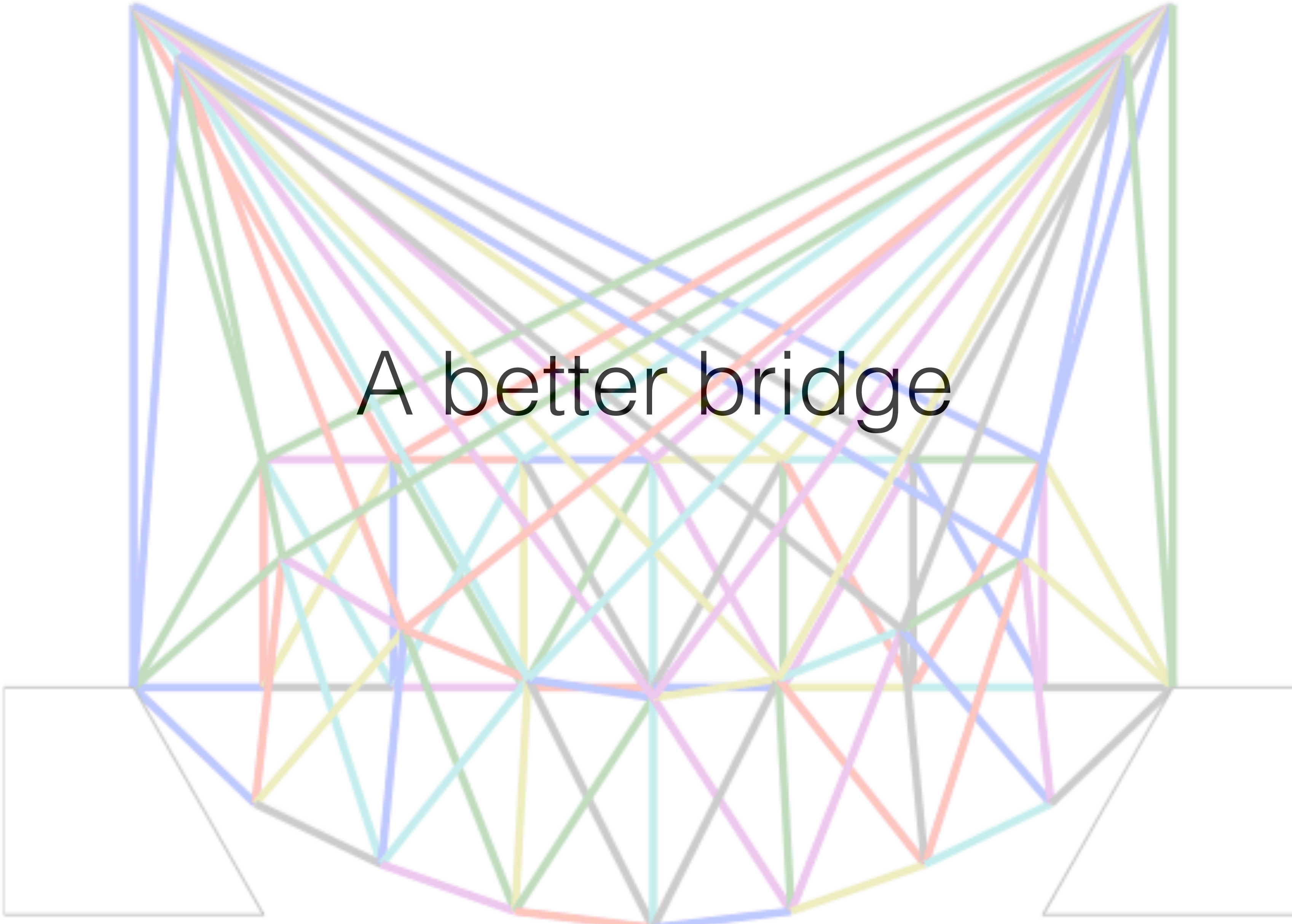
A better bridge



Checklist

1. add second story of pylon fibers to adjacency matrix, length matrix, and coordinate matrices.

