### **Descriptions of** Pedagogical Strategies

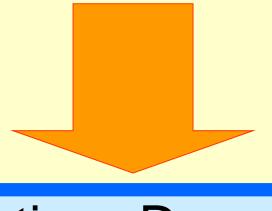
### Kinesthetic Activities

There are a number of circumstances where having the students use their own bodies to represent aspects of the physical situation helps them visualize the geometric situation. These kinesthetic activities are the most unusual of the interactive engagement activities used in the Paradigms courses.

These activities break the typical norms of university classrooms, where students are rarely asked to move away from their notebooks, let alone engage in "play"-like activities. Kinesthetic activities explicitly call for students to imagine themselves part of a physical system, and for some students to move around in space. (Many students feel goofy doing this, which probably also increases their memorability and makes them more fun - see our article about the importance of laughter in the classroom). This use of imagination creates a convenient opportunity to discuss the nature of physical modeling and idealizations.

A cognitive motivation for doing kinesthetic activities is to help students develop geometric reasoning skills. Many of these activities emphasize spatial relationships and motion. The classroom and the students become a toy model of some interesting physical phenomenon, and it is hoped that this concrete model encourages students to make connections between visualization and conceptual knowledge. Furthermore, some cognitive theories describe a kinesthetic mode of learning 🗗, based on experimental evidence that visualization and kinesthetic experience are cognitively linked. From this perspective, kinesthetic activities reinforce students' visualization skills.

Faculty may not know how to implement unusual pedagogical strategies. The wiki provides an easy way both to describe the rational and provide tips for different strategies, but also to link to classroom video and detailed narratives of specific examples.





### [00:03:11.29] - [00:08:57.06] iz began the new material by posing a small whiteboard question:

order in which to focus attention as the class considered one board at a time

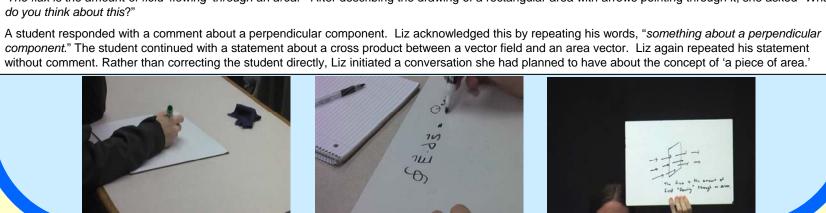
do not-know

L: And the first idea we're going to talk about, we're going to talk about the idea of FLUX. On your small white boards, write something that you know about flux. She gave them about two minutes to form their responses. Picking up whiteboard responses to consider. Liz moved around the room to see what the students were writing and/or drawing. As some were finishing, she began picking up a few of the whiteboards and placing them, back side to the class, on the ledge of the black board at the front of the room. By hiding what was written, she allowed the students still working to

continue without distraction. By taking care with how she placed the whiteboards, she also could choose the

As Liz continued walking around picking up whiteboards that she wanted to discuss, she commended the students, "I am seeing lots of good things." She also made a joke that prompted student laughter, a way of diffusing some of the tension that can occur when students are asked to display what they do-or

Considering the first whiteboard. Liz began the discussion by holding up one of the whiteboards so all could see it. She read the inscription, "This one says 'The flux is the amount of field 'flowing' through an area." After describing the drawing of a rectangular area with arrows pointing through it, she asked "What



### Narratives Describing **Specific Activities**

#### Engaging Students in an Activity and Discussion to Demonstrate a Abstract Concept To illustrate the appropriate interpretation of flux in the context of electricity and magnetism, Liz handed out some rulers and meter sticks to students sitting near one another. She identified the rulers and meter

sticks as vectors and the set of them as the vector field. The students held the rulers and meter sticks at different angles with respect to the plane of the hoop as she brought the hoop near. First she held the hoop so that some of the rulers and meter sticks started in the plane of the hoop. : So I can think about flux as being the measurement of how much of

your vector, how much of my vector is pointing through my little gate. So here I have some non-zero flux because at the points that lie along the surface of my area there is some value of the field. ok? Next she moved the hoop where there were no rulers or meter sticks: L: If I move my area over here, there's no flux, no vector field. Then, however, she moved the hoop where a meter stick poked through the hoop but was held by a hand outside of the plane of the hoop.

