An atom cannot be described using the laws of Isaac Newton

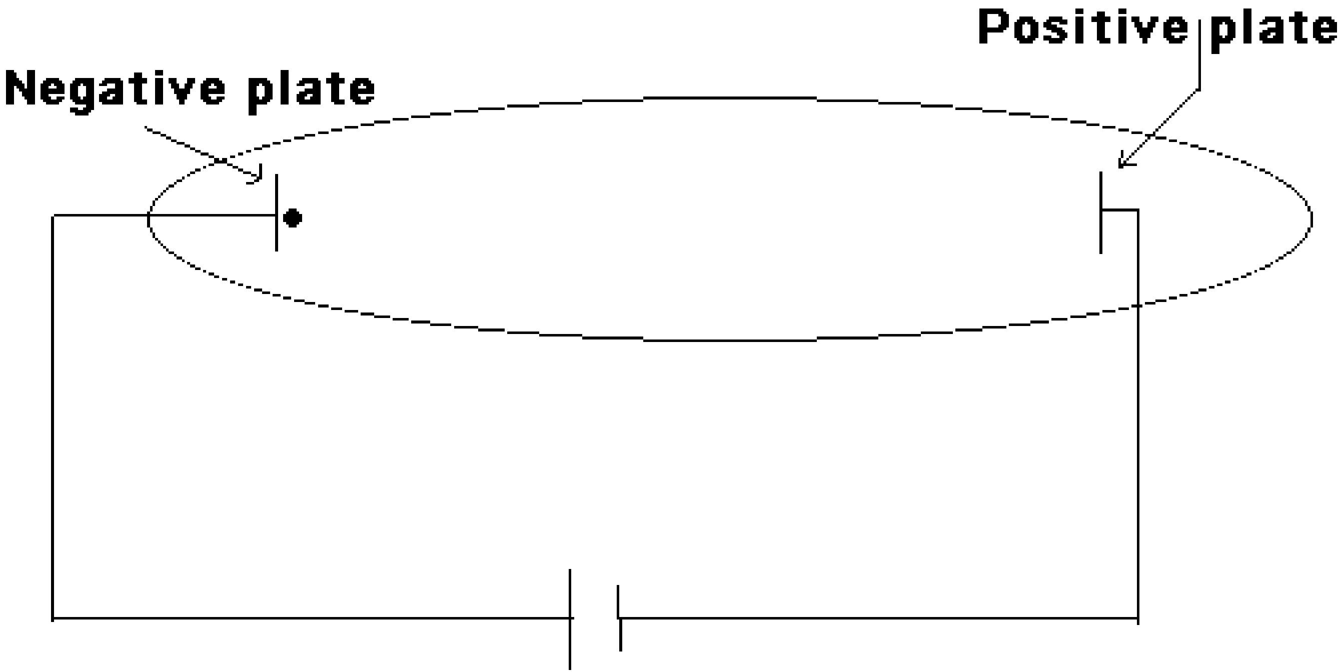
These are the laws of classical mechanics. To describe the atom and other very small objects, we must use Quantum mechanics.

Quantum mechanics tell us that we cannot measure all the properties of a small particle such as the electron at the same time.

For example, we cannot measure both the position and momentum of an electron without some uncertainty. Hence, there are some properties of individual electrons (and other particles) that we can never know exactly.

Fortunately, quantum mechanics allows us to calculate the probability of an electron having certain properties.

