make *8*

The time for half-measures and talk is over.
    – Maximus, in "Gladiator"

intro

Just the ideas in this book can bring relief and hope. But 99% of their value lies in their application. This requires a darkroom, an uncommon thing. But buildings are plentiful. These last four "make" chapters explain how to build darkrooms inside existing buildings.

Whether you build a darkroom or not, reading these chapters will give you a sense of being in one. You will see how the abstractions in the first part of the book apply concretely, how its theory, process, and design make up an integral whole. You will know what is going on around you during a retreat. You will know what to look for in a darkroom. You will not be useless should yours break down during your retreat!

This chapter provides basic information that applies to all components of a darkroom. The next three chapters provide blueprints and instructions for components related to three elements: air, darkness, water. They are vents, silencers, seals, blinds, and kitchen and bathroom fixtures. Designs are low-cost, low-tech, and work off-grid.

A darkroom is a real thing you see and touch, make, use, and offer others. It is not a metaphor. It takes a knowledge, imagination, design, measurement, plans, materials, craftsmanship, construction, testing, and improvement.

These are normal activities. Everyone does them to some degree. and get help with the rest. If you can walk down stairs without falling, slice a loaf of bread, hit a plate when you aim food at it, hold a pencil, cognize sentences, tell light from dark, and feel a breeze, you are mechanically sufficient to begin. As Jack Nuckols, a mechanical engineer and my grand-elder, once

told me when my time came, "Become a craftsman." Perhaps your time has come. Become a craftsman.

A sniper's rule could belong to craftsman, too: "Aim small, miss small." The precision of the plans to follow helps you aim small. The designs and materials are forgiving. Little mistakes can be absorbed, bigger ones, corrected or repaired.

I suggest that, your first time through these last chapters, you read everything in this one. But just read the prose parts of the next three. Save the lists of instructions till you make something. They make dense reading. Eventually, they'll be replaced with graphical assembly instructions like IKEA's. For now, we slog through.

All components rely on the basic instructions in the following sections: **metric**, **tools**, **plans**, and **fabrication**.

Each component has special instructions and design constraints in its own section in later chapters: air *9*, darkness *10*, and water *11*.

After improvising darkness to sleep in tonight *4*, the instant mask *10* probably comes next. Thus initiated, you can begin your training as a darkroom-building ninja. You will become invisible to everyone for a while. And everything will be invisible to you, too. Haha.

If you need more specific advice for darkening your space, I provide design consultation *w*. I guide people through text, voice, and image on a chat app toward a completed darkroom and successful retreat. Likewise, feel free to use these open-source *e* designs and my consultation to darken other people's spaces as a service for money. See license *x* for my liberal terms.

metric

I give all measurements in metric. Unlabeled measurements are in millimeters (mm).

Are you used to the inches, pounds, and gallons of the imperial system? Get a handle on the brain-descrambling metric system in a split-minute:

1. Count to 10 and multiply by 10 like you do with other

numbers. Wrangle no more with fractions and many con-
version factors.
- basic metric conversions:
    - length: 1000mm=100cm=1m (millimeter, centime-
      ter, meter)
    - volume: 1L=10dL=1000mL (liter, deciliter,
      milliliter)
    - mass: 1kg=10hg=1000g (kilogram, hectagram,
      gram. Mass is like weight. But it uses a balance,
      not a spring scale, so it does not depend on
      Earth's gravity. Build a darkroom in space!)
- cool intra-conversions:
    - 1L=10cm x 10cm x 10cm (1000cm^3)
    - 1L water=1kg
    - thus, 1mL water=1cm^3=1g
    - brilliant! simple! humane!
2. Make the metric system tangible. Visualize the following
   imperial near-equivalents. Use them to imagine my de-
   scriptions, and make estimations. Not for precise conver-
   sions or large quantities.
   - length
       - 25mm = 1" (inch)
       - 100mm = 4"
       - 30cm = 1' (foot)
       - 1m = 1 yard & 4"
       - 3m = 10'
       - 1km = 0.6 mile
   - area
       - 1m^2 = 11'^{2}
       - 4' x 8' sheet = 120cm x 240cm ($\sim$3m^2)
       - A0-A8 paper size system. A sheet's 1:$\sqrt{2}$ propor-
         tion remain the same when cut in half the short
         way. A0 = 841 x 1189 = 1m^2. A1 = 595 x 841 =
         0.5m^2. A4, the metric counterpart to North Amer-
         ican letter size paper, is 210 x 297 = 0.0625m^2
         (1/16m^2)
   - volume
       - 4L = 1 gallon
       - 1.7cmh = 1cfm (cubic meter per hour to cubic feet
         per minute; for airflow)
   - mass
       - 28g = 1 oz
       - 1kg = 2.2 lb

tools

Making components requires most or all of these tools:

1. table or desk
2. measure
    1. Note: before purchase, test tools for accuracy, which can vary between identical tools, even of good brands. Instructions below.
    2. metric ruler, 45-50cm, clear plastic. If reproducing plans by hand rather than printing them, also get a 30cm Incra ruler. For its effortless marking precision, I recommend it for making anything at all ever. It's the greatest hand tool I have ever used.
    3. meter stick, steel with engraved marks
        1. put marked edges of two sticks together so 40cm mark of one meets 60cm mark of other
        2. push ends of both against a wall and check how well marks line up
        3. repeat with other sticks till you find a match
        4. buy one of them
    4. metric measuring tape, 5m
        1. use a tape whose case length is easily and accurately added to the figure on the tape itself. Some measuring tapes are designed to give highly accurate internal measurements, eg, between sills.
        2. hook tape on end of meter stick and compare marks for accuracy of external measurement
        3. push end of meter stick against a wall, put tape on top of meter stick, and compare marks for accuracy of internal measurement
3. mark
    1. 0.5mm mechanical pencil
    2. ballpoint pen, black or blue ink
    3. black marker
    4. straight pin with colored plastic head or masking tape handle
    5. magnifying glass (even a tiny plastic one works, like the one in a Swiss Army knife)

4. crease, score, cut
    1. straight edge 200mm longer than your longest piece
       will be. 1-2mm-thick steel is best. An aluminum door
       or window frame member also works well. A board
       less than 12mm thick with a perfectly straight edge
       (check it!) is fine.
    2. table knife: use back of tip for creasing
    3. razor knife with new blade: use for scoring and cut-
       ting. To score is to cut halfway through thickness of
       material with razor knife so it remains one piece and
       folds very easily
    4. scissors for both paper and fabric
5. join
    1. masking tape
    2. wood glue, unthickened, any grade
    3. glue syringe, 20-50mL for precise, efficient gluing
        • available
            – at kitchen supply shops, with 2-3mm stainless
              needles
            – at discount variety stores (dollar stores,
              bazars)
            – at woodworking shops, with needles
        • remove needle and plunger. Cover nipple with
          finger and fill from back, leaving 10mm unfilled.
          Replace plunger barely. Point nipple upward and
          uncover it. Wait for air bubble to rise to top. Then
          push plunger in till air is cleared from syringe.
          Replace needle and use.

plans

I have drawn the plans on a computer for precision, clarity,
and ease of modification. However, at first, they can be baffling
to look at.

1. use the **key** to understand the symbols and marks
2. compare drawings to photos.
3. read the instructions through a couple times in the days
   before making begins.

4. then *follow the instructions*, one step at a time, and you ought to end up with the intended component.
5. dimensions are X x Y x Z (left-right, up-down, in-out, ie, width, height, depth)

Understanding often comes through doing. If this does not work, write me and I'll try to sort out the confusion and maybe improve the instructions and drawings for others, too.

A drawing has one or two *views*, depending on the best way to communicate its information:

- *plan:* from above, two dimensional (2D). Default view if unlabeled.
- *pattern:* flat, unfolded part from above (2D)
- *elevation:* from the side (2D)
- *section:* a cutaway or slice of the object showing all parts when assembled (2D)
- *perspective:* from a non-right-angled point of view to capture more sides (3D)
- *exploded:* all parts separated but in correct order and linear relation (3D)

For example, the helix vent *9* has pattern views of its parts and a section + elevation view showing how parts are assembled. The toilet frame *11* has both plan and elevation views, while the shower *11* has an exploded view. The threshold vent has a perspective view.

All plans can be reused except the mask *10* plan, which is destroyed as you make it. So make as many prints of it as masks you intend to make.