What if I put my hoop here. Is there flux or no? When some students answered, "yes," Liz asked, "How can you tell?" When a student responded, "There's a vector going through it," Liz

asked, "What is the field at a point that's lying in my area? Then she articulated the idea she wanted them to grasp, that the vector started at a point outside the loop, "NOT in my area." While ging confusion, she reiterated what she wanted them to

understand, that the base of the vector needed to be on the surface of

the area



## **Reflections from Adopters**

article discussion edit this page old revisions You are here: start » activities » reflections » adopters » fluxconcept

Comment from S. Pollock (CU Boulder, visiting OSU and teaching Paradigm "Vector Fields), Nov 2009: used this activity on day 1. It was quick, simple, and worked very well. I used a small hula-hoop for the "area" and passed out rulers to just one small cluster of 4 students. I gave them half a dozen rulers (4 of one size, 2 of another), and said "make a uniform field". Happily, 2 picked small rulers, 2 picked big ones, and they held them up all parallel to each other. So other students immediately chimed in that this wasn't uniform in magnitude.

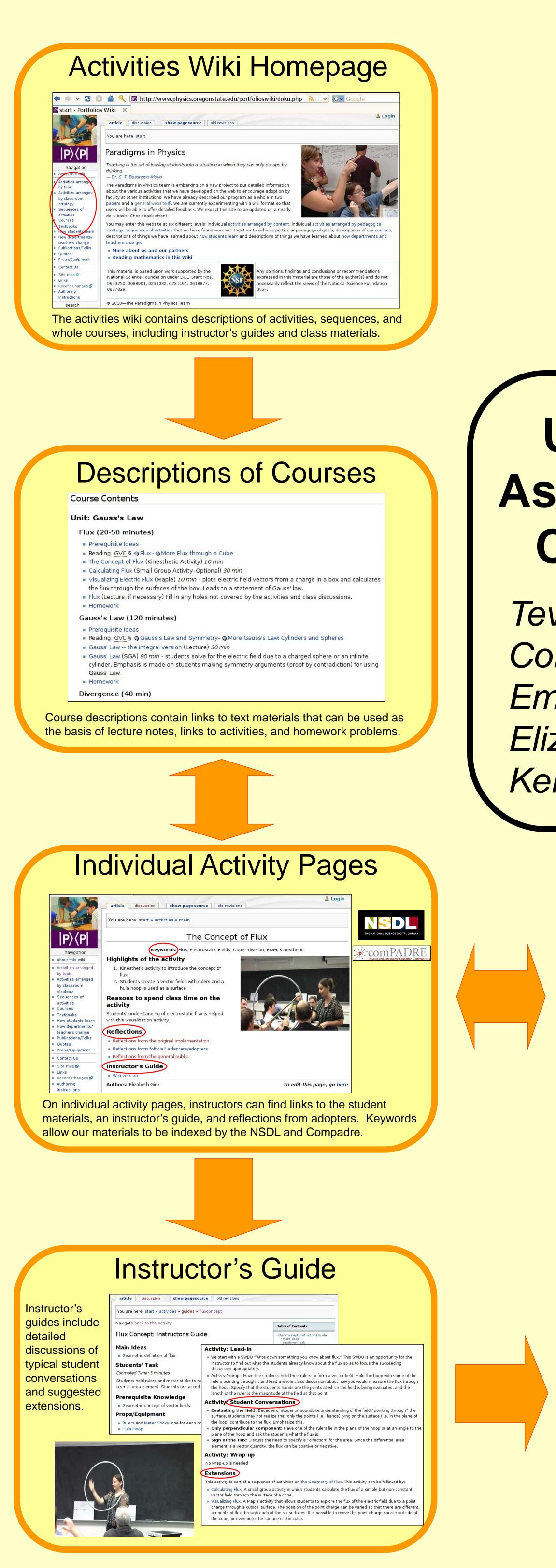
Next, I asked them to make a more jumbled field, (but their hands were all on the desk), so I purposefully