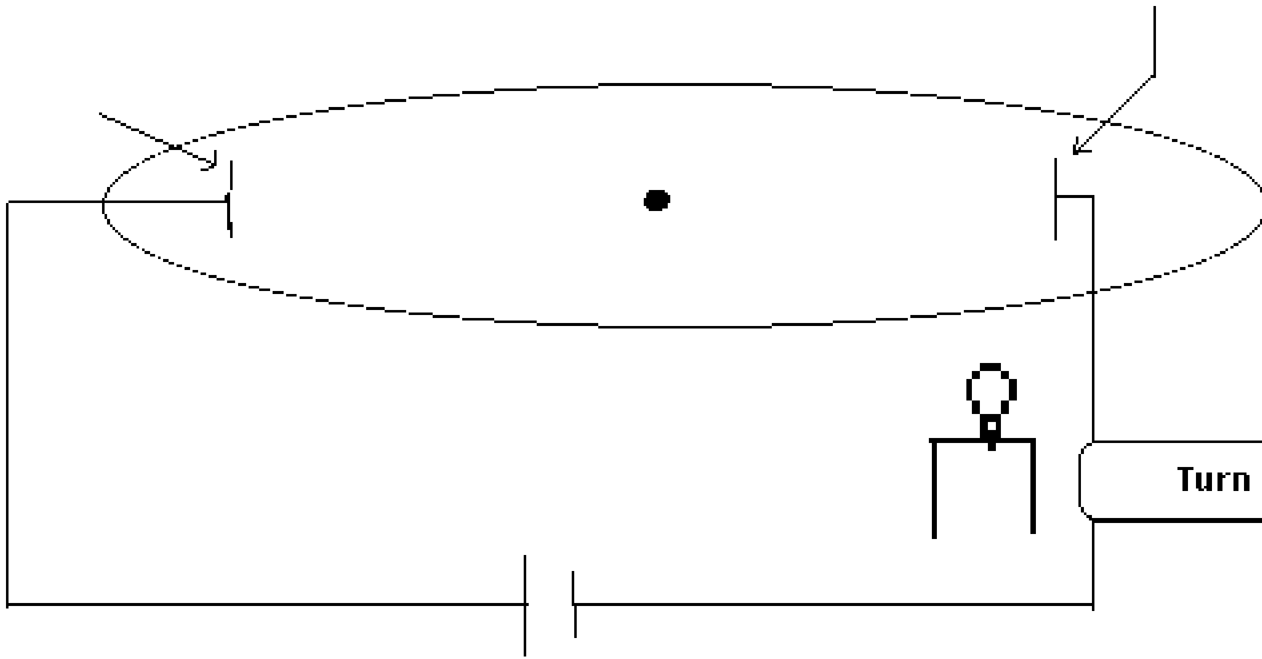
Atoms emit electrons. But can we "see" the electrons?



Turn on

We only "see" the electrons when they interact with somthing

We cannot measure the position of an electron exactly by shining a light on it as we would a baseball



Turn on Light

Turn on and off quick

Reset

The Heisenberg Uncertainty Principle:

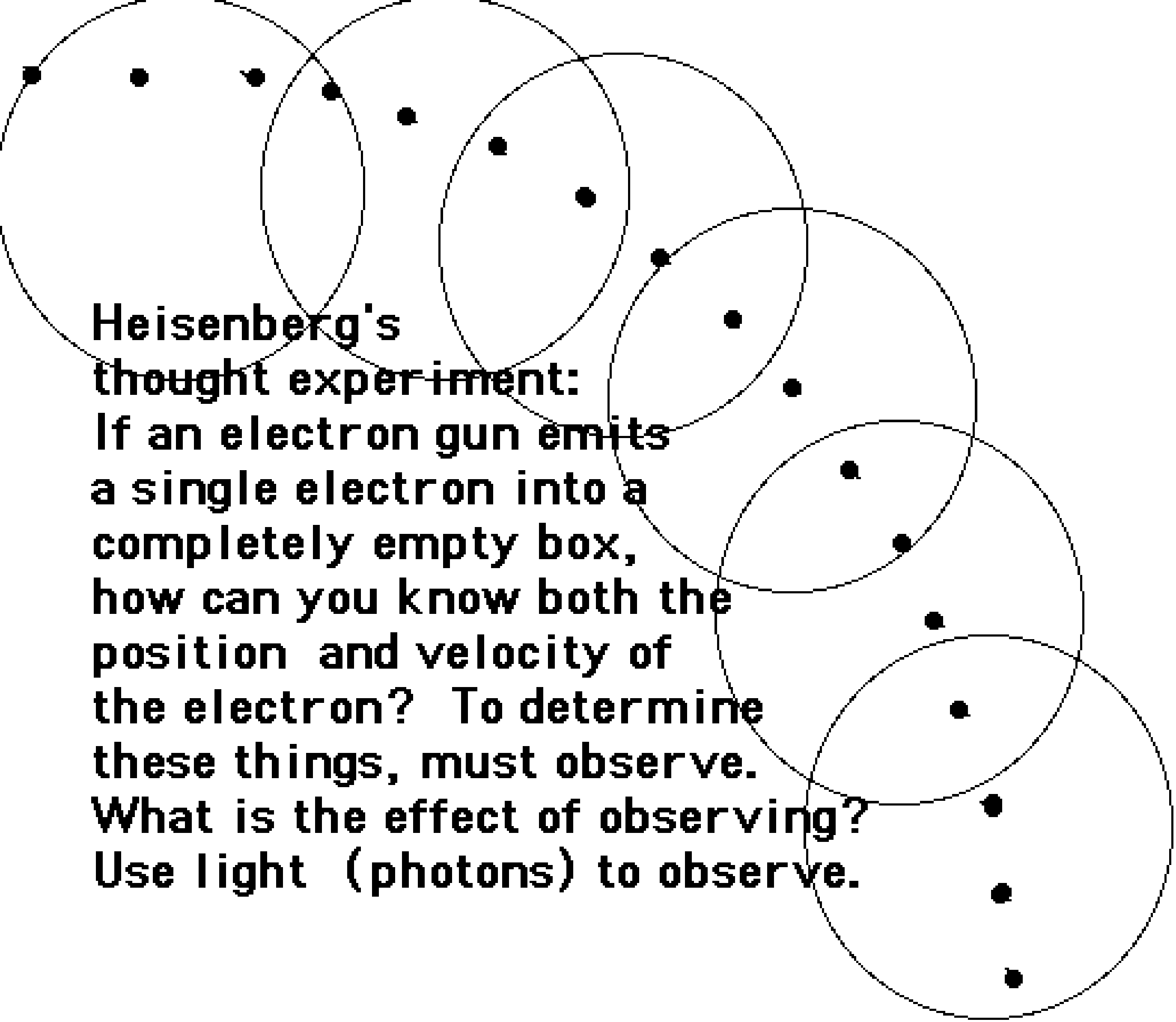
It is impossible to know the exact position and momentum of an object at the same time