Images in this book are only for reference and hand-reproduction. They are reduced to fit book pages. Thus they are neither full-scale nor in proportion to each other. If reading on a screen while online, you can zoom in. Download a full-size PDF with link below each image.

1 - download

Download all plans at once with the darkroom retreat zip file. Extract (decompress) the file. Contents:

- plans: a complete set of PDF plans
- all photos below plus extras from website
- SVG source files of plans for modifying them, originally drawn in Inkscape.

2 - print

1. large format
    1. large format printing is cheap, extremely accurate, and much faster and easier than desktop printing. Most print shops, including Staples and Office Depot, now offer large format printing.
    2. email your files to print shop or take them on a USB flash drive
    3. paper
        1. specify cheapest option
        2. if print shop has 300gsm acid-free black paper on a roll for large format printing, print the helix vent's channels and walls directly onto it. Yes, black ink on black paper is visible enough to work with.
    4. have files printed in actual size, with no scaling. Before paying, check measurements with ruler or measuring tape. Distortion should not exceed 1mm over a 250mm span.
    After resigning myself to 2mm distortion per 250mm (0.8%) with desktop printers, I was shocked to find almost no distortion with large format printing, maybe 0.5mm/500mm (0.1%). But then it made sense because architects, engineers, and builders depend on this service for their blueprints.
2. desktop
    1. only do this if you are absolutely broke or can't find a large format printing service on your desert island. Desktop printing of plans takes a lot of time and yields imperfect results.
    2. print
        1. open file with Adobe Reader (not Adobe Professional)
        2. in print dialogue, select: "Poster"; Tile Scale: 100%; Overlap: 1.0in; Cut marks: yes; Labels: yes
        3. use A4, letter, or legal size, possibly A3
        4. Distortion over 250mm span should not exceed 1mm.

      5. after printing one file, check measurements against ruler to 1mm tolerance.

    3. join sheets

      1. cut a small wedge out of overlapping cut mark to align it with matching cut mark on sheet below

      2. align cut marks at perimeter of plan first, then the one(s) in the middle.

      3. use masking tape to join sheets

3. by hand

  1. ruler and magnifying glass

    1. get large white paper to make a reusable pattern with. Don't measure directly on materials.

    2. to keep drawing orthogonal, use some combination of graph paper, drafting table, and extra careful measurement and marking. An Incra ruler will help a lot with this.

    3. use magnifying glass to see small words and numbers in the book

    4. plans are as symmetrical and uniform as possible. If two similar-looking areas of a plan look the same size, they are. So from measurements given in plans, infer the rest. There is some redundancy so you don't have to figure out everything and can double-check essential measurements with arithmetic.

    5. use grey-numbered cumulative measurements in plan to quickly mark lines

  2. trace

    1. trace directly from a flat screen monitor

    2. zoom image till stated measurements match a ruler both horizontally and vertically

    3. tape paper to the screen

    4. mark ends, corners, and intersections of lines precisely and lines just well enough to know what you are looking at later

    5. you will have to overlap multiple sheets of paper for most plans, as with a desktop printer. On each new piece of paper, repeat the last set of marks from the previous so you know where to overlap and tape the sheets together.
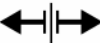
3 - key

Here is a key to the plans. Find further explanation of symbols, especially dash-dotted lines, in **fabricate** section below.

k e y

l i n e s

dashed	– – –	crease & fold toward yourself
dotted	······	crease & fold away
solid	——	cut
dash-dotted	– · – ·	guide
dash-dotted-arrow	– · – ▸	dimension
asterisk-dashed	–✳–	score front & fold toward yourself
asterisk-dotted	·✳·	score back & fold away
sausage short	⬭	glue

s y m b o l s

opposing arrows	◄‖►	spread plan
	►‖◄	overlap plan, solid over hollow
crosshairs	⊕	hole
letter	A	joint point or line
black number	72	mm between lines, corners, or hole centers
grey number	72	mm from bottom or left edge
number with tilde	72~	adjustable measurement

l a b e l

component and part
view (plan, elevation, section, etc)
dimensions (Width x Height x Depth ; x,y,z)
material, type, weight
amount needed

plan: key - download

fabricate

These instructions apply to all components, or as indicated. Read special instructions for each component in its respective chapter and section afterward.

1 - prepare plans

1. for fabric parts (helix vent *9*, mask *10*)
    1. using ruler and razor knife, cut out parts at outlines
    2. cut out tape holes on dash-dotted lines
    3. skip to 3 - make parts *8* below
2. customize threshold vent *9* with instructions in drawing

2 - transfer plans to materials

1. tape plans to materials
    1. helix vent shell *9*: skew plan roughly diagonally (20°-70°) to edges or folds (corrugations) of cardboard
    2. cut out small wedges from outlines of plans to align them with edges of materials.
    3. parts with stretch arrows
        1. tape one half to edge of material
        2. using derived measurements and tape measure, mark material where opposite edge of part should be and tape it there
    4. lay out other plans on materials and tape opposite corners
2. put three layers of cardboard on work surface
3. transfer plan with straight pin
    - use magnifying glass for ease of marking and geeky precision thrills
    - poke pin through
        - all black lines close to ends (not grey glue sausages)
        - centers of holes
4. remove plan from material
5. mark pin holes:

- dashed lines: circles
- dotted lines: double circle
- solid lines: squares
- dash-dotted lines: triangle
- holes: star

6. mark the marked holes again
    - draw short lines from circles, triangles, and squares in the same direction as lines in plan
    - circles/double circles: add asterisks where indicated
    - copy joint letters (A, B, C...)
7. label drawing, words oriented the same as in plan

3 - make parts

1. keep scrap cardboard on work surface
2. fabric parts (mask, vents)
    1. tape plans to fleece over tape holes
    2. cut parts exactly around plan outline with scissors
    3. leave plans taped to mask side seals
    4. remove plans from other parts
    5. repeat steps 1-4 to make
        - 2 mask center seals
        - 4 mask covers. For the 4th cover, use optional cotton fabric, add 20mm on side for seam allowance, and leave plan taped to fabric.
    6. skip remaining steps 3-4 and resume special instructions
3. cardboard shell of helix vent
    1. trim excess cardboard around pattern but don't cut its edges yet (between squared holes)
    2. with straight edge and razor, score between circled-asterisked holes, cutting through top face and most of corrugations, but not the bottom face.
    3. press 90° edge of board into scores at 45°
    4. lightly crease between circled holes with back of table knife tip, avoiding breaking the surface of cardboard
    5. press straight edge into creases to deepen them

6. turn cardboard over and repeat steps 3 & 4 with double-circled holes
7. cut between squared holes
8. fold cardboard at creases, bending it well past 90°

4. paper parts
    1. between holes with asterisks
        • circled pairs, score back, fold forward
        • double-circled pairs, score front, fold backward
    2. between circled and double-circled holes
        • crease front side with back of table knife tip
        • fold at creases forward
        • then, fold double-circled creases backward
    3. between squared holes: cut with razor knife
    4. between starred holes
        • expand to diameter indicated in plan
        • use a pointed dowel of appropriate diameter
        • spin it with your fingers or a power drill as you gently push it into hole

Voila. You've got the basics of all darkroom components. You've prepared their plans and parts. Now, let's see how they come together in the air department.

air *9*

The tricky part of making a darkroom is not darkening it but ventilating it. After all, now its windows and doors are sealed. So we'll address ventilation first.

Silencing a room is even trickier. But we have a couple aces up our sleeve for that.

We need to understand how ventilation works so we can design a good system. Ventilation affects both the silence and temperature of a darkroom. We will examine each of these conditions, then see how they work together in a mechanical system. Then we will make the components of the system.

ventilation

This section is on ventilation in general. I will give design constraints and describe various systems. But first, I will address its physiological importance.

breathe

Nature gives us a constant, abundant supply of fresh air. Our buildings should, too.

I have observed a shocking number of people who seem oblivious to their own need for fresh air. Everyone knows we die within minutes without air. Yet the importance of a continuous fresh supply of it has escaped many.

I can only attribute this negligence to mass psychosis. It is my stock explanation for the appalling features of civilized life. The need for fresh air is one of the most basic, most obvious facts of life. At the risk of insulting your intelligence, I am bound to address it.

Fresh air is always important. It is a normal condition of life. Along with warmth and safety, it is one of our most urgent necessities. Every second of our lives, quintillions of organic processes occur. Virtually all of them require oxygen. It is the

most important nutrient we consume. We can live days without water and weeks without food. Not so, air.