lowered the hoop just \*above\* their hands, and asked what flux this represented. (So the rulers poked through, but the "field points", the hands, were below the plane of the hoop) There was a mix of responses, many 'positive", and a couple of "zero", and one of the 4 participants spontaneously moved his hand up so that IT was in the plane of the hoop. So I asked the class "why do you suppose T. just moved his hand"? Got a good discussion going about how flux is evaluated IN the plane, the E arrows are represented by rulers but don't

have physical length. Lastly, asked one student " could you adjust your field so that it contributes zero flux"? And she quickly turned it parallel to the loop.

Pretty brief and easy activity, no problems, seemed to get out several of the key ideas in a visual way.

Adopters can easily post comments on how their adaptations of our activities have worked at their institutions.



## Paradigms in Physics

In the Paradigms in Physics Project at Oregon State University we have restructured the upper-division curriculum to be more modern, more flexible, and more inclusive. The content has been reordered to present physics the way professional physicists organize their own expert knowledge. Our pedagogical approaches now include interactive small-group learning, technology-based visualization activities, and project-based classes.

# Using Technology to **Assess and Disseminate Curricular Innovation**

Tevian Dray Corinne Manogue Emily van Zee Elizabeth Gire Kerry Browne



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Oregon State University •Department of Physics •Department of Mathematics •College of Science •University Honors College •Academic Affairs

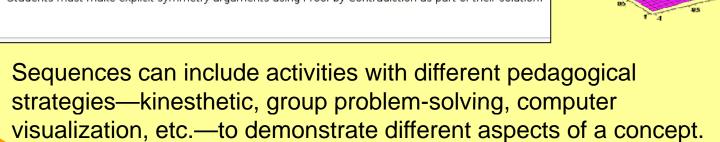
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### Sequences of Activities

You are here: start » whitepapers » sequences » flux The Geometry of Flux and Gauss's Law

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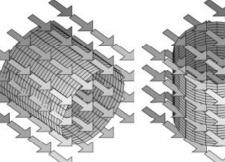
- We use the first three activities in rapid succession, to emphasize to students the geometric nature of flux. These make a nice stand-alone introduction to the geometry of flux or they can be used as a warm up for a final activity-using Gauss's law to find the electric field in situations with high symmetry. (The second activity is and and can be omitted if students will not be expected to calculate flux on complicated surfaces.)
- Activities Included The concept of flux. A kinesthetic activity in which students use rulers to represent a vector field and a hula hoop to represent a surface. The class discussion focuses conceptually on what contributes to the
- Calculating Flux. A small group activity in which students calculate the flux of a simple but non-constant vector field through a cone. Visualizing Flux. A Maple activity that allows students to explore the flux of the electric field through a cubical surface due to a point charge. The position of the point charge can be varied so that there are
- different amounts of flux through each of the six surfaces. It is possible to move the point charge source outside of the cube, or even onto the surface of the cube. Gauss's Law. A compare and contrast activity in which students are asked to work in groups to find the electric field using Gauss's Law for either a spherically or cylindrically symmetric charge density. Students must make explicit symmetry arguments using Proof by Contradiction as part of their solution.



Instructors can see suggested homework problems directly as links from the Course pages. They can also access a password protected archive with solutions.