$$\Delta q \times \Delta p \geq h \quad \text{(Planck's constant)}$$

or

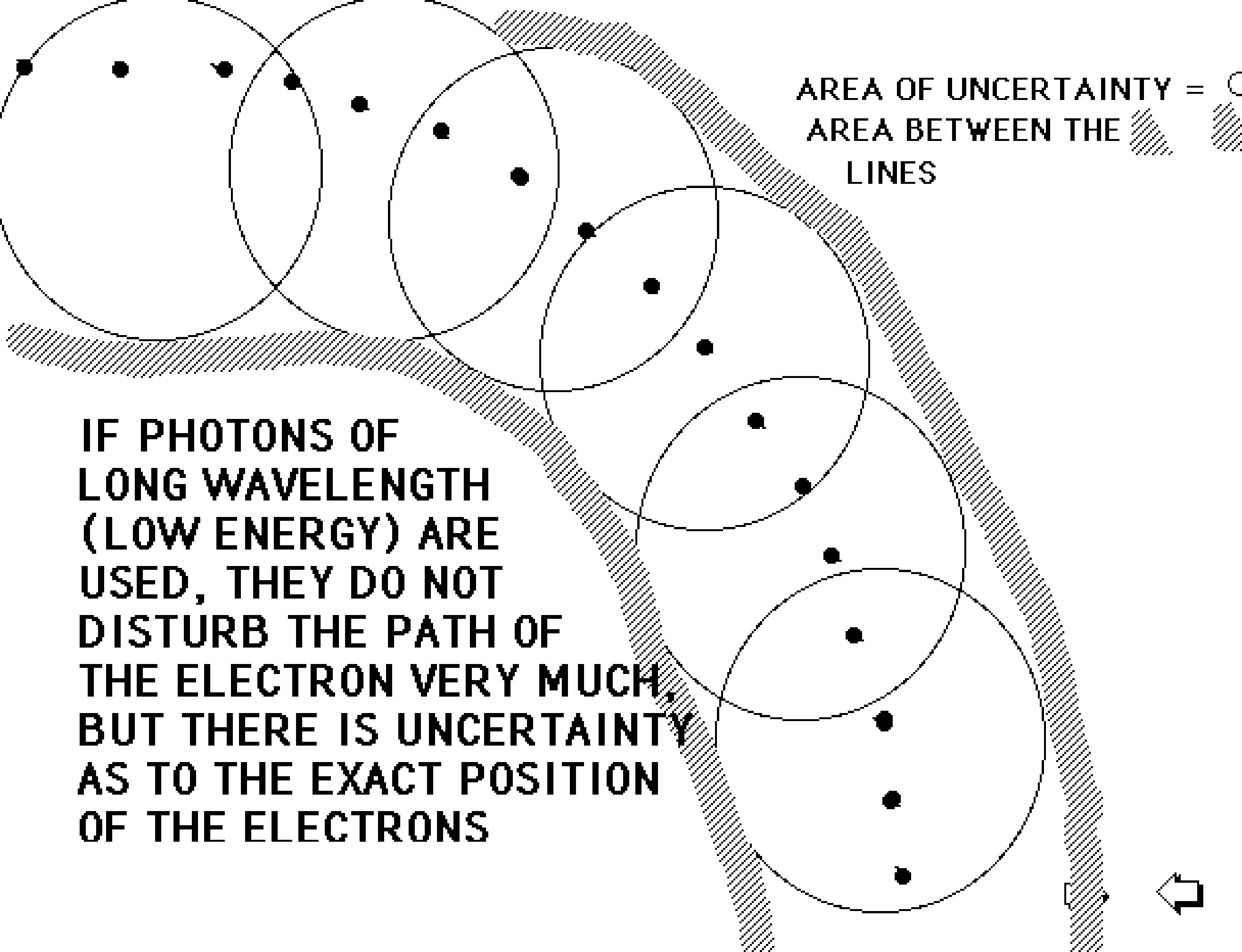
It is impossible to know the energy and lifetime of an object at the same time