Just like food, air becomes a part of one's organism. It affects quality of life to a very great degree. It seems like nothing. But the amount of air you breathe masses twice as much as the food you eat. In a darkroom, you have little to do besides breathe. If you haven't paid attention to air quality, you will notice it in darkness.

Even if you don't, poor air quality cancels most benefits of a retreat. Intermittently airing the room out *does not work*. I mean opening the door a couple times a day with eyes covered. Put this approach out of your mind. This is darkness, not the dark ages. Whatever it takes, no matter where you are or what you are doing, always provide yourself with continuous fresh air.

For a darkroom retreat, this means:

1. following the instructions below
2. hiring an HVAC contractor to clean, repair, replace, or install ventilation in your home
3. moving somewhere the ventilation system just works (like the tropics or a new house in northern Europe)
4. using houseplants: high oxygen producers and air-purifiers
5. a combination of these

Somehow, it must be done. Forget darkness a moment. We rarely have a more urgent concern in life than arranging to breathe fresh air continuously and comfortably. Keeping it foremost in your thinking about darkroom design and construction will help ensure a successful retreat.

Not freezing to death and avoiding danger are more urgent than continuous fresh air. Building systems can meet all these needs harmoniously. Unaddressed fear and ignorance result in design conflicts between them. For example, we still often depend on windows for ventilation instead of a proper, separate system. The rest of this chapter will help you avoid such errors.

constraints

- system provides plenty of fresh air
- absolutely lightproof
- silent: absolutely no hum or harmonics from fan and exterior noises mostly extinguished
- comfortable temperature: no undesired cold drafts
- economical: ie, no wasted heat to the outdoors. This is more involved and a lower priority than retreating itself, so don't get stuck on it. It requires a heat recovery ventilator (HRV). Besides significantly lowering heating costs, an HRV improves air quality and comfort in nearly all climates. More about it below.

system

Somehow, fresh air has to get into the darkroom and stale air has to get out, without letting in noise or light.

In the terms of the HVAC industry (Heating, Ventilation, Air Conditioning), the fresh air vent is the *supply* and the stale air vent is the *return*.

Sometimes, supply and return vents exist in the same room. This is the fanciest version of *balanced* mechanical ventilation. If your place has it, thank your lucky stars. Just make sure it runs continuously. Unless your room is huge, intermittent is not good enough.

More commonly, balanced systems put supplies in bedrooms and living rooms, and returns in kitchens and bathrooms. This means air escapes a bedroom around the door. Unless the space outside the door is totally dark, this calls for a *threshold* lightproof vent (plans below).

Balanced systems are rare. More common are negative pressure systems: bedroom and living room windows act as passive supplies and bathroom and kitchen exhaust fans as active returns. In this case, a lightproof multi-purpose *helix* vent, built into a window blind, is the supply. Or a silencer if noise surrounds your dwelling. A threshold vent is the return, letting stale air escape the bedroom to the exhaust fan.

Rooms with totally passive ventilation rely on open windows, exterior vents, and infiltration through cracks. These will get

sealed against light. Such rooms will need helix vents in blinds at different heights to take advantage of convection. But they probably call for a fan and a silencer, maybe ducting.

By closely observing buildings I have discovered some simple ways to ventilate them. Sometimes rooms have lightproof and sound-dampened holes built into them in unexpected places:

- unused holes for pipes, wires, chimneys, and ventilation.
- behind a cupboard or inside a closet
- a removable panel or wide piece of trim that could be temporarily replaced with a panel with a hole in it.

For example, I once salvaged a cosmetically damaged door from the garbage at a building supply store exactly the same size as my darkroom's door. So I stored the original door and cut holes in the damaged door for ventilation.

Another darkroom had no ventilation or suitable holes anywhere. It also had no door. So we built a frame inside the doorway with a narrow door on one side and a narrower panel on the other. We cut holes in the panel for ventilation ducts. We fixed the frame in the existing doorway with metal straps screwed into old hinge holes. When dismantling the darkroom, we left no trace.

Similarly, we hung 7m of ducting that ran through three rooms; attached a silencer to it; made three window panels; and imperfectly covered five more windows with only one new screw hole in the entire rented house. And that hole was invisible behind a loose piece of trim. "Leave no trace" is a fun game that often improves design.

Sewage pipes drain downward but are ventilated upward. Once, friends and I replaced a flush toilet with a composting toilet. The exposed drain pipe, being oversize and in a single-story house, wasn't subject to backflow. So it proved a perfect exhaust duct for a case fan at floor level. Imagination conquers all obstacles (and renews itself in darkness).

If you are building a new house or are at liberty with an existing one, separate ventilation from windows. Give it its own holes in walls. This improves many attributes of a shelter: security, economy, comfort, silence, darkenability, and overall control.

vent

Here are further design constraints, photos, plans, and instructions for making and installing lightproof vents.
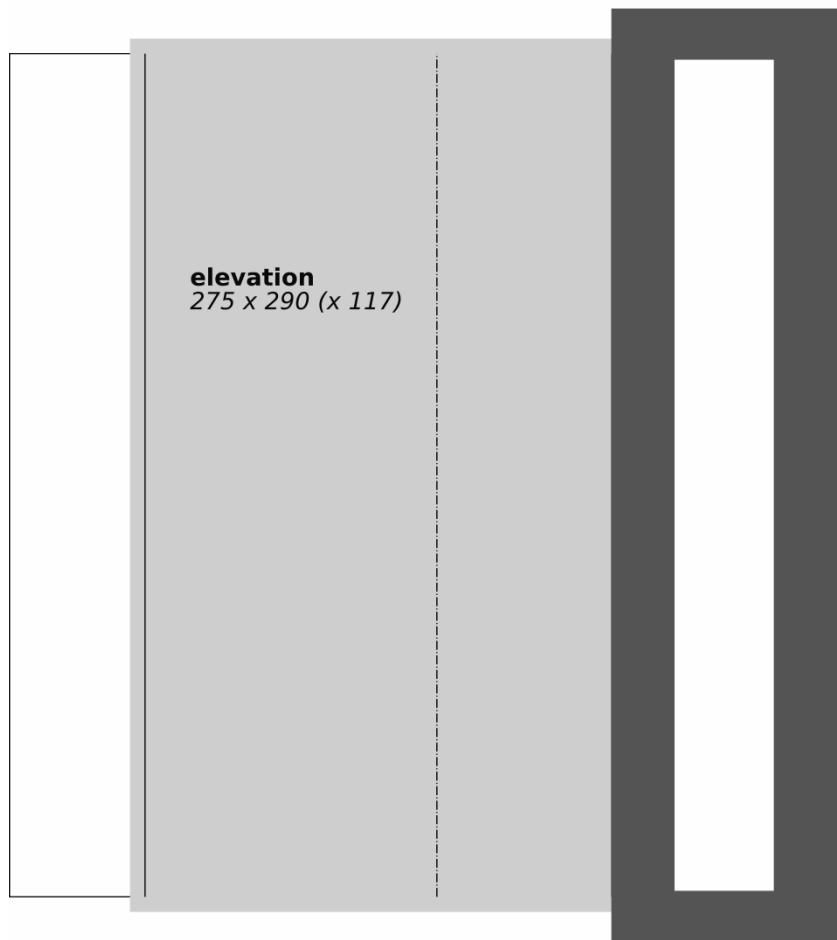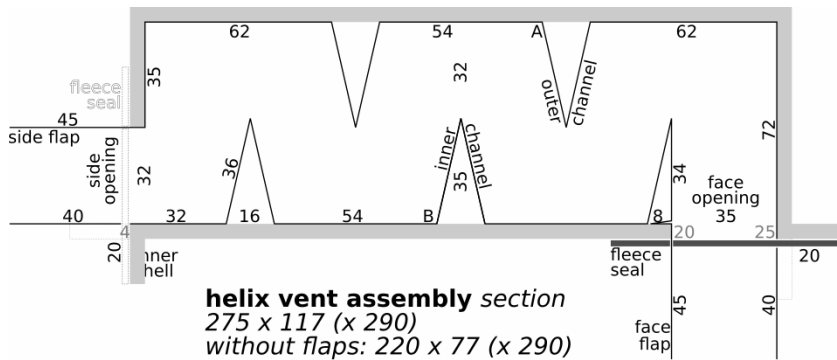
constraints