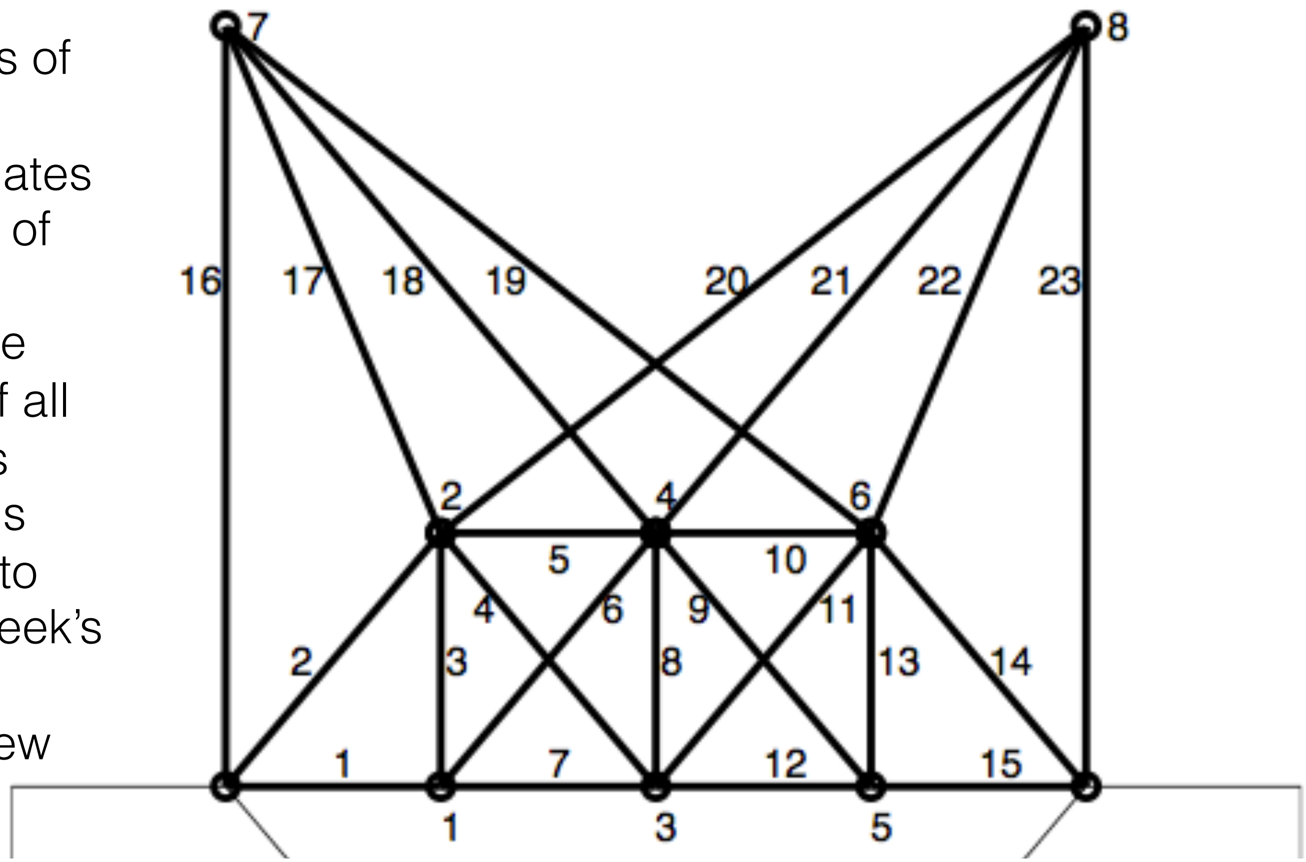
2. use **fmincon** to optimize fiber thicknesses
   -restructure work function to find gradient

