The MiniMaker Faire, Sunday August 21, 2010

Jim Emery

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1 Coupled Oscillators (Pendulums)

Reference: Vibration, Section Coupled Oscillators:

`http://www.stem2.org/je/vibra.pdf`

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2   Corner Reflector

`http://www.stem2.org/je/corner.pdf`

3   Linkages Based on Inversive Geometry

`http://www.stem2.org/je/inversivegeometry.pdf`

4   Tangent Galvanometer

`http://www.stem2.org/je/electromagnetictheory.pdf`

5   Astronomy Locator, Right Ascension and Declination

`http://www.stem2.org/je/astronomy.pdf`

6   Pythagorean Theorem

`http://www.stem2.org/je/zeus.pdf`

7   Flow in Pipes

In the case where the stress tensor is a linear function of the deformation tensor $\mathbf{D}$, the Cauchy equation of fluid motion become the Navier-Stokes equation:

$$\rho\frac{d\mathbf{v}}{dt} = \rho\mathbf{f} - \nabla p + \nabla \cdot (2\mu\mathbf{D}).$$

The Navier-Stokes equation is solvable in closed form for only a few special cases. One of these is the steady laminar flow in cylindrical pipes . This flow is called Hagan-Poiseuille (pwah-zweez) flow. We find that

$$Q = \frac{\pi R^4 \Delta p}{8\mu\ell},$$

where Q is the volume rate of flow, R is the pipe radius, Δp, is the pressure drop, μ is the viscosity, and ℓ is the pipe length. At any cross section the velocity distribution is parabolic.

This can be illustrated with paper cups and straws that are hot glued together.

`http://www.stem2.org/je/fluidmechanics.pdf`

8   Bicycle Wheel Gyroscope

`http://www.stem2.org/je/mechanics.pdf`

9   The Ellipse Engine

A machine to draw an ellipse.

`http://www.stem2.org/je/ellipseengine.pdf`

10   Einstein's Field Equations, An Illustration of Riemannian Curvature by Parallel Transport Around a Path on a Sphere.

References:
    Document **Relativity**, (relativ.tex)

`http://www.stem2.org/je/relativ.pdf`

pdf version of the ppt document (relativity.ppt)

`http://www.stem2.org/je/relativityslides.pdf`

Einstein's field equation of general relativity, in tensor form, is

$$R_{\mu\nu} - (1/2)Rg_{\mu\nu} = 8\pi G T_{\mu\nu}.$$

It says essentially that the curvature of the 4-dimensional space-time is proportional to mass-energy. Gravitational force is not a true force, but a curvature of space-time. $R_{\mu\nu}$ is the Ricci tensor, the contraction of the Riemannian curvature tensor, R is the scaler curvature, $g_{\mu\nu}$ is the Riemannian metric tensor, which determines local distance, G is the Newtonion gravitational constant, and $T_{\mu\nu}$ is the stress-energy tensor, i.e. mass-energy. This equation is for a system of units where the velocity of light is taken to be 1. So if we take a piece of wire and bend it, we see that the wire is now curved. Similarly we know what we mean by a two dimensional curved surface, say a torus or a donut surface. We determine that something is curved by looking at it from an external point. But we can't look at space itself from an external point because we are in space. So what does it mean for space to be curved? Well we can determine curvature without leaving space. We do that by using an intrinsic rather than an extrinsic definition of curvature. Curvature can be determined using a technique called parallel transport of tangent vectors. So consider a simplified problem of a two dimensional surface. In flat Euclidian two dimensional space, the distance between two points (x_1, y_1) and (x_1, y_1) is

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

If we wanted to determine the distance between Kansas City and London, we could not use such a formula because the shortest path lies on a sphere. So this is where the metric coefficients g_{ij}, which were first introduced by Gauss to solve this very problem of measuring distance on the surface of the Earth, came from. Look at the path on the globe outlined by the tape. Suppose we were to use an arrow as an indicator of direction and suppose we point the arrow in a given direction and never change this direction as we walk around a path on the floor. We would find that when we came back to the starting point that the arrow still points in the same direction. We parallel transported the arrow (vector). However look how this works on the globe. After returning to the starting point we find that the final direction of the vector is different from the initial direction. this is because the surface of the globe is curved, it is a sphere. If we shrink the area of the path to zero and divide the vector rotation angle by the area, and take the limit, we obtain the Riemannian curvature of the two dimensional surface. Using a similar parallel transport of tangent vectors in higher dimensional spaces we get a higher dimensional Riemannian curvature. And we have not left our space. So this is an indication of what we mean by curvature of space-time.