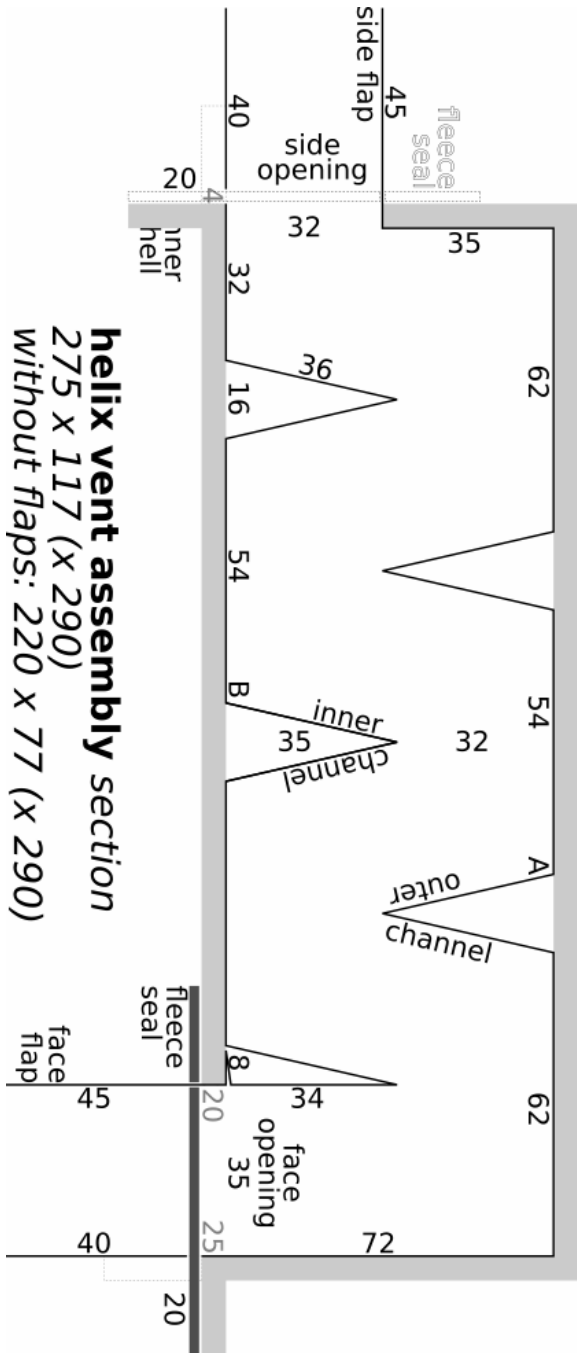(helix / helix-z specifications in parentheses)
{threshold vent specifications in curly braces}

- durable (protected by cardboard shell or silencer){protected by wood reinforcement, subject to damage by kicking but easily rebuilt, could be made of sheet metal or shielded with cardboard or thin wooden boards}
- thin enough to fit between blind and window (<80mm) or door and threshold {adjustable}
- cross-sectional area >75cm^2 (90cm^2){60–120cm^2} to equal standard 100mm diameter ducting
- fully traps light, sending light around at least 5 corners (7 corners / 5 corners){2-6 fabric-covered corners}
- short airway (240mm / 160){140mm}
- minimal size (220 x 77 x 290 / 140 x 67 x 281){fits under door, sticks out 20mm each side and up 60mm}
- easy to make (so-so){yes}
- elegant (yes: simple compact form, uses common materials, zig-zag-shaped passage accommodates natural helical movement of air){yes}
- cheap ($4 in materials, 2-hour assembly time){$2 in materials, 1-hour assembly time}

helix

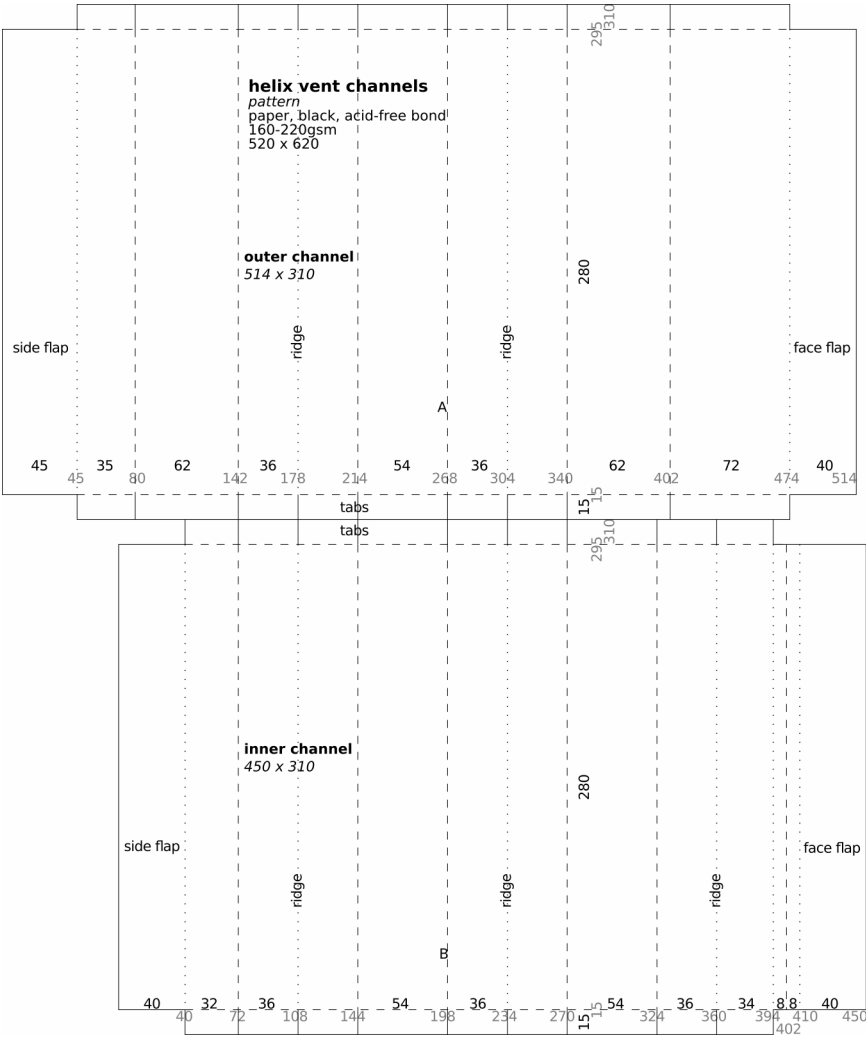I call it a helix vent because of how air actually moves through it: like a corkscrew. It might look like air would zigzag through like light. But air is a fluid like water. It takes the path of least resistance. It maintains the same curved trajectory by *helixing* through. The helix is the natural form of fluids in motion under any circumstance. So this minimizes friction within the airstream as well.

helix vent assembly *section*
275 x 117 (x 290)
without flaps: 220 x 77 (x 290)

fleece seal
side flap
45
35
62
54
A
62
32
outer channel
inner channel
72
36
35
side opening
32
40
32
16
54
B
8
34
face opening
35
20
inner shell
20
fleece seal
20
25
25
face flap
45
40

