The Demonstration Corner

A Demonstration of the Production of Sound

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For this demonstration, a small open loudspeaker driver is necessary, driven from a sound source with output power sufficient for a loudspeaker. A ghetto-blaster is convenient if it has an output jack or can be modified to direct the loudspeaker output to an external device. For best results the small driver should be of moderate or better quality. It helps if its compliance is high so that bass notes cause substantial cone motion.

When listened to by itself, the sound is thin and wispy, with largely treble output and no bass. If several square sheets of cardboard are provided with dimensions of, say, 40×40 cm, and 1×1 m, these can have holes cut into their middle so that the small driver will seal relatively well to these baffles. The smaller baffle causes the sound to improve dramatically, with much more midrange balancing the sound. The larger baffle will restore even more of the bass. With rock music the effect is very dramatic! You can listen to either side of the baffle

If you have the resources, try to build an exponential horn such as shown in Fig. 1. It not only gives a balanced full-range sound, but the loudness is much higher.
As a final demo, place the driver over a sealed container, say a small dewar, or a closed cardboard box with a hole cut into one face (Fig. 2). The sound will be rich and full again.

With the baffles, horn or box, the sound will revert to its poor condition very quickly if the driver is moved even a centimetre or two from a good seal with the baffle.

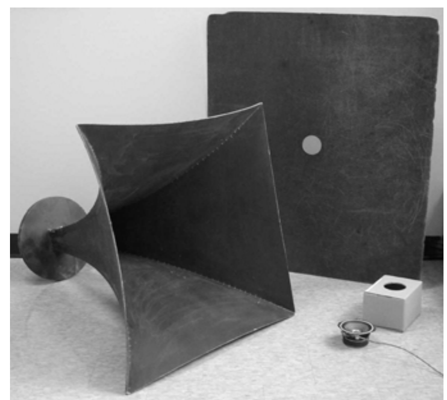

Figure 1 *Equipment: speaker, baffle, cardboard box, and exponential horn.*

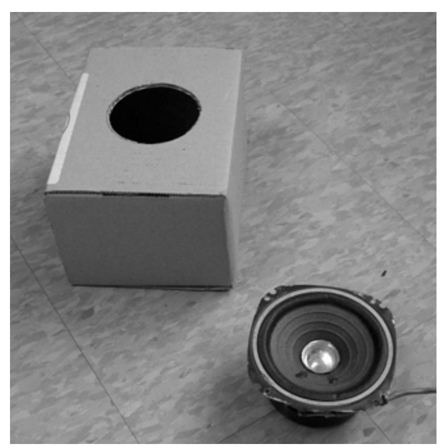

Figure 2 *Cardboard box and speaker.*

Understanding it all

Sound is a longitudinal pressure wave in air, and it is produced by sources that provide appropriate air motion. A radially oscillating small balloon would produce sound pressure that radiates spherically outwards, proportional to the radial surface acceleration of the balloon. If the balloon produces say a volume acceleration (surface area of balloon S multiplied by its surface acceleration a, units m^3/s^2) of $A = S\,a$, we can show from Newton's second law of motion and the ideal gas law that the sound pressure p at distance r from the balloon's centre will be

$$p = \rho S\,a/(4\pi r),$$

where ρ is the density of air, and the factor 4π comes from the fact the sound is spreading out over a solid angle of 4π steradians.

The problem with our open driver is that it produces two sound sources, one on each side of the cone, that are exactly 180° out of phase. This causes cancellation at those frequencies where the path difference between front and back sources is less than half a wavelength, and thus the lower frequencies, having longer wavelengths, are progressively more cancelled, leaving only the treble. A baffle increases the path difference, reduces the cancellation of the lower frequencies and improves the midrange and bass response. For a 1-m square or round baffle, the path difference of 1 m progressively causes only those sounds below about 150 Hz (corresponding to 1/2 wavelength) to be cancelled, and that makes it sound good in a demonstration.