# Homework

- You are here: start » courses » vectorfields » order » hw » hwflux . (FluxCube) This problem is an easy, quick follow-up to test your understanding of fluxem activity. A charge q sits at the corner of a cube. Find the flux of  $ec{E}$  through each side of the cube. Do not do a messy calculation!
- 2. (FluxCylinder) This problem is an easy, quick conceptual question about flux, from Hughes Hallett vector calculus book. What do you think will be the flux through the cylindrical surface that is placed as shown in the constant vector field in the figure on the left? What if the cylinder is placed upright, as shown in the figure on the right? Explain



(FluxParaboloid) This problem is a long calculation testing whether you can calculate surface elements and flux in a complicated curvilinear coordinate setting. Find the upward pointing flux of the electric field  $ec{E}=E_0\,z\,\hat{z}$  through the part of the surface  $z=-3r^2+12$  (cylindrical coordinates) that sits above the (x,y)-plane

### Flexible Tables of Contents

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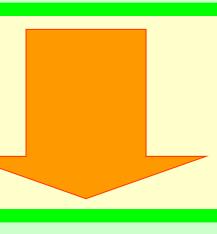


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- Tables of Contents
- Math Book (The complete math section of the book.) Physics Book (The complete physics section of the book.)

Symmetries (Text materials for the Symmetries course at Oregon State University.) Vector Fields / Text materials for the 🤿 Vector Fields course at Oregon State University.)

A separate wiki contains a textbook on the geometry of vector calculus with applications to physics. Short, modular sections allow the construction of multiple paths through the material. The wiki will provide sample paths, but instructors are also free to construct their own path by linking content directly to their course home pages.



### Blends of Math and Physics

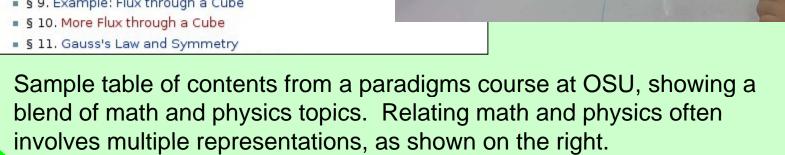
u are here: start » toc » gauss

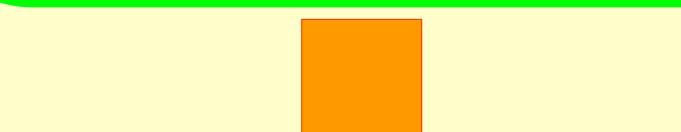
### Static Vector Fields

- Unit 1: Gauss's Law
- § 1. Surfaces (review)
- § 2. The Cross Product (review) § 3. Surface Elements (review)
- = § 4. More Surface Elements on Surfaces and Spheres (re
- = § 5. More Surface Elements on Planes, Cylinders, and Sp = § 6. Flux

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- = § 7. Flux of the Electric Field
- s 8. Gauss's Law ■ § 9. Example: Flux through a Cube
- § 10. More Flux through a Cube
- § 11. Gauss's Law and Symmetry



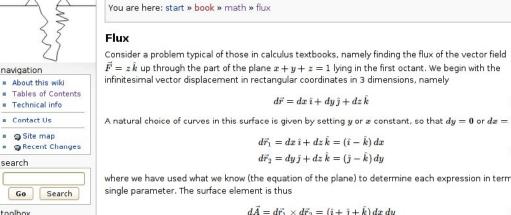




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We have chosen a level of sophistication appropriate for beginning upperdivision students.

In a subsequent project, we intend to add links to material at other levels, both more basic and more advanced.



and the flux becomes

two-dimensional!

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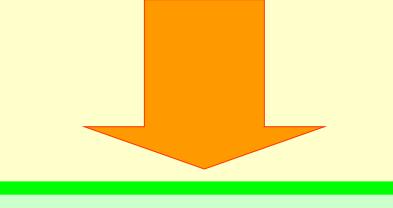
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Special Pages

A natural choice of curves in this surface is given by setting y or x constant, so that dy = 0 or dx = 0:  $d\vec{r}_1 = dx\,\hat{\imath} + dz\,\hat{k} = (\hat{\imath} - \hat{k})\,dx$  $d\vec{r}_2 = dy\,\hat{\jmath} + dz\,\hat{k} = (\hat{\jmath} - \hat{k})\,dy$ where we have used what we know (the equation of the plane) to determine each expression in terms of a single parameter. The surface element is thus  $dec{A} = dec{r_1} imes dec{r_2} = (\hat{\imath} + \hat{\jmath} + \hat{k}) \, dx \, dy$ 