$$\Delta E \times \Delta t \geq h$$

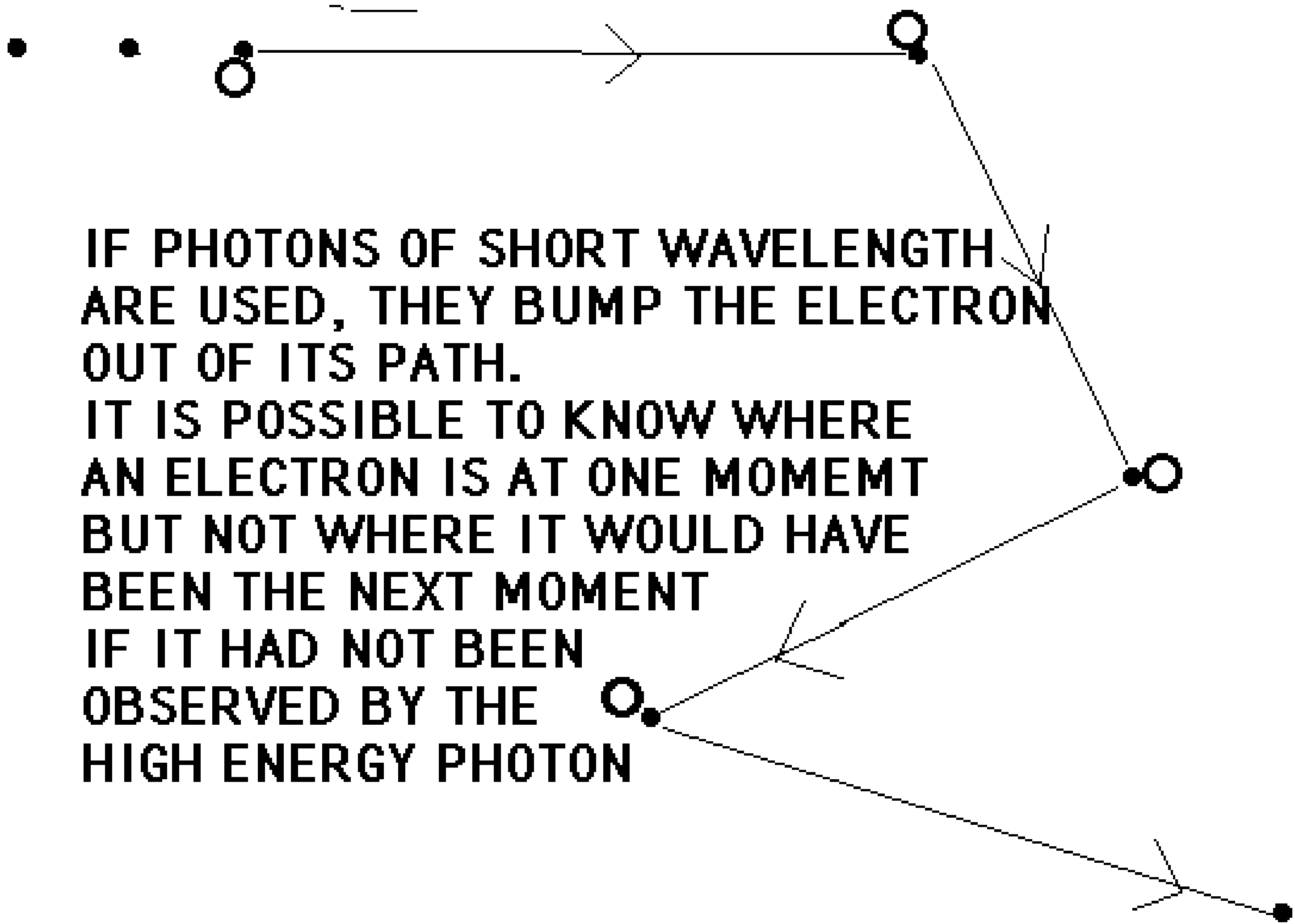


Heisenberg's thought experiment:

If an electron gun emits a single electron into a completely empty box, how can you know both the position and velocity of the electron? To determine these things, must observe. What is the effect of observing? Use light (photons) to observe.



IF PHOTONS OF LONG WAVELENGTH (LOW ENERGY) ARE USED, THEY DO NOT DISTURB THE PATH OF THE ELECTRON VERY MUCH, BUT THERE IS UNCERTAINTY AS TO THE EXACT POSITION OF THE ELECTRONS