The horn causes the efficiency of the sound source to rise remarkably, since the confinement of the air in the throat increases the pressure there. Thus the moving cone does more thermodynamic work on the air, producing more acoustic energy. The horn eventually spreads out and allows this energy to move into free air. Although we have stated that for a free source spreading sound into 3 dimensions, the pressure amplitude is given by the volume acceleration, in a horn the sound is more 1-dimensional, and then the pressure amplitude is proportional to the volume velocity of the source (units m^3/s), with much higher efficiency.

The small box prevents the sound inside the box from cancelling that which comes from the front, so the sound has a full-range character. Naturally we would mount the river with its cone facing outwards, but all students will see that this is the origin of the box loudspeaker. Of course there are refinements; the box may be filled with sound absorbing material, or it may have a port to give resonant enhancement of the bass. Only the bass creates the need for a box of substantial size; in fact for normal loudspeakers the size of the box is inversely proportional to the cube of the lowest frequency it will reproduce. Halving the lower cutoff frequency requires eight times as large a box! That is why satellite speakers, which respond only down to say 80 Hz, can be quite small. The single subwoofer accompanying the satellite speakers often has a reduced-size box as well, but then it must have a powerful amplifier that just pushes and pulls harder on the air in the box, giving good bass.

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Submissions describing demonstrations will be gladly received by the column editor.

Editor's note: Carol Croft has done a wonderful job looking after our memberships for over 20 years. We wish Carol all the best on her retirement and look forward to saying good bye when see joins us at this year's conference banquet at the Ontario Science Centre. See Carol's note below

RETIREMENT CALLS!! TIME TO SAY MY GOODBYES!

It is with a bit of sadness and lots of joy that I wish to say 'Goodbye' to all the members of the OAPT as I am retiring as of August 1/07. I have been looking after the updating of your memberships for Ernie McFarland, Membership Secretary, since I joined the Physics Department at the University of Guelph in 1986. Some of you I have had lots of interaction with (some were actually Guelph students), a few I've met in person, and many of you that I haven't met; but I still will miss that contact. I wish you all the best in your teaching endeavours, knowledge is a great thing! Thanks to you all! Carol Croft, secretary to the Membership Secretary (bit of humour here!).

Don't miss the deadline for the OAPT photo contest

*submit your entries to **Diana Hall**, Contest Coordinator (diana.hall@ocdsb.ca) **by May 1st***
Please visit www.OAPT.ca and read complete contest details, see past winners and sample photos

QUANTUM PHYSICS

Experimentally Determining Relativistic Momentum

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I don't know about you, but I have always had trouble dealing with momentum in Special Relativity. I have yet to find a theoretical derivation for it that is sufficiently rigorous and yet relatively easy to understand. N. David Mermin's treatment in his new book "Its About Time" is getting close, but is still too difficult. Most textbooks simply say that the derivation is beyond the scope of the book and then present the formula, $p = \gamma mv$. I'm especially uncomfortable with this approach in relativity where the consequences are so counterintuitive. We want our students to be sceptical of wild claims and we aren't doing this properly if we resort to "It must be true because Einstein said so."

Fret no more! The problem has been solved by the people at TRIUMF in B.C. - home of the world's largest cyclotron. They have produced a great tool that will allow your students to derive the formula for relativistic momentum on experimental grounds. They have produced a DVD "Approaching the Speed of Light" with accompanying materials that are a fantastic resource.

The DVD is not a slick flashy production. Instead, it feels as if you have gone on a field trip to the TRIUMF facilities. Two physicists show you around the huge bending magnets and beam line. Simple animations help the students visualize how the bending magnets are used to select particles with specific momenta and how the speed of these particles is measured.

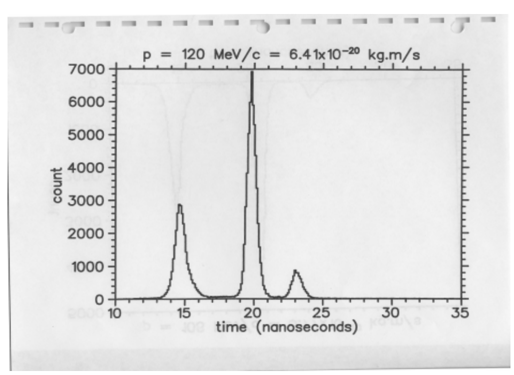
After 15 minutes you should stop the DVD and have the students analyse the data provided. This data consists of a dozen histograms. Each one shows the different arrival times of electrons, muons and pions with a set momentum. The students use these graphs to calculate the speeds of the particles.