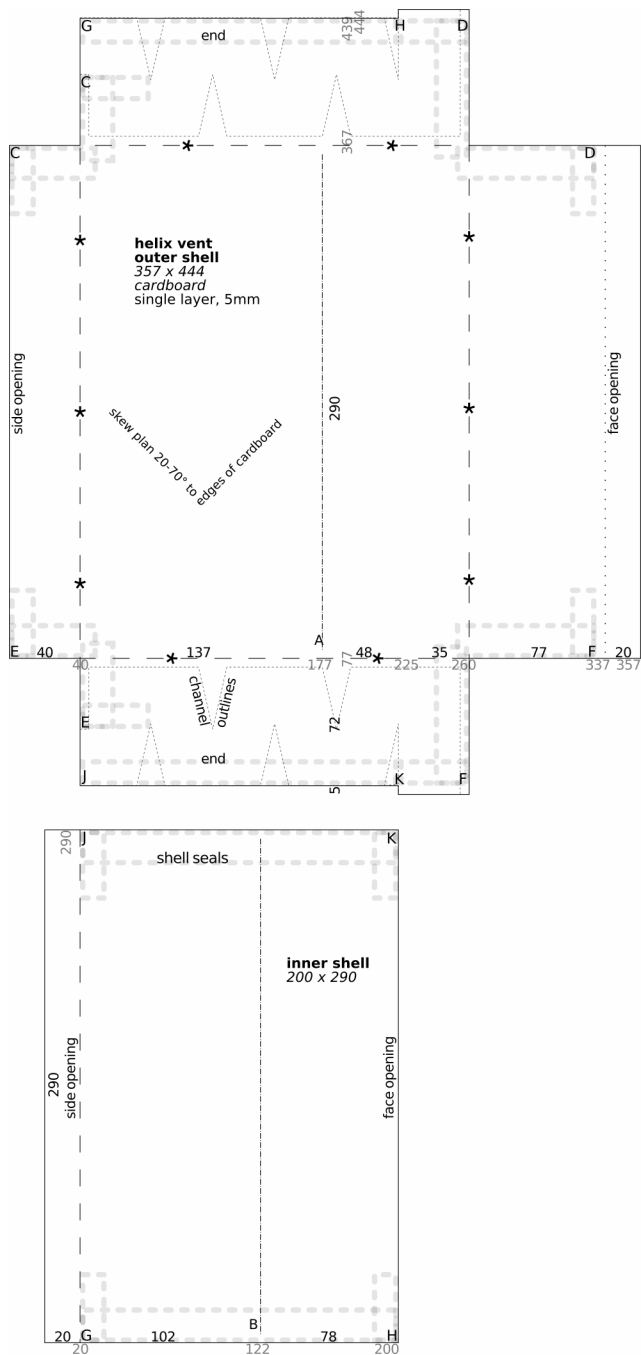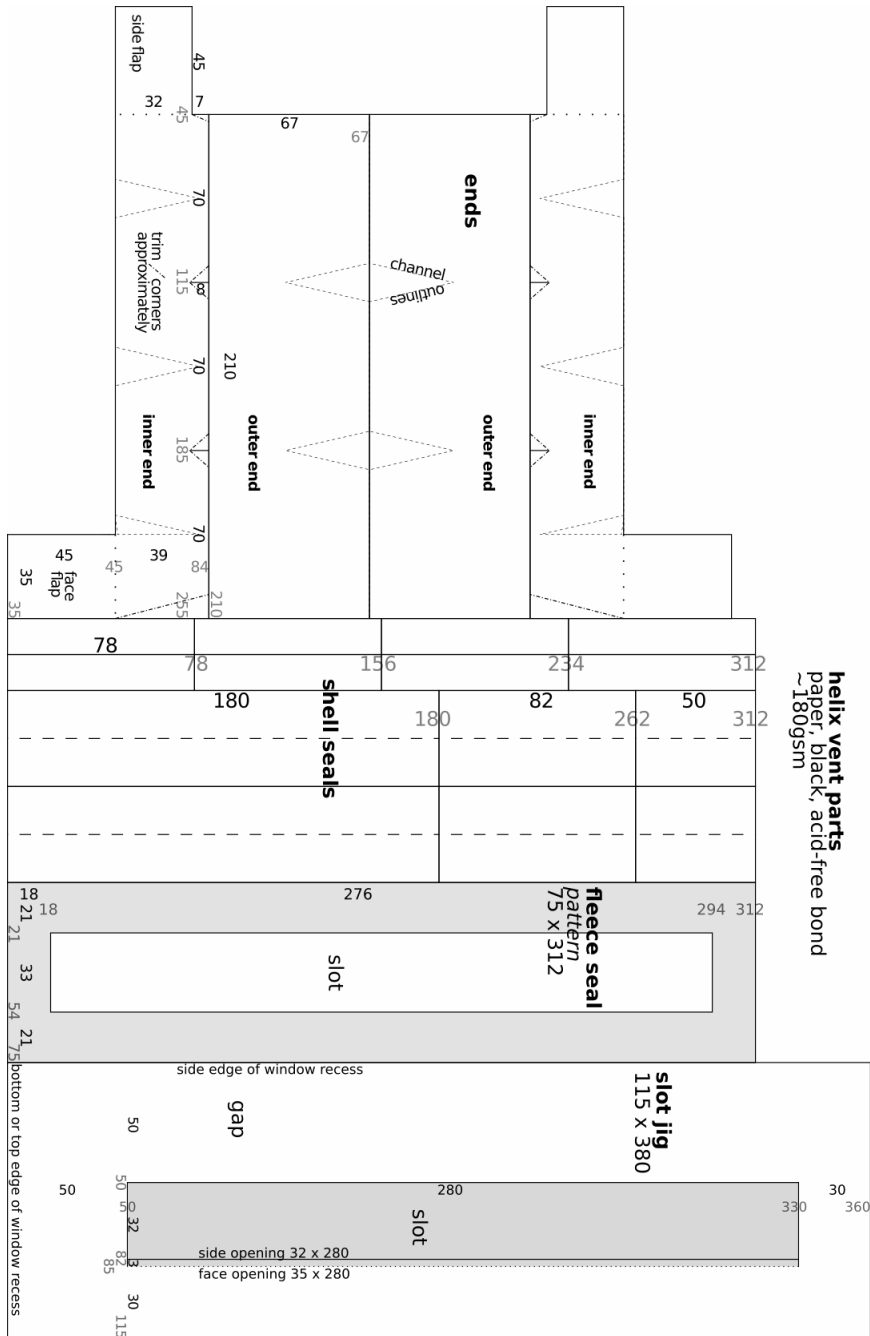**elevation**
275 x 290 (x 117)

plan: helix vent assembly elevation - download

plan: helix vent assembly - [download](#)

plan: helix vent channels - download

plan: helix vent shell - <u>download</u>

side flap

45 7
32

67

67

ends

70

channel
outlines

trim corners
approximately

115

80

70

210

inner end

outer end

185

outer end

inner end

70

45 39
face
flap
35 45 84
35 255 210

78

78 156 234 312

180 **shell seals** 82 50

180 262 312

helix vent parts
paper, black, acid-free bond
~180gsm

18 18 276 **fleece seal** 294 312
21 *pattern*
21 75 x 312
33
54 21
75 bottom or top edge of window recess

slot

side edge of window recess

50

gap

slot jig
115 x 380

50 280 30

50 50 330 360
32
82 **slot**
85
side opening 32 x 280
face opening 35 x 280

30

115

plan: helix vent parts - download

The helix vent can go anywhere: a blind, a door, a wall, etc. Flaps of either opening poke through a slot and get taped or glued down. Mostly it attaches to a blind with the face opening. Put fleece seal on the side opening if attaching it there.

- blind: attach it to a blind and slightly open the window behind it.
- door: cut slot in it and use helix vent instead of a threshold vent.
- existing vent through a wall: in a cardboard box, cut hole the same size as the existing vent. Cut a slot on the opposite side of the box for a helix vent. Attach helix vent to box and box to wall over existing vent. Vent can be either supply or return.
- silencer
    - inside or outside, attached at face or side opening.
    - z version: simpler, more efficient, higher capacity version especially for inside the silencer. Short and straight, it has fewer light-stopping corners and no shell. It is only for installing inside the silencer or other enclosure with two or more corners for light to go around. See drawings in next section.

If your darkroom's ventilation is passive, put vents both low and high in room to enable convection. This works better the greater the inside and outside temperature difference; the greater the vertical distance between vents; and the more vents.

Do you wish to manufacture vents? A set of simple wooden or sheet metal templates and jigs can speed production tremendously while keeping equipment and investment to a minimum. Start in your garage.

Read through instructions once while studying plans.

