-42 in.

2 (double)

Wrist—4-8 in.

Hand Grip—5-14 lbs.

Shoe Size—4-9

(2) Compute date's torque number by multiplying height (inches) by weight (pounds). Enter chart at upper left, at "Torque Number."

(3) Move horizontally across graph until you reach the calculated NR ratio. Mark this spot on the graph; you will use it later.

(4) Move down from this spot, going to the NP ratio you have calculated. NP is the PARTY GIRL rating, so move horizontally to the RIGHT and read her PARTY GIRL rating.

(5) You're not done yet. From the same NR ratio (where you marked the graph) move down until you reach the calculated NB ratio. Move horizontally to the LEFT and read your date's WORKING GIRL rating.

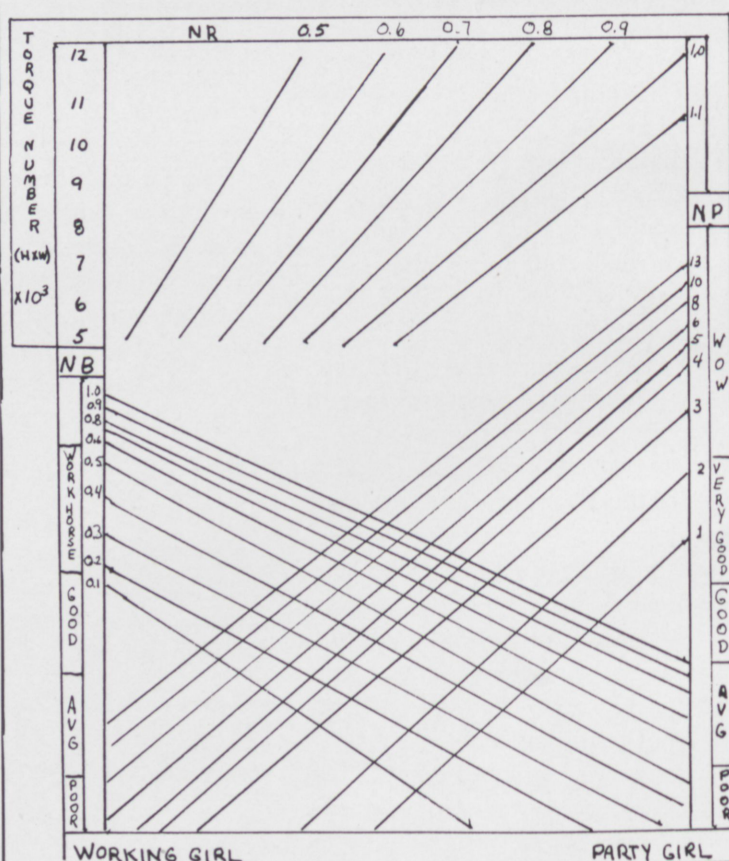
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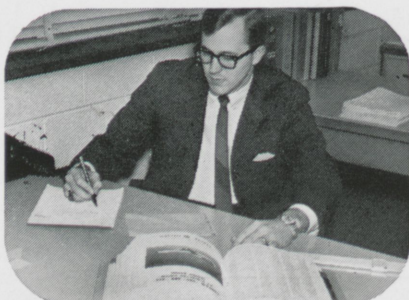


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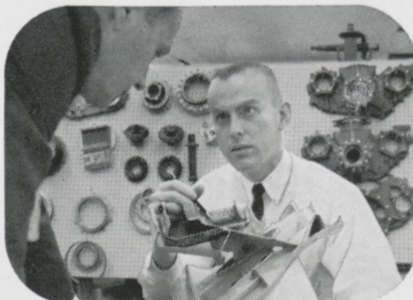




SIX G-E J93 ENGINES push USAF XB-70 to MACH 3.



**JACK WADDEY**, Auburn U., 1965, translates customer requirements into aircraft electrical systems on a Technical Marketing Program assignment at Specialty Control Dept.



**PAUL HENRY** is assigned to design and analysis of compressor components for G.E.'s Large Jet Engine Dept. He holds a BSME from the University of Cincinnati, 1964.



**ANDY O'KEEFE**, Villanova U., BSEE, 1965, Manufacturing Training Program, works on fabrications for large jet engines at LJED, Evendale, Ohio.

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