Next, the students plot momentum against speed. If momentum is equal to mass times velocity, then the graph should yield a straight line. It clearly doesn't. I like to challenge the students to find out what the relationship is by trying to linearize the graph. They plot momentum against v^2 and then v^3 and then v^4 etc. but no power of velocity works. This exercise is not tedious as long as the students use graphing calculators or a spreadsheet program. Sometimes one group figures it out on their own but usually I need to give them a hint by asking them how time and space are altered in relativity. They then plot momentum against γv and voila! a straight line. They have shown that momentum is proportional to γv and the last thing they do is find the slope of the straight line which turns out to be the mass of the particle, so $p = \gamma mv$.

I have put together a worksheet for my students that differs from the one provided with the DVD and I would be happy to send it to anyone who is interested. I'd also like to hear from anyone who has found a theoretical derivation for relativistic momentum that works at the high school level.

P.S. You can get a copy of the DVD by contacting the outreach coordinator at TRIUMF by emailing outreach@triumf.ca or by phoning 604 222 7525. TRIUMF is planning three more DVDs for the near future - the second will involve how the electromagnetic equations can be used to understand how the cyclotron and spectrometers work. Keep an eye out for these.

ww.ubc.ca/announce/



Email Addresses

We send timely information of interest to Physics Teachers by email to all members. If you have not received any messages from the OAPT in April 2007, it means that we do not have your current email address on file. Please send an message to Patrick Whippey <pwhippey@uwo.ca> and we will update our records.

The OAPT does not share members' data with anyone. You can find our privacy statement here: http://www.oapt.ca/members/privacy.html.

FUN With PHYSiCS

Uniform Circular Motion Misconception Rap

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In our classroom you might get the notion
That we're sitting here still and there is no motion.
The illusion that you experience
Is due to your frame of reference.

On the perimeter of the earth we ride
From this fact we can't hide.
Speed demons would get their fix
To know we're going 1600 klicks.

Our motion story isn't done
We're also in orbit around the sun.
At a speed that would make Paul Tracy cower
We're moving at 107,000 kms per hour.

Speed and velocity are another misconception
Where kids today don't make the right connection.
Speed is just a magnitude
But velocity is a vector with attitude.

When an object 'tis in circulation
It has a perpendicular acceleration.
The source of the centripetal force
Causes the inward acceleration, of course.

Next time you take a roller coaster ride
You might think you're being forced against the side.
Your body just wants to continue in a straight line
Which Newton's 1st law states is just fine.

But from the coaster's non-inertial point of view
It has got to accelerate you to.
Up and down and Side to side
A fictitious force you feel on this ride.

Centrifugal…is the name
In this accelerated, non-inertial….frame.

Banked curves and inclined planes
Cause students' headaches in vain.
All they need to remember
Is where the net acceleration is

For curves the acceleration is in the horizontal plane
But for inclines it is along the plane.
So for curves resolve your vectors horizontally and vertically

But for planes resolve them parallel and perpendicularly (to the plane)

In orbit you may think there's no gravity at all,
But you're really in free fall.
You might drift off into space
If gravity didn't keep you in your orbital place.

This ends the misconception rap
Now you wear the expert uniform circular motion cap.

ONTARIO SCIENCE CENTRE

Come and Join us for annual OAPT conference May 31st to June 2nd at the Ontario Science Centre

- Learn about what the Ontario Science Centre can offer to you and your students
- Listen to dynamic speakers like Bob McDonald for CBC's Quirks and Quarks
- Participate in practical "hands on" workshops
- Learn new demonstrations to engage your students
- Network with your colleagues from around the province

To register go to http://www.oapt.ca/conference/2007/register.html