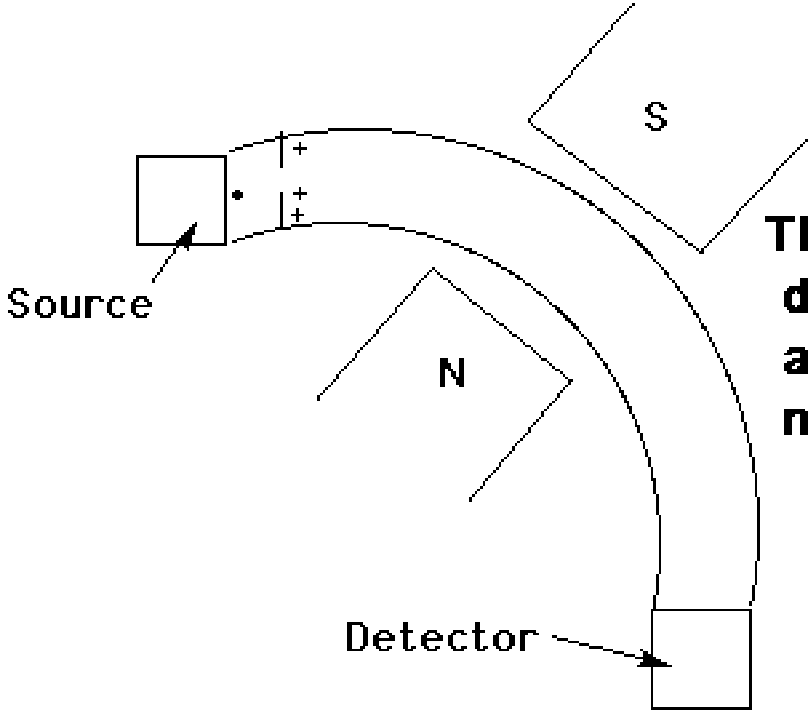


IF PHOTONS OF SHORT WAVELENGTH ARE USED, THEY BUMP THE ELECTRON OUT OF ITS PATH.

IT IS POSSIBLE TO KNOW WHERE AN ELECTRON IS AT ONE MOMEMT BUT NOT WHERE IT WOULD HAVE BEEN THE NEXT MOMENT IF IT HAD NOT BEEN OBSERVED BY THE HIGH ENERGY PHOTON

Question: Is the electron a wave or a particle?

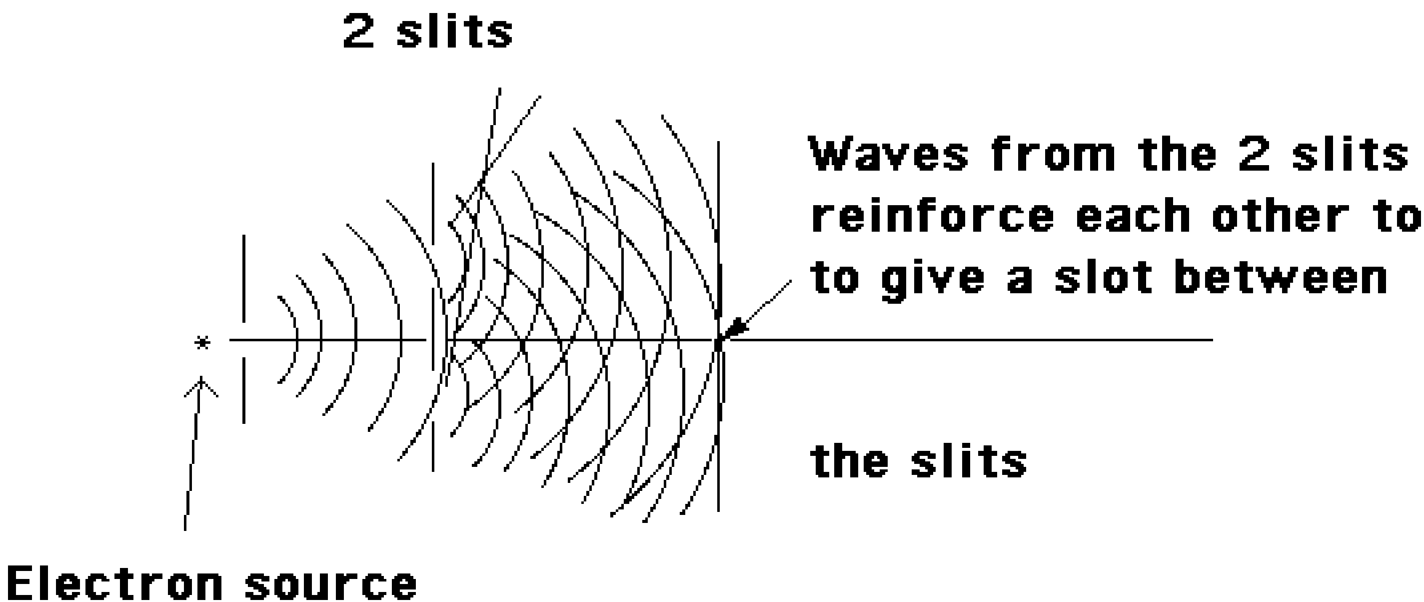
Answer: It depends upon what experiment you do



