```
┌─────────────┐                          ┌─────────────┐
│   ENERGY    │        E=mc²             │    MASS     │
│  has mass   │  ⟸─────────────⟹        │  is energy  │
└─────────────┘                          └─────────────┘
       │                                        │
     (and)                                    (and)
       ▼                                        ▼
┌─────────────┐                          ┌─────────────┐
│ Light from a│                          │   Matter    │
│ hot source  │                          │ appears to be│
│ appears to be│                         │ CONTINUOUS  │
│ CONTINUOUS  │                          └─────────────┘
└─────────────┘                                 │
                                              (but)
                                                ▼
┌─────────────────┐                      ┌─────────────┐
│   Light is      │                      │ Atomic Theory│
│  PARTICULATE    │     (and)            │ says matter is│
│  mass:          │  ◄───────────        │ PARTICULATE │
│   $m_\nu=h\nu/c^2$ │                   │             │
│  momentum:      │                      │             │
│   $p_\nu=h/\lambda$ │                  └─────────────┘
└─────────────────┘
       │
   (and also)
       ▼
┌─────────────────┐                      ┌─────────────┐
│   Light has     │                      │ Matter has  │
│    WAVE         │     (and)            │   WAVE      │
│  PROPERTIES     │  ──────────►         │ PROPERTIES  │
│  frequency $\nu$ │                     │ wavelength  │
│  wavelength $\lambda$ │                │ $\lambda=h/p$ │
│   $\nu=c/\lambda$ │                    │             │
└─────────────────┘                      └─────────────┘
```
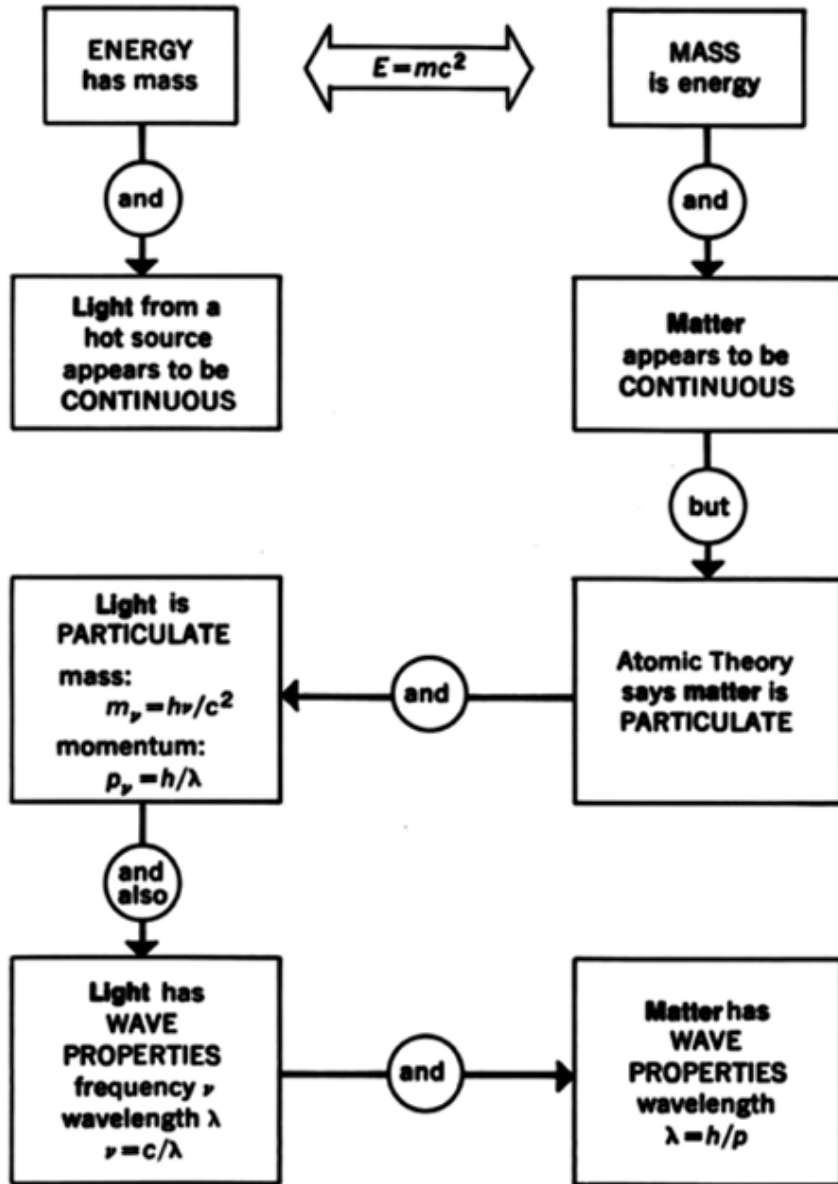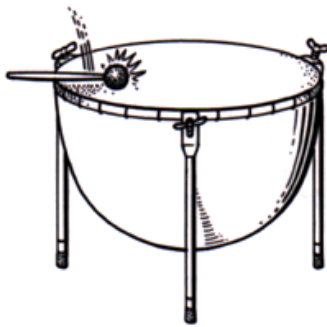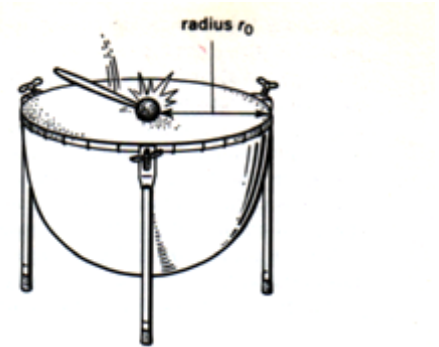
The Wave Nature of Matter