 $\int \vec{F} \cdot d\vec{A} = \int z \, dA = \int_{0}^{1} \int_{0}^{1-y} (1-x-y) \, dx \, dy = \frac{1}{6}$ Just as for line integrals, there is a rule of thumb which tells you when to stop using what you know to compute surface integrals: Don't start integrating until the integral is expressed in terms of two parameters, and the limits in terms of those parameters have been determined. Surfaces are

 $d\vec{r} = dx\,\hat{\imath} + dy\,\hat{\jmath} + dz\,\hat{k}$ 



### **Options for Printing**

Flux

book:math:flux - The Geometry of Vector Calculus	http://physics.oregonstate.edu/BridgeBoo	k/doku.pbp?id=
Flux		1
Consider a problem typical of those in calcult vector field $\vec{F}=z\hat{k}$ up through the part of th octant. We begin with the infinitesimal vector 3 dimensions, namely	ie plane $x+y+z=1$ lying in the f	first lv
$dec{r} - dx\hat{\imath} + c$	$dy\hat{\jmath}+dz\hat{k}$	(1)
A natural choice of curves in this surface is $dy=0$ or $dx=0$ :	given by setting $y$ or $x$ constant, so	othat A
$egin{array}{ll} dec{r}_1 = dx\hat{\imath} + dz \ dec{r}_2 = dy\hat{\jmath} + dz \ \end{array}$	( )	(2)
where we have used what we know (the equa expression in terms of a single parameter. T		ch w
$dec{A}=dec{r}_1 imes dec{r}_2=$	$(\hat{\imath}+\hat{\jmath}+\hat{k})dxdy$	(3)
and the flux becomes 1)		aı
$\int\limits_{S}ec{F}\cdot dec{A} = \int\limits_{S}zdA = \int_{0}^{1}\int$	$\int_{0}^{1-y} (1-x-y)  dx  dy = \frac{1}{6}$	(4)
lust as for line integrals, there is a rule of th	umb which tells you when to stop i	usina

what you know to compute surface integrals: Don't start integrating until the integral is xpressed in terms of *two* parameters, and the limits in terms of those parameters have been determined. Surfaces are two-dimensional!

Consider a problem typical of those in calculus textbooks, namely flux of the vector field $\vec{F} = z  \hat{k}$ up through the part of the plane.	
lying in the first octant. We begin with the infinitesimal vector of	lisplacement
in rectangular coordinates in 3 dimensions, namely	
$d\vec{r} = dx\hat{\imath} + dy\hat{\jmath} + dz\hat{k}$	(1)
A natural choice of curves in this surface is given by setting $y$ or so that $dy = 0$ or $dx = 0$ :	x constant,
$d\vec{r}_1 = dx \hat{i} + dz \hat{k} = (\hat{i} - \hat{k})  dx$	(2)
$dec{m{r}}_2 \;\;=\;\; dy \hat{m{j}} + dz \hat{m{k}} = (\hat{m{j}} - \hat{m{k}}) dy$	(3)
where we have used what we know (the equation of the plane) t each expression in terms of a single parameter. The surface eler	
$d\vec{A} = d\vec{r}_1 \times d\vec{r}_2 = (\hat{\imath} + \hat{\jmath} + \hat{k})  dx  dy$	(4)
and the flux becomes <sup>1</sup>	
$\int_{S} \vec{F} \cdot d\vec{A} = \int_{S} z  dA = \int_{0}^{1} \int_{0}^{1-y} (1-x-y)  dx  dy = \int_{0}^{1} \int_{0}^{1-y} (1-x-y)  dy$	$\frac{1}{6}$ (5)
Just as for line integrals, there is a rule of thumb which tells y stop using what you know to compute surface integrals: Don' grating until the integral is expressed in terms of <i>two</i> paramet limits in terms of those parameters have been determined. Surfa	't start inte- ers, and the

Modules are written in "WikiTeX", allowing online display (previous slide) and a printable version (left) using jsMath, as well as traditional printing (right) using LaTeX and PDF, all from a single source file.