1. materials (see plans for quantities)
    1. paper (for channels and walls)
        - black, acid-free bond, coverstock
        - available at art supply, stationery, and book shops. In Europe, common posterboard is usually acid-free, Canson Iris, for example.
        - 2 sheets (550 x 700) per vent

- weight: 120–400gsm (200 ideal)
  2. cardboard, 5mm thick for shell (plan must be adjusted for different thickness)
  3. fabric: polar fleece, black, medium weight for seal. (Quality check: 10 layers of it in a stack should measure 30-35mm high)
2. follow instructions in fabricate *8*
3. glue channels to inner and outer shells 1. figure out how parts go together. Note that channel plan is oriented to shell plan, including the direction of folds and lettered joint points and lines 3. mock up assembly by taping parts together till you've got everything right. 4. glue lettered lines first. Use a 2mm bead, ie, as little glue as possible, minimizing warping
4. glue ends to channel tabs
5. assemble
   1. bend shell ends up. Trim them to match outer ends.
   2. position halves for joining
   3. test joints
      - align corners of inner and outer shells
      - match letters
      - inner ends go inside outer ends
      - note how notches of inner ends fit around outer ridges
      - practice using table knife to press ends together when you glue them
   4. glue inner ends to outer ends, using table knives
   5. glue shell seals on shell corners
   6. glue halves together, one end at a time using table knives
   7. glue long shell seals on joints between halves
6. shell
   - glue on fleece seal
   - before installation, tape flaps over openings
7. installation
   1. determine vent location
      - in blind, panel, or silencer
   - whether it will attach at side or face opening

- shell is unnecessary when installed inside silencer or other enclosure
- vent should not touch window handles, locks, or frame

2. mark slot with slot plan
   - the slot plan spaces slot correctly on most blinds and panels
   - face opening, 35 x 281, on blinds, panels, or outside silencer, with shell
   - side opening, 32 x 281, inside silencer or other enclosure, without shell
3. cut out slot
4. position vent over slot and fit vent flaps through it
5. when attaching to soft window covering like fabric, plastic sheeting, or cardboard, pull long flap snug, use back of table knife tip to crease the outside of it right where it passes through slot
6. fold flap at crease and tape it to cover. Tape makes vent removable. Only glue it in place if you are certain of not moving it for years.
7. repeat with other long flap, then with short flaps
8. tape or
9. cover shell with foil and/or white paper to minimize warping by sun

helix-z

This is a shorter version of the helix vent with no shell. It goes inside a silencer or other enclosure. Which gives it protection and two or more corners that light must go around. Follow instructions for helix vent above, adapting as necessary.

Only assembly is shown. Click links to get full size plans of elevation, channel, inner wall, and outer wall. They are also in the zip file.
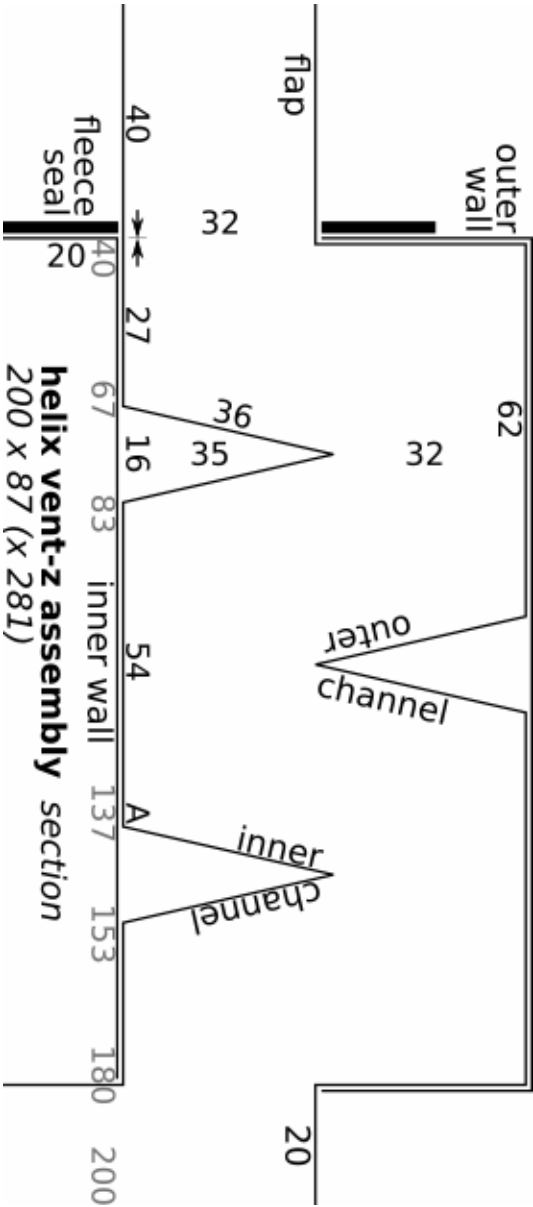
plan: helix vent-z assembly - download
plan: helix vent-z assembly-elevation - download
plan: helix vent-z channels - download
plan: helix vent-z inner wall - download
plan: helix vent-z outer wall - download

threshold

A bedroom door often has a gap at the bottom—the threshold—for ventilation. The threshold vent lets air through there but no light in. Its design adapts to door width, door thickness, and gap under the door between 12-33.
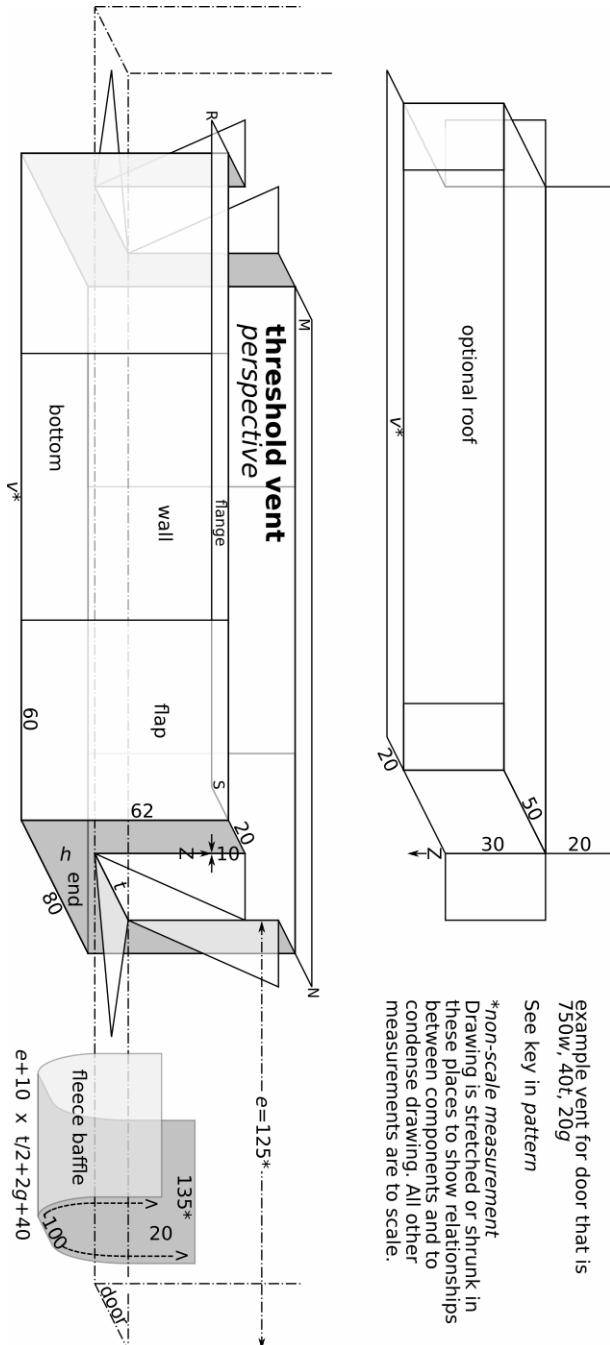
If the gap is greater than 33, add cardboard or wood to bottom of door or build up threshold with boards. Or modify the design. If less than 12, trim bottom of door. Otherwise, or if bottom of door fits into a stepped threshold, vent will not work.