This experiment detects particles and gives their mass to charge ratio

Turn on

The "2 slit" experiment reveals the wave nature of the electron



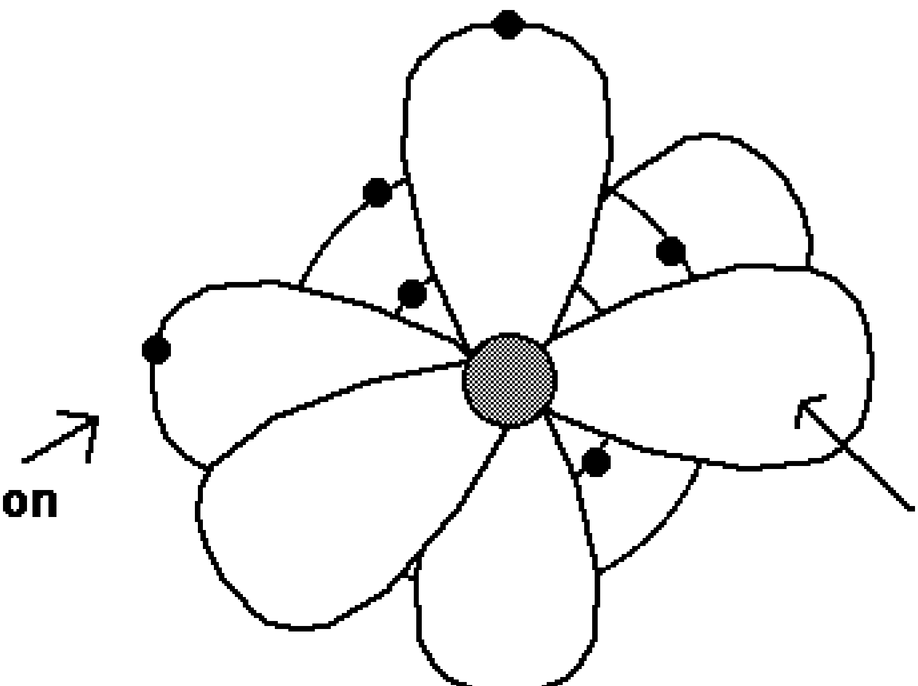
Question: If the properties of the electron depend upon the type of experiment we do, what are its properties when we don't do the experiment?

Answer: Quantum mechanics says that they are undefined. The electron doesn't have properties until we measure them

"It is wrong to think that the task of physics is to find out how Nature is. Physics concerns what we can say about Nature"

Neils Bohr

Bohr's model worked well for the hydrogen atom. However, larger atoms were more complex and quantum mechanical calculations of orbital paths of electrons showed them to have a variety of shapes in addition to circles (spheres in three dimensions), as Bohr assumed. The electons are in three dimensional regions called orbitals



A carbon atom

an orbital

Nuclear physics showed that half or more of the mass of most nuclei is due to uncharged particles fractionally heavier than protons, called neutrons.