3. Deform as instructed; answer questions

The better bridge

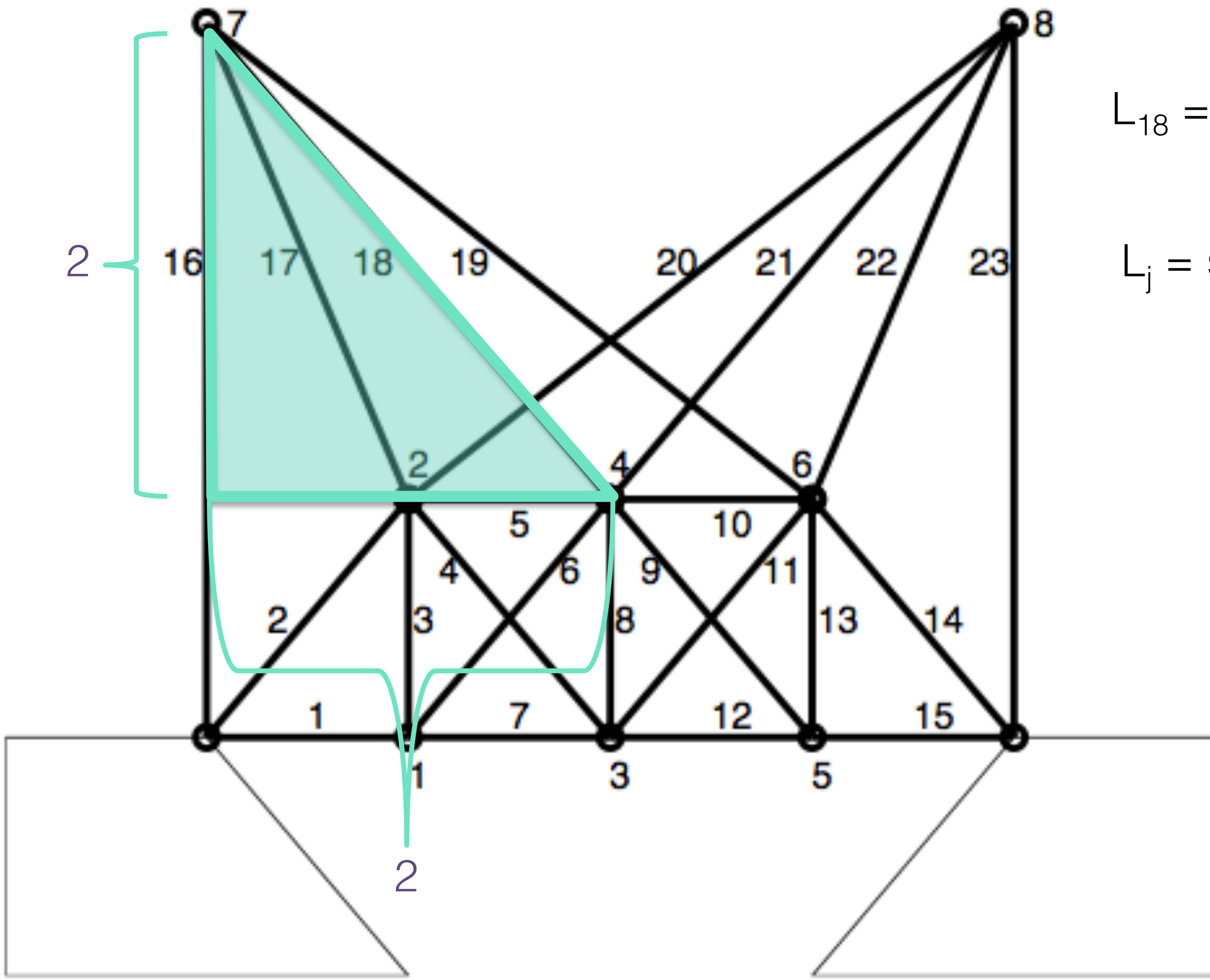
1. Draw bridge on piece of paper
2. Label nodes
3. Label fibers
4. Label degrees of freedom
5. Label coordinates
6. Label lengths of new fibers
7. Write down the elongations of all the *new* fibers

→ Doing all of this tells you how to update last week's automation to account for new structure.