I once adapted the idea by splitting the vent in half so it was on one side of a door. On the other was a 100 wide board on edge across a hallway floor 20 away from bottom of door.
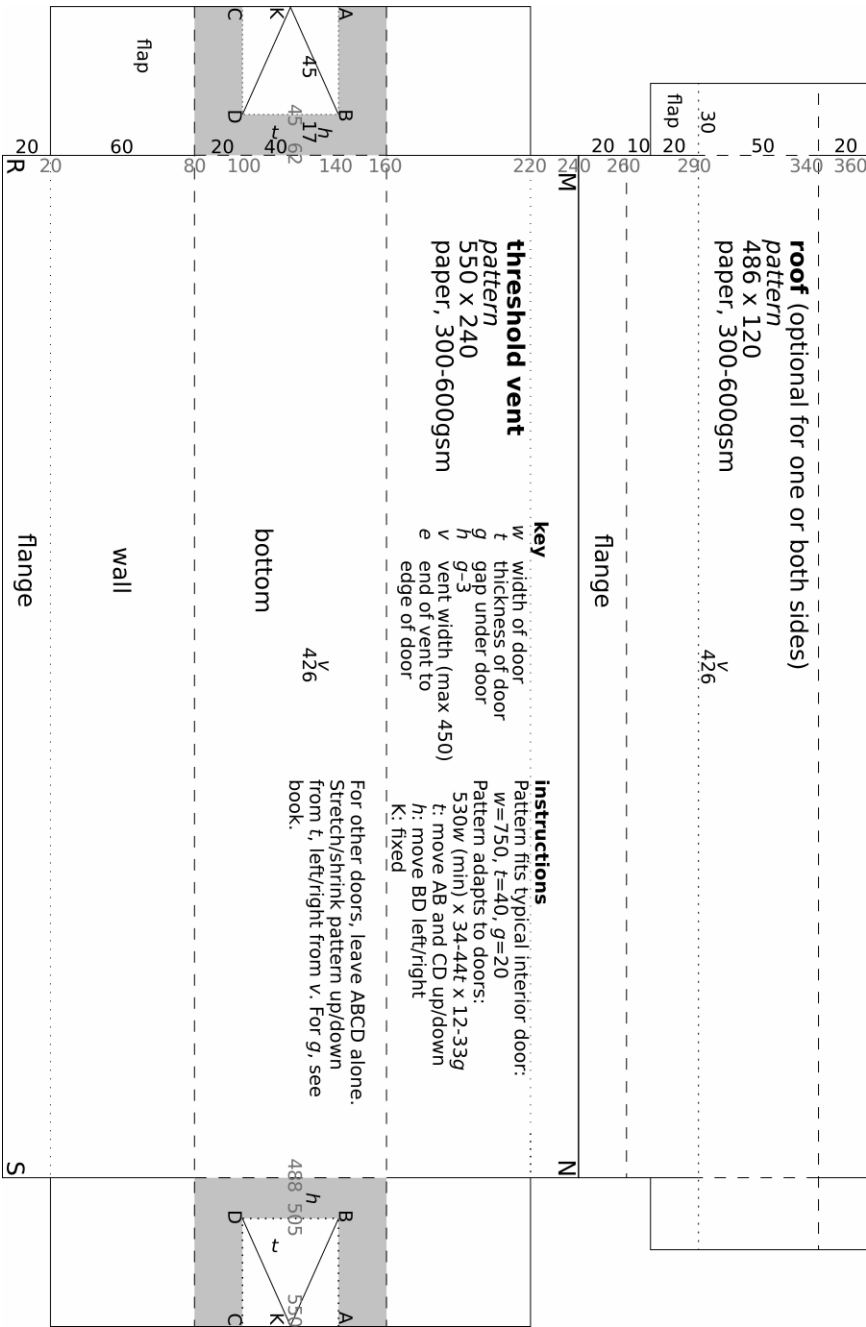
Block light outside the door as much as possible. Maybe you need to darken a path between darkroom and bathroom. Cover windows in the hallway. Make a curtain across it with a dark blanket fixed to the walls and ceiling with tape or tacks.

Or make a removable partition. It's a wooden frame a little wider than the hallway so it wedges in place at an angle. It has a fleece seal around the frame. It is filled with black plastic sheeting. It is penetrated by ducting or helix vents as needed.

The drawings below are of a vent for a typical door, 750 *w*ide x 40 *t*hick, and a *g*ap underneath of 20.

threshold vent
perspective

M

flange

wall

bottom

v*

flap

60

62

S

h

end

80

$v*$

R

N

10

20

t

N

$e=125*$

fleece baffle

$e+10 \times t/2+2g+40$

135*

20

100

door

optional roof

v*

20

30

50

20

N

example vent for door that is
750w, 40t, 20g

See key in *pattern*

non-scale measurement
Drawing is stretched or shrunk in
these places to show relationships
between components and to
condense drawing. All other
measurements are to scale.

plan: threshold vent perspective - <u>download</u>

roof (optional for one or both sides)
pattern
486 x 120
paper, 300-600gsm

threshold vent
pattern
550 x 240
paper, 300-600gsm

key
w	width of door
t	thickness of door
g	gap under door
h	g–3
v	vent width (max 450)
e	end of vent to edge of door

instructions
Pattern fits typical interior door:
w=750, t=40, g=20
Pattern adapts to doors:
530w (min) x 34-44t x 12-33g
t: move AB and CD left/right
h: move BD up/down
K: fixed

For other doors, leave ABCD alone.
Stretch/shrink pattern up/down
from t, left/right from v. For g, see
book.

flap

flap

flange

flange

wall

bottom

426

426

plan: threshold vent pattern - download

1. materials
    - paper, black, acid-free, 400-600gsm
    - dowel or stick, 10 diameter, or popsicle sticks
    - fabric, black: muslin and fleece
2. prepare pattern with instructions in fabricate *8*
3. blacken interior of ends (grey area) with marker
4. key (example measurements in parentheses)
    - *w*: width of door (750)
    - *t*: thickness of door (40)
    - *g*: gap under door (20)
    - *h*: g – 3
    - *v*: vent width (426)
    - *e*: end of vent to edge of door (162)
5. cover threshold with black paper: *w* + 40 x *t* + 70; trim ends (790 x 110)
6. cover part of door inside vent with black muslin: *v* + 20 x *t* + 150 (446 x 190)
7. cover underside of vent with black fleece + 20mm up the walls: *v* + 40 x *t* + 80 (486 x 140). Glue it just to the walls, not the bottom for best seal.
8. attach fabric/paper
    - to door and threshold with tape
    - to vent with glue
9. glue dowel or stick, or popsicle sticks in 2 offset layers, to tops of walls under flanges. Press flat with a board and weights till dry. Fold flanges down over sticks and glue.
10. fold up walls and ends to make a box
11. tape flaps to outside of vent body (undo later to store vent flat)
12. tape vent to door at triangular flaps
13. make fleece baffle: *e* + 10 x *t*/2 + 2*g* + 40 (172 x 100)

    The baffle fills in spaces at ends of vent. Tape top edges of fleece 20mm above bottom of door. Baffle is 5 wider than *e* on each end to seal against vent and door jam. Cut away any fleece that interferes with door seal *10*. If baffle drags out of position, weight it with a strip of cardboard inside: *e* x *t*/3. (162 x 13)
14. if light comes through vent, make a roof for one or both openings. Line with black fabric. Glue stick over flange. Tape to door by the flaps.

soundproofing

principles

Shelter must control exposure *7* to pollution. Noise is a form of pollution. Noise comes from outside from machines, traffic—including boats, trains, and airplanes—construction, music, fireworks, and talking and playing people. It comes from inside from machines—refrigerators, fans, water pipes and pumps), people in adjoining spaces, and their music. At some point, noise defeats a retreat. One must attenuate it somehow, even in remote locations.

The four principles of soundproofing are:

1. mass: heavy materials absorb low-frequency (bass) sounds
2. absorption: fine fibers absorb high frequencies and prevent echoing in air cavities
3. dampening: using rubbery material to dampen vibration in resonant materials like metal, wood, masonry, glass
4. decoupling: disconnect structures and airspaces to prevent transmission of sound vibration from source to receiver

Soundproofing tutorials abound online.

These principles apply to ventilation as well. Dampening and decoupling figure in the fan mount, mass and absorption, in the silencer. The silencer eliminates most noise, including from the fan.

Fans make noise directly and indirectly. Small fans have little hum to start with, but they run at high speed, so they develop harmonics. Bigger fans start with more of a hum but they run more slowly for the same air output, so they develop less noise overall. Use fan mount below to avoid amplifying these vibrations.

Even the quietest fan makes noise because of the friction of air itself against the fan blades, housing, ducting, and vents. Because of air friction, fully silencing a ventilation system requires a silencer of some type at the room-ends of ducts.

silencer

A silencer is an larger duct section lined with insulation. Its greater volume depressurizes the airstream. This transforms low-frequency sound into into high-frequency sound. High-frequencies vibrate the fine fibers lining the silencer, transforming the sound into heat. Genius!

You can make or buy silencers.

- my double-turn box design is below, $2-$10 depending on your material salvaging skills.
- DIY straight tube design
- acoustic ducting, at least 3m with 2-3 bends
- silencer for sound booths. With dark insulation and enough bends, this eliminates the need for a lightproof vent.
- manufactured silencers are made of metal and other super durable materials and cost $100-200.

Thanks to Richard Nöjd of Skattungbyn, Sweden, for pointing out these cool solutions. Silencers and acoustic ducting are standard industrial components, making buildings quiet worldwide.

I built silencers into window recesses on two occasions. They were simpler and more effective than I hoped. They swallowed up sound. The window, open at one end, provided one face of the box. The thick wall provided 4 sides. Boards against the inside of security bars formed the box's outer face, about 20cm from the glass. Shredded fabric insulation lined the box. This technique disables the window as a light source. It is a temporary solution. It works if you have other windows you can uncover during transition days.