If we use wave math to describe matter then the quantization is due to the boundary conditions that exist. We can see examples of how boundary conditions create quantization:
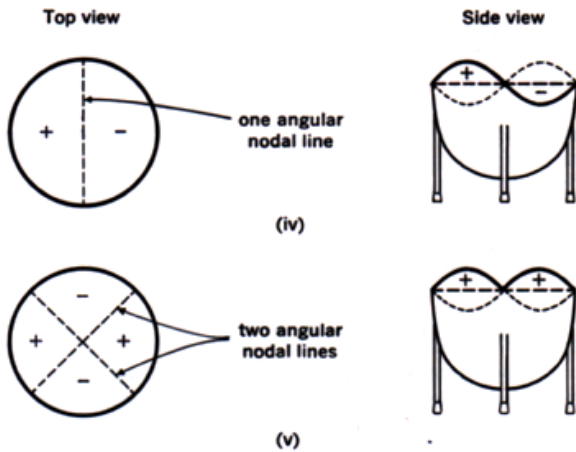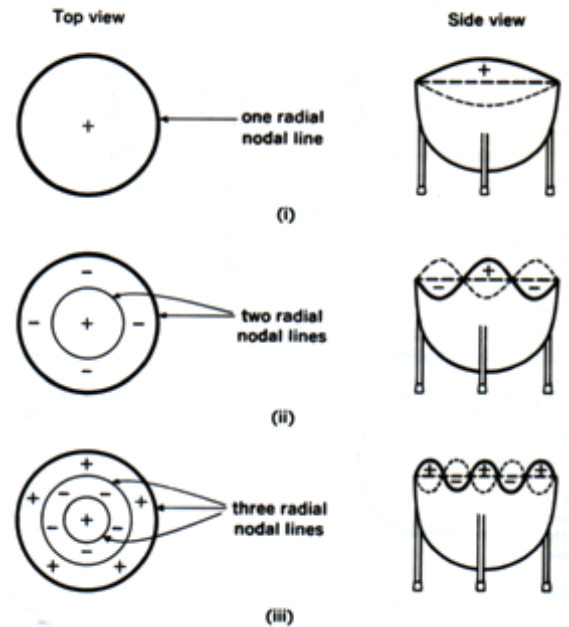
Radial nodes
are circular.

Angular nodes
are linear.

In a one dimensional
vibrator the node is a
point.

Top view

one radial
nodal line

Side view

(i)

two radial
nodal lines

(ii)

three radial
nodal lines

(iii)

Top view

one angular
nodal line

(iv)

Side view

two angular
nodal lines

(v)

In a two
dimensional
vibrator there are
nodal lines.

radius r_0

The Wave Function

By the late 1920's the work of three scientists had formalized the mathematics that are used to describe an atom.

Louis de Broglie- Derived the wavelengths for matter.

Erwin Schrödinger- Uses the math that converts the classical description of the atom in to a wave description.

Werner Heisenberg- Working with Bohr develops a physical understanding of the wave function as the uncertainty principle.

There is a fundamental limit to how well we can know the position and momentum of a particle at the same time.

$$\Delta x \cdot \Delta(mv) \geq \frac{h}{4\pi}$$