$$e \approx (x_3 - x_1)\cos\theta + (x_4 - x_2)\sin\theta.$$

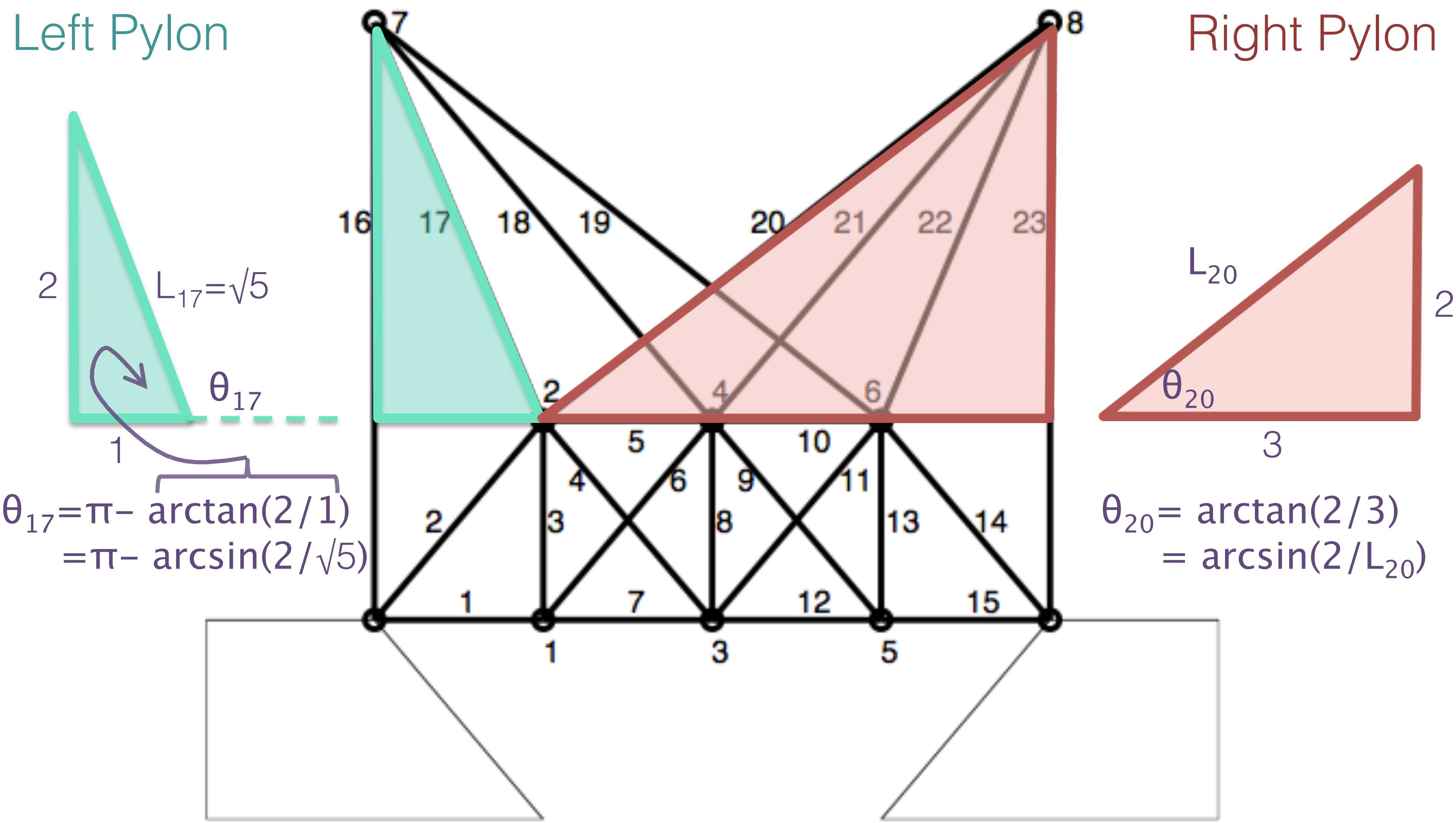
Pylon fiber *lengths*



$L_{18} = \mathrm{sqrt}(2^2 + 2^2) = \mathrm{sqrt}(8)$

$L_j = \mathrm{sqrt}(2^2 + ?^2)$

Pylon fiber *angles*



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Unpacking Optimization

This is our objective function.

We solve for a set of a-values (fiber areas)….

$$\min_{a} x^T f$$

That minimize the amount of work done.

Subject to a set of constraints:

$$A^T K(a) A x = f$$ must obey our equilibrium equation

$$L^T a = V$$ total thickness must meet volume constraint- amount of fiber material we have

$$alo \leq a(j) \leq ahi$$ thickness of each must stay within a given range

fmincon

- The good news: MATLAB has a built-in optimization package with solvers that take care of the minimizing.
- *Your* work is in handing fmincon the right objects.