The design below is a zig-zag channel through insulation inside a wooden box with a hole at each end. Each hole has 4 possible locations: face, sides, or end. Cut a circle for ducting or fan, a slot for a helix vent. The fan mount adapts to all 4 locations, inside or out.

The box is lined with porous non-toxic insulation. clean wool, shredded fabric, wood fiber could all work. Note, the shredded fabric and wood fiber I've tried had faint smells that I disliked.
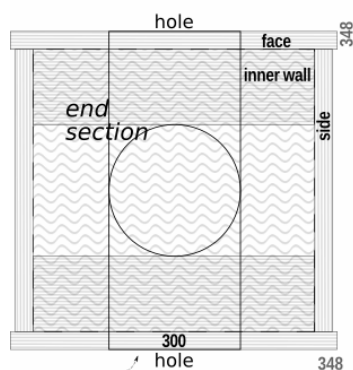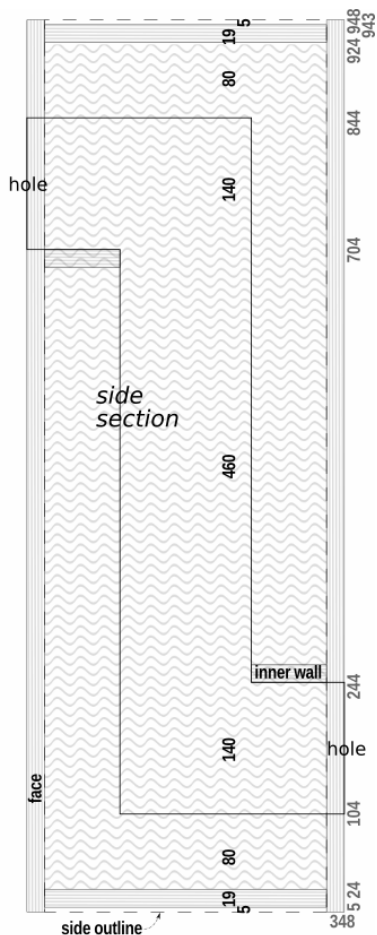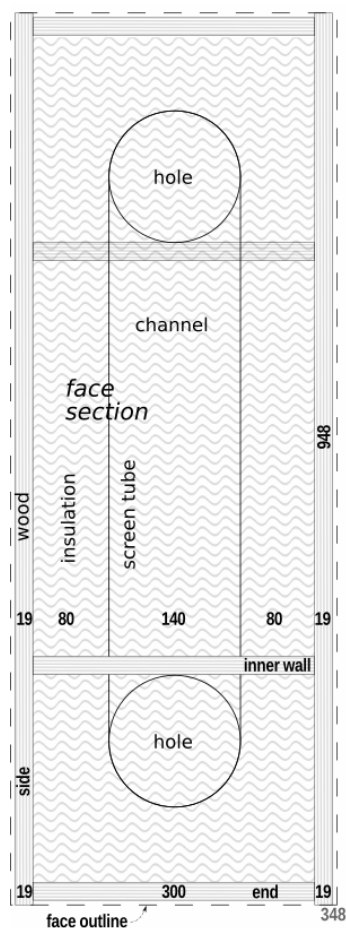
Rockwool works. It is unpleasant to work with, but it is fairly odorless. Polyester pillow filling and quilt batting and acoustic foam work. But I don't like my air going through plastic.

Fiberglass is terrible to work with and often smells of chemicals. Closed cell foam, like styrofoam, polyisocyanurate boards, camping pads, etc, does not work due to non-porosity.

Discarded furniture is made of melamine, an excellent material for silencer boxes. It is particle board with resin veneer, usually 15 or 19mm thick. Marine plywood uses non-toxic glue. Otherwise, avoid plywood or line with foil or mylar.

Use a table saw to cut the 8 pieces so they come out square. Or have a carpenter do it for you, including the holes. Just take the drawing with you, modified for your needs. The carpenter probably has some extra melamine laying around to sell you cheap. To screw pieces together, first drill pilot holes so edges don't break. I always drill pilot holes in wood less than 30mm wide for this reason.

To insulate, make round tubes of plastic screen. Cover with porous fabric if insulation is fine, like cellulose. Stuff insulation around it and close the box. Roughen the plastic surface first with sandpaper so the glue sticks.

face section

- hole
- channel
- face section
- wood
- insulation
- screen tube
- 19 80 140 80 19
- inner wall
- side
- hole
- 19 300 end 19
- 348
- face outline
- 948

side section

- hole
- side section
- inner wall
- face
- hole
- side outline
- 5 19 80 140 244 140 460 80 19 5
- 704 844 924 948 943
- 5 24 104 348

end section

- hole
- face
- inner wall
- end section
- side
- 300
- hole
- 348 348

silencer
348 x 948 x 338
wood, insulation, screen

wood pieces
12-19 thick

2 faces 348 x 948
2 sides 300 x 948
2 ends 300 x 300
2 inner walls 300 x   80

plan: silencer - download

hum

People all over the world have reported hearing a strange hum. Its source is rarely found. In Europe, I heard it in many places.

The hum is a low-frequency sound and vibration that comes through the air and ground. My first explanation was that all the machines we use combined generate this hum. This includes cars, trains, airplanes, factories, ventilation (ironically), underground pumps (whose sound carries far), farm machinery, etc.

Most people can't hear it. I talked to a famous musician in Australia. She knew people worldwide who had heard it. She said it tends to occur in people who feel their internal conflict and disconnection acutely but cannot resolve or repair it yet. They still project responsibility for their suffering on the world at large. It's not all in one's head, but one is too vulnerable due to an error in attitude.

I had started to suspect something like this. She already had it nailed.

In Czech Republic, I visited a large music recording studio in the middle of Brno on a busy street. It was 8m x 14m inside with a 4m ceiling. The engineer let me lie on the floor in the dark for 10 minutes. I don't recall if I was hearing the hum at that time. Their building technique was extremely effective in stopping the deafening noise outside.

They called it "house-in-house". In America, "room within a room". My brother had mentioned building a few music studios like this. The walls and ceilings of each structure don't touch. The inner room's floor "floats" on vibration-dampening springs or rubber blocks.

Then I visited an anechoic chamber at the Petrof Piano Factory in Hradec Kralove. It was extreme soundproofing! It was a 6m concrete cube, resting on leaf springs inside another building, with a 1m gap between the two. One stepped over a gap between the two, as in a subway, through a 1.2m thick door. Cones of foam 1m long protruded from the ceiling, walls, door, and floor. Suspended in the middle was a steel grill platform for a piano and engineer. With no measurable noise or echo inside, they could test a piano's sound with extreme

precision.

You have probably heard of these rooms. People claim to start going crazy. That is hype. The silence was heavenly. I would have happily stayed inside for a week.

The engineer was kind enough to give me 10 minutes. Sigh.

Anyway, the house-in-house technique is practical for silencing bedrooms for darkrooms. The gap between the houses must be at least 50mm all around. The floated floor is 12-19mm plywood on a frame, insulated and sheathed. Walls and ceiling are also insulated frames with drywall on both sides. Dual pane windows, airtight door seals, and silenced ventilation complete the construction.

machines

fan

Use an axial case fan, also known as a squirrel cage fan. Most common in desktop computers. Specifications:

- DC (direct current)
- 12V (volts) but run on as little as 6V, reducing speed, noise, and airflow
- 120–200mm diameter
- 600–1200RPM (revolutions per minute)
- maximum 20dB (decibels)
- 65–200cmh (cubic meters per hour) or 40–120cfm (cubic feet per minute)

I recommend 200mm fans. I redesigned the fan mount for them rather than the 120mm fans I used for years. They move a lot of air and are very quiet. I have Cooler Master brand. Noctua makes the best and quietest fans available, running as low as 7dB.

However, a common 120mm fan is better than nothing. It usually requires a silencer. It is salvageable from a desktop computer power supply, $3 at thrift stores or flea markets, or $5–40 at a computer or electronics store. Avoid AC (alternating current) fans due to their penetrating hum (more on noise below).

Power it from the grid with an AC/DC adapter. 12V case fans run on as little as 6V. A universal adapter with pole switching and variable voltage (3-12V) for speed control is $5-10 at variety stores. Thrift stores have boxes of cheap adapters of fixed voltage if you know