The Atomic Number of an element = number of protons

The Atomic Weight of an element = number of protons + neutrons

Since atoms are neutral, the number of protons = the number of electrons

The chemical properties of an atom are largely determined by the configuration of the electrons associated with it

Dimitri Mendeleev, in 1869, announced his PERIODIC LAW OF THE ELEMENTS: The properties of the elements are periodic functions of their atomic weights

Mendeleev

hydrogen			
lithium	sodium	potassium	rubidium
beryllium	magnesium	calcium	strontium
boron	aluminum	____21__	___31____
carbon	silicon	(titanium)	_____32__
nitrogen	phosphorus	(vanadium)	arsenic
oxygen	sulfur	(chromium)	selenium
fluorine	chlorine	(manganese	bromine
		(iron, cobalt, nickel)	

A Modern Periodic Table

by John G. Cramer

Radioactive → (corner mark on box); 84 Po (209) ← METALLOID (elements to left of metalloids are metals; to right, non-metals)

ATOMIC NO.; CHEMICAL SYMBOL; ATOMIC WEIGHT

Parentheses indicate element is artificially produced & mass number of longest-lived isotope.

	1	2											3	4	5	6	7	
			TRANSITION ELEMENTS															
1	1 H 1.008																	2 He 4.003
2	3 Li 6.940	4 Be 9.013											5 B 10.82	6 C 12.011	7 N 14.008	8 O 15.999	9 F 19.00	10 Ne 20.183
3	11 Na 22.991	12 Mg 24.32											13 Al 26.98	14 Si 28.09	15 P 30.975	16 S 32.06	17 Cl 35.457	18 Ar 39.944
4	19 K 39.100	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.95	24 Cr 52.01	25 Mn 54.94	26 Fe 55.85	27 Co 58.94	28 Ni 58.71	29 Cu 63.54	30 Zn 65.38	31 Ga 69.72	32 Ge 72.60	33 As 74.91	34 Se 78.96	35 Br 79.916	36 Kr 83.80
5	37 Rb 85.48	38 Sr 87.63	39 Y 88.92	40 Zr 91.22	41 Nb 92.91	42 Mo 95.95	43 Tc (98)	44 Ru 101.1	45 Rh 102.91	46 Pd 106.4	47 Ag 107.88	48 Cd 112.41	49 In 114.82	50 Sn 118.70	51 Sb 121.76	52 Te 127.61	53 I 126.91	54 Xe 131.30
6	55 Cs 132.91	56 Ba 137.36	57† La 138.92	72 Hf 178.50	73 Ta 180.95	74 W 183.86	75 Re 186.22	76 Os 190.2	77 Ir 192.2	78 Pt 195.09	79 Au 197.0	80 Hg 200.61	81 Tl 204.39	82 Pb 207.21	83 Bi 208.9	84 Po (209)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra 226.03	89†† Ac 227.0	104 Rf (261)	105 Ha (262)	106 OV (260)	107 OW (262)	108 OX (265)	109 OY (266)									
	Alkali Metals																Halogens	Noble Gases

† Lanthanides (Rare Earths)

6	58 Ce 140.13	59 Pr 140.92	60 Nd 144.27	61 Pm (145)	62 Sm 150.35	63 Eu 152.35	64 Gd 157.26	65 Tb 158.93	66 Dy 162.51	67 Ho 164.94	68 Er 167.2	69 Tm 168.94	70 Yb 173.04	71 Lu 174.99
7	90 Th 232.04	91 Pa (231)	92 U 238.07	93 Np (237)	94 Pu (242)	95 Am (243)	96 Cm (245)	97 Bk (247)	98 Cf (251)	99 Es (254)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

†† Actinides

PERIODIC TABLE

A Portion of a Modern Periodic Table

1 H 1.008							2 He 4.003
3 Li 6.941	4 Be 9.021	5 B 10.81	6 C 12.01	7 N 14.01	8 O 15.99	9 F 18.99	10 Ne 20.18
11 Na 22.99	12 Mg 24.31	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
19 K 40.00	20 Ca 40.08	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80

Rows →

Columns ↓

Transition metals