

Modern Concepts in Physics - ~~Journal~~ ^{Part 1}

By Professor K.S. Krishnan, F.R.S

During the last sixty years
Physics has taken immense strides.
Even ~~the~~ her most ardent votaries
have found it difficult to keep pace
with her advances. Many of them, ~~and~~
~~have felt~~ ^{at} weaker moments, must-
have wished that ~~some~~ ^{the muse} ~~mercifully~~
~~god~~ ^{so} mercifully
declared a two years
holiday for physics so as to enable
them to take breath. But ^{sixty years ago} ~~conditions~~
were very different ~~sixty years~~
~~ago~~. The general feeling among
physicists then was, if I may use
a recently much-used word, one
of ~~an~~ ^{great} ~~supreme~~ complacency. ~~They~~
~~had~~ ~~the~~ ^{they} were satisfied ~~with~~
a ~~kind~~ ~~of~~ ~~comforting~~ ~~conviction~~ that
not only the foundations of physics had
been ^{truly} and firmly and laid, but ^{the frame} ~~the~~ ^{work and} ~~plan~~
the superstructure had been correctly
built, and that all that was left-
for future generations of physicists
to do was to add details to the
structure, and ~~and~~ to give the
finishing touches; — in other

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would to push the ~~calculations~~ to
theoretical investigations to the next
higher approximation, and the
measurements to the next decimal
place. Even a physicist in the
forefront like Maxwell, who was
the most original among the physi-
cists of the day, and who repeatedly
emphasised the ^{reshner of attempting} dangers ~~of~~

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to ~~of~~ setting limits to the possibilities
of science, even he was ~~not~~
thinking ^{not} so much in terms of
possible ^{and fertile} extensive ^{new} territories

that might lie beyond the horizon,
^{in one case} and might be annexed, ^{as of} ~~as of~~ ^{improving} already known
territories. ~~For example~~ Evidently he

had in view systematic investigations
of residual effects of the type
which ~~led to the~~ ^{enabled} Gauss

^{later in the century} to predict ^{in an uncanny manner} the existence of ~~a~~ electrical
charged layers in the upper regions

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of the atmosphere. It was ^{by} similar
systematic study of residuals that
Lord Rayleigh, at a much later date
was led to the discovery of the
rare gas argon.

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From a detailed analysis of the ~~magnetic~~ constants of the earth's magnetic field observed at various places on the surface of the earth he was able to predict that about 96% of the magnetism should be attributed to causes inside the surface of the ~~earth~~ earth, and the remaining 4% to causes outside the surface. In ~~attempting to~~ ~~find~~ attempting to track the latter causes he was led to the possible existence of large electrically charged regions in the upper atmosphere, which as we know today plays an important part in the propagation of radio waves over long distances over the ~~surface~~ earth.

Fortunately this feeling of complexity proved to be the calm before a storm. A ~~series of~~ ~~experiments~~ ~~of~~ ~~the~~ ~~19th~~ ~~and~~ ~~20th~~ A very popular demonstration experiment of the 19th century — ~~is~~ ~~the~~ ~~discharge~~ ~~of~~ ~~electricity~~ ~~through~~ ~~rarefied~~ ~~gases~~. Lurking in this experiment were two of the major discoveries in Physics which have made it possible to revolutionize ~~the~~ ~~Physics~~ ~~altogether~~. One was the ~~discovery~~ ~~of~~ ~~X-rays~~ ~~by~~ ~~Röntgen~~ which ~~introduced~~ ~~into~~ ~~Physics~~ ~~the~~ ~~submicroscopic~~ ~~world~~ ~~of~~ ~~atoms~~, and the ~~discovery~~ ~~of~~ ~~the~~ ~~electron~~ ~~by~~ ~~J.J. Thomson~~ which was the first ~~fundamental~~ ~~particle~~ ~~an~~ ~~elementary~~ ~~particle~~, much smaller than the ~~atom~~ — about which I shall ~~have~~ ~~more~~ ~~to~~ ~~say~~ ~~presently~~. These two discoveries following closely on each other ~~do~~ ~~not~~ ~~with~~ ~~the~~ ~~discovery~~ ~~of~~ ~~radioactivity~~ which ~~significantly~~ ~~came~~ ~~in~~ ~~between~~ ~~them~~ ~~and~~ ~~the~~ ~~discovery~~ ~~of~~ ~~the~~ ~~electron~~ ~~may~~ ~~be~~ ~~generally~~ regarded as ushering in the New Physics on some ~~of~~ ~~aspects~~ ~~of~~ ~~which~~ ~~I~~ ~~shall~~

which has ever since been given prominence and at a phenomenal rate as
 which ~~is~~ ~~mentioned~~ ~~in~~ ~~the~~ ~~beginning~~ ~~of~~ ~~my~~ ~~Speech~~