Constraints

```
[x, fval] =
fmincon(function,initval,A,B,Aeq,Beq,LB,UB,nonlcon, options)
```

- function: (objective) function we are minimizing
- initval: initial values of function
- A,B: Linear *in*equalities A*a <= B
- Aeq,Beq: Linear *equalities* Aeq*a = Beq
- LB,UB: Lower and Upper bounds on a-values
- nonlcon: nonlinear constraints
- options: set to handle gradients

```
[optimal_a, work] =
fmincon(@(a) work(a,A,L,w),a0,[],[],L,V,LB,UB,[], options)
```

fmincon

[x, fval] =

Constraints

fmincon(function,initval,A,B,Aeq,Beq,LB,UB,nonlcon, options)

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[optimal_a, work] =

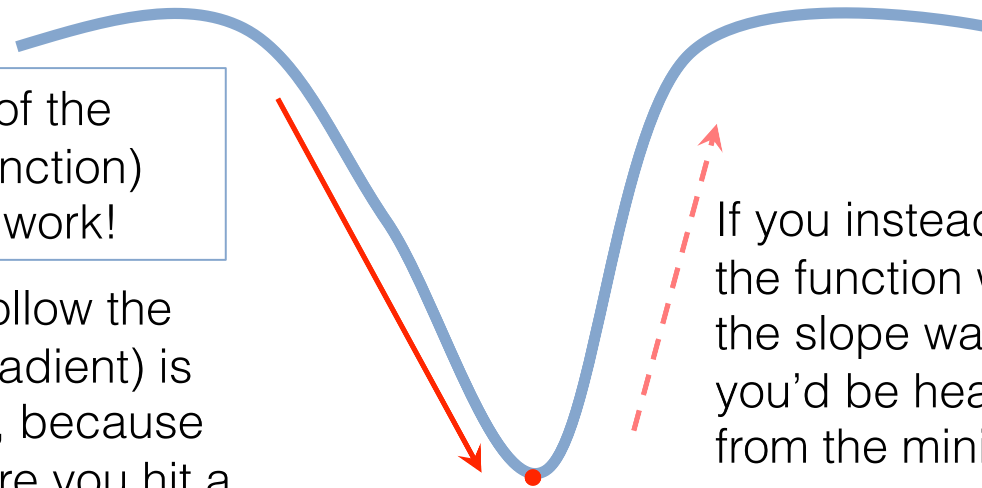
fmincon(@(a) work(a,A,L,w),a0,[],[],L,V,LB,UB,[], options)

- What are our initial a-values (what did we use in the last project?) all a-vals =1. So, as an example, a0=ones(numfibers,1)
- You computed matrix L in your adjacency automation. What is V? We base the amt of material available on the initial case.
- LB=alo= 0.1, UB=ahi=10, but we need them in vector form (for *each* a-val) …we are solving a linear system
- options = optimset ('display','iter', 'gradobj','on');

[workfun]

Gradients for optimization

the objective function: work as a function of (a)



We're looking for a minimum (of the objective function, the work function) because we want to minimize work!

To get to the minimum, we follow the function where the slope (gradient) is *negative*. This makes sense, because the function decreases before you hit a minimum.

If you instead followed the function where the slope was positive, you'd be heading *away* from the minimum!

At this *minimum,* the *gradient* is 0.

We are lucky because the gradient of the work has been computed for us in the notes!!

$$\nabla \mathrm{work}(a) = -\begin{pmatrix} e_1^2(a)/L_1 & e_2^2(a)/L_2 & \cdots & e_m^2(a)/L_m \end{pmatrix}^T$$

How can we write this grad more simply using just e and L?

```
function [val,grad] = work(a,A,L,W)
```

- compute work as you would have last week

  … (matrix multiplication operations)

  …

  val = x'*f; (this is your work value)

- Now the gradient: $= -(Ax(a))^T \frac{\partial K(a)}{\partial a_1} Ax(a)$

What are these "e"s representing?

$$= -(e_1 \; e_2 \; \cdots \; e_m) \begin{pmatrix} 1/L_1 & 0 & \cdots & 0 \\ 0 & 0 & \cdots & 0 \\ \vdots & \vdots & \cdots & \vdots \\ 0 & 0 & \cdots & 0 \end{pmatrix} \begin{pmatrix} e_1 \\ e_2 \\ \vdots \\ e_m \end{pmatrix}$$

$$= -e_1^2(a)/L_1.$$

$$\nabla \text{work}(a) = -(e_1^2(a)/L_1 \quad e_2^2(a)/L_2 \quad \cdots \quad e_m^2(a)/L_m)^T$$

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