~~Speak today.~~ Personally ~~however~~

I should like to ante date
the beginning of New
Physics by a few years ~~and~~
~~start it from~~ the discovery
of photo-electricity by Hertz —
a phenomenon well-known to lay-
men today as ~~being~~ application in
photo electric cells. ~~Though~~ The explanation
of the phenomenon was not known
till several years later, ~~the phenomena~~
but it now forms one of the best
supports for the corpuscular aspects
of radiation. It is ~~under~~ ~~one~~ ~~of~~ ~~these~~ ~~things~~
of fate, that Hertz, who by his
the production of long electromagnetic
waves in the laboratory was
supposed to have placed the classical
wave theory on a sound basis,
should have been later dis-
covered of the best support for
the corpuscular theory which
at the same time seemed irreconcilable
with the known wave nature of light.

Whether we date the beginning
 of new physics from the discovery of
 X-rays, or from the discovery of photo-
 electricity - made a few years earlier
 there is little doubt that many of
 our physical concepts have ^{not} undergone
 a radical change since this epoch.
 One of the such, major change is
 in our concepts ^{regard} the ultimate
 constituents of matter, the elementary
 particles out of which all matter
 is built. The idea of a few
 fundamental particles which by their
 grouping form all known manifesta-
 tions of matter is a very old one, and
~~The~~ ~~study~~ ~~of~~ ~~and~~ Its study is
 of special interest, since ~~it~~
~~is~~ ~~in~~ ~~its~~ ~~place~~ it offers a
 striking illustration of the ~~new~~
 general tendency ~~of~~ which Physics
 shares with other sciences, ~~of~~ ~~the~~
~~subject~~ ~~grows~~ ~~the~~ ~~it~~ ~~may~~ ~~of~~ ~~the~~
~~side~~ ~~by~~ ~~the~~ ~~acquisition~~ ~~of~~
~~more~~ ~~knowledge~~ ~~and~~ ~~concepts~~ ~~become~~
~~simpler~~ ~~and~~ ~~clearer~~ ~~and~~ ~~the~~ ~~concepts~~
 Physical laws become more generalized ~~and~~ ~~more~~
 actual ~~in~~ ~~the~~ ~~way~~ ~~as~~ ~~is~~ ~~usually~~ ~~the~~

and
 which
 at first
 might
 appear
 paradoxical,
 many
 other

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(then before) to
simpler / secondly the history of
development of our knowledge of
elementary particles ~~is the~~ the
the best example of the ~~the~~ happy
collaboration of the ~~the~~ theoretical and
the experimental physicists ~~and without~~
which ~~the proper development~~ ^{without} which
~~made~~ ~~the~~ development possible.

The idea of building up all
known matter out of a few ~~atoms~~ ^{ultimate}
~~particles~~ is very old, and is a natural
one. But it is a far cry from ~~the~~
fundamental known matter out of a few ~~atoms~~ ^{ultimate}
~~particles~~ is very old, and is a natural.

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The idea to the ~~ultimate~~ ^{ultimate} ~~particles~~
of these ~~atomic~~ ^{fundamental} particles ~~ultimate~~ ^{ultimate} ~~particles~~
and ~~particles~~ The first identification
a universal constituent of matter, ~~with~~
a definite ~~charge~~ negative charge, and
a definite mass, about $1/1840$ times
that of the lightest atom known,
namely, the hydrogen atom, ~~and which~~

That a heavy ~~particle~~ ^{particle} having the mass of the
~~same~~ presumably ~~of the~~ mass of the
hydrogen atom, and having a
positive charge, of the same magnitude
as the charge of the electron ~~is~~
~~indicated~~ should also be involved
in the building of atoms ~~is~~ ^{is} soon

That matter normally is
electrically neutral and
is atoms much heavier than
the electron, and usually much

and therefore must beavier than the electron

That matter normally is electrically neutral, and ~~its~~^{the} atoms ~~much~~ heavier than the electron and ~~roughly~~ with their mass ~~roughly~~ as integral multiples of the various elements have masses which are ~~probably~~^{roughly} integral multiples of the mass of the hydrogen atom. ~~It indicates~~ ^(in addition to the electron) that λ a

heavy particle, having ~~the~~ a mass roughly that of the hydrogen atom, and a positive charge equal in magnitude to that of the electron, but of positive sign, should also be involved in the building up of the atom.

Thus ~~at~~ these ^{requiring charge} two elementary particles named the light particle, ~~which is negative~~^{the electron -} and the positive charged heavy particle, ~~namely~~^{or} the proton, are necessary constituents of matter. ~~Indeed~~^{Further} at first sight P.T.O.

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it appears that these two ^{also} ~~particles are or~~ ^{may be} sufficient to constitute all the known atoms. ~~The~~ According to modern views the ~~atom~~ atom consists of a central nucleus ^{in which the} bulk of the mass of the atom is concentrated, ~~and~~ which is positively charged, and ~~surrounding~~ revolving round it are a number of electrons. The amount of ^{positive} charge ^(i.e. the number of unit charges or protons) carried by the nucleus determines the number of electrons that revolve around it since the atom as a whole should be electrically neutral ~~total negative charge~~ ^{carried} by all these electrons should together be just sufficient to neutralize the positive charge of the nucleus.

core of nucleus

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~~Start~~ Thus ~~a~~ by successive ^{atom} starting with the hydrogen (1), which contains a single positive charge in the nucleus, and has one electron outside, by successively increasing the positive charge ^{protons} by 1 unit, and the number of electrons outside, also by 1 unit, we can build up successively ^{the atoms of} all the known 92 elements. The number

of ~~positive charges~~ electrons ~~is~~ revolving round the nucleus of the atoms, which is also ^{gives} the ~~number~~ ~~of~~ positive charge magnitude of the positive charge possessed by the nucleus ~~is~~ characteristic of the ^{particular} ~~atom~~ ^{element}, and ^{is called the atomic number, it} determines uniquely its chemical properties, and also its position in the periodic table of the elements.

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~~The picture would be partially~~
~~Now~~ ~~the~~ masses of the atoms, which ~~is~~ ~~concentrated~~ ~~in~~ the nucleus;

To be filled in as in question paper of the last year.

.....PAPER ()

Time allowed : hours.

Maximum marks

Please assign marks to questions

Now if the masses of the atomic nuclei were ~~exactly~~ ^{just} that of the protons that are requisite to give it the observed charge ^{the}

Serial No. of question

No. of Marks.

~~expressed in terms of the mass of the proton, is nearly an integer, as is mentioned, of this integer ~~were~~ which determines the mass of the atom or the atomic weight were found to be equal to the atomic number, the picture ^{of the nucleus} would be particularly simple. The nucleus ^{would then} consist of Z protons, their ~~atomic~~ ^{atomic} number being equal to the number of ~~unequal~~ ^{unequal} that number of electrons residing outside the nucleus which go to make the nucleus.~~

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Actually the atomic masses are ~~found to be much~~ ^{greater} than would correspond to the above simple

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showing that ||

picture; ~~the~~ nucleus ~~can~~ ^{is} ~~not~~ ~~be~~ built up wholly ~~of~~ ~~protons~~ alone. This is indeed to be expected since we can not put together positive charges alone, since they would repel one another and fly apart. But ~~these~~ ^{required} extra particles ~~inserted~~ ~~in~~ ~~the~~ ~~nucleus~~ may be the electrons themselves, in which case the picture may still remain simple. ~~Now~~ These electrons ~~will~~ ~~indeed~~ ~~be~~ ~~in~~ ~~the~~ nucleus may, because of the negative charges which they carry, act as the cementing material between the ~~electrons~~ protons. Now the atomic number ~~does not~~ will not describe the number of protons that go ~~to~~ into the making of the nucleus but will denote the excess of the number of protons over the number of electrons which go into the making of the nucleus.

At this stage however, one meets with a fresh difficulty. In the first place there are various ~~evidences~~ ~~of~~ ~~it~~ factors that

It-2 ~~with~~ ~~also~~ provides the mechanism for increasing the ~~the~~ mass of the nuclei without corresponding increase in charge.

We can then ~~say~~ that we need

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which we need not go into
 which do ^{do not} ~~penetrate~~ ^{penetrate} ~~the~~ ^{an} ~~nucleus~~
 particle as light as an electron
 to stay inside the nucleus. The binding
 energies ^{required} become for the great
~~and~~ ~~and~~ ~~that may~~ ~~when~~ ~~in their~~ ~~spectral~~ ~~character~~ ~~is~~ ~~fit~~ ~~with~~ ~~observation~~ ~~the~~
~~total number~~ ~~of~~ ~~particles~~ ~~present~~ ~~in~~ ~~nucleus~~ ~~does~~ ~~not~~ ~~also~~ ~~come~~ ~~out~~ ~~proper~~.

~~We~~ have spoken till now about
 the mass and the charge of the particles
 the heavy particle ^{with} ~~the~~ ^{unit} ~~of~~ ⁺ ~~we~~ ~~charge~~
 named the ~~positron~~ and the light
 particle, ~~with~~ ~~unit~~ ~~negative~~ ~~charge~~
 named the electron. It was ~~only~~
~~soon~~ recognized that ~~addition~~

these ~~are~~ elementary particles ~~possess~~
 have ~~spin~~ ~~like~~ ~~a~~ ~~top~~ ~~with~~ ~~spin~~ ~~of~~ ~~the~~ ~~particle~~ ~~spinning~~
 also ~~a~~ ~~spin~~ ~~and~~ ~~the~~ ~~spin~~ ~~is~~ ~~the~~ ~~same~~
 angular momentum and they
 have ~~posses~~ also spin motions
 like a top, both the particles
 spinning with the same angular
 momentum. By virtue of these spins
 the particles behave ^{also} like elementary

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 1
 11/5/50
 envelope
 10/4/50
 3/5/50

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magnets, the ^{magnets} strengths of the magnets PLEASE SIGN HERE

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however being very different for
~~two~~ ~~to~~ ~~be~~ ~~the~~ ~~same~~
~~lighter~~ ~~particle~~ ~~than~~ ~~for~~
 the heavier, nearly in the inverse
 ratio of their masses. When we
 with an aggregate of several such
 particles ^(as we imagine the nucleus to be)
~~the~~ ~~properties~~ ~~of~~ ~~the~~ ~~aggregate~~ ~~which~~ ~~is~~ ~~called~~
 as the total number of particles in
 the aggregate is odd or even. ~~The~~
 Hence ~~from~~ ~~the~~ ~~assumption~~ ~~that~~ ~~the~~
 nucleus consists of only protons and
 electrons, ~~the~~ ~~total~~ ~~number~~
~~the~~ ~~the~~ From a study of these properties
 it is easy to decide uniquely
 whether the total number of elementary
 particles that constitute the nucleus
 is odd or even. Actually these
 deductions ~~do not fit~~ regard ~~to~~
~~odd~~ ~~and~~ ~~even~~ ~~the~~ ~~total~~
 number do not fit ~~with~~ the
 number of protons and electrons that
 would be required to explain the
 charge and mass of the nucleus
 which ~~go~~ ~~into~~ ~~the~~
~~nucleus~~ ~~if~~ ~~it~~ ~~were~~ ~~to~~ ~~be~~ ~~built~~ ~~up~~ ~~of~~ ~~protons~~
 and ~~electrons~~

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if we assume as we have done that these are the two types of elementary particles that go to constitute the nucleus. ~~This result~~ — This supplies another good reason why ~~the~~ electrons ~~can~~ the nucleus can not be constituted in this way.

regarded as
Lacked the
evidence is
overwhelming
that the

~~Actually~~ All the considerations ~~depend~~ is ~~are~~ ~~based~~ on well satisfied that the list of the elementary particles that go to ~~the~~ ~~part~~ constitute the nucleus are not the ~~to~~ ~~elementary~~ protons and electrons ~~of~~ ~~but~~ protons are not the ~~of~~ electrons ~~at all~~, but heavy particles, having ~~very~~ ~~the~~ same mass as the proton, but with no charge at all. Thus ~~we~~ get a

and the
experimental
physics has
been this
particle for
some time
effected
discovery
atoms

third doubt
~~new~~ particle, which is of the heavy type comes into the picture, and it has ~~been~~ ~~already~~ been identified outside the nucleus. Because of its electrical neutral character it has been named

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the neutron. ~~The~~ neutron also has the same spin as the ~~two~~ elementary particles.
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We ~~the~~ have ^{so far} ~~the~~ ~~now~~ encountered
 three elementary particles, the light
 one with unit ^{negative} charge, ~~and~~ the
 electrons, and two heavy ones, one
 with H unit ^{positive} charge, the proton,
 and the other with ~~no~~ charge at all,
 the neutron. ^{In addition to these three} all these particles
~~have spin moments like tops, the~~
~~spin of being the same for all the particles~~
~~I mentioned just now. Though this~~

Though this picture is not symmetrical
 as regard the charge and mass, it
 is at least simple. ~~and~~ the mass
 as of ~~long~~ two types, the heavy and
 the light, and ^{on the} charge ~~is~~
~~is~~ is involved, though its
 sign may vary. ~~Unfortunately for~~

The actual picture however, is not
 quite so simple. Particles having
 masses intermediate between the light
 and heavy types are also in
 evidence. I referred just now to the
 nucleus as being constituted of protons
 and neutrons. If we further enquire
 how these ^{two} types of particles are held
 together, ~~and~~ ^{and} in other ^{words} what are the
 forces that are involved ~~in~~ ^{between} ~~the~~ ^{particles}
 their mutual interactions, ~~we~~

~~the spin of being the same for all the particles~~

~~spin~~

and all of them have the same spin moment.

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To be filled in as in question paper of the last year.

.....PAPER ()

Time allowed : hours.

Maximum marks

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Serial No. of question

No. of Marks.

are led to ~~conclude~~ quite unexpected ~~conclusions~~ ~~results~~. ~~The forces between them~~ ~~rapidly move~~ ~~from outside~~ ~~till the particles~~ ~~approaches~~ the. Experimentally it is known that the nucleus, because of its possessing a large positive charge, repels ~~strongly~~ ~~of~~ ~~the~~ ~~short~~ ~~positively~~ ~~charged~~ ~~particles~~ of, however, the second particle ~~etc~~ comes closer to it - then a certain ~~short~~ ~~distance~~, ~~less than a~~ ~~million-millionth~~ of a centimetre, its force changes to one of attraction. ~~It is not possible to explain such a rapid change in one of the repulsion to attraction, taking place at the critical distance actually observed.~~ ~~There is only one kind of interaction between the protons and the neutrons constituting the nucleus that can possibly~~

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They ~~have~~ ~~not~~ ~~changed~~
particles, and ~~to~~ ~~account~~ ~~for~~ ~~the~~ ~~fact~~ ~~that~~ ~~these~~ ~~particles~~ ~~have~~
~~shown~~ ~~to~~ ~~be~~ ~~150~~ ~~to~~ ~~200~~
must be ~~150~~ ~~to~~ ~~200~~
times heavier than the electron,

(blue) ~~may~~ ~~be~~ ~~the~~ ~~particle~~ ~~we~~ ~~are~~ ~~looking~~ ~~for~~
This is a ~~new~~ ~~particle~~
intermediate in mass between
the electron and the proton and
the neutron or the ~~same~~ ~~thing~~
it is called a meson because
of its intermediate medium mass -
makes its appearance. Indeed its
existence was said a particle had
been ~~predicted~~ ~~by~~ ~~Pauli~~ ~~in~~ ~~1930~~
considerations, namely to explain
certain observed anomalies in the
penetration of cosmic rays. These
particles have since been identified
experimentally in ~~cosmic~~ ~~ray~~ ~~experiments~~
~~Cosmic rays.~~

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Several years ago Dirac
from certain abstract ~~theoretical~~ ~~investigations~~
was led to the conclusion that
electrons can possess not only positive
kinetic energies, but also negative
kinetic energies - ~~in order to~~

which is not understandable physically. In
 order to ~~make~~ make the results
 physically plausible he had to assume
 that all possible ^{negative} energy ~~levels~~ ^{levels} ~~have~~ ^{already}
~~been~~ filled up. Now the question
 naturally arises what would happen
 if ~~one~~ ^{one of} the electrons in the
 filled up ^{negative} energy levels is given
~~sufficient energy to~~ ^{to} ~~escape~~ pulled
 out by supplying ^{the requisite} ~~sufficient~~ energy
 from outside. ~~The result~~ We have
 created an electron, and ~~in~~
 addition a vacant ~~space~~ place
 or a hole in the continuum of
 electron occupying the ~~at~~ negative
 energy states. ~~which~~ ^{this hole} will ^{behave}
 in all respects like an electron
 but with the sign of the charge
 reversed. In other words ^{we have}
 created a pair of electrons ^{both of the same mass,} ~~one~~
~~positively charged~~ ^{can} the usual unit
 negative charge, and the unit positive
 charge. The requisite energy can be
 supplied by γ -rays from radioactive
 sources, which are sufficiently energetic
 for this purpose, and ~~such~~
 the creation of such electron pairs
~~has~~ ^{has} ~~not~~ ^{indeed} been observed.



~~2700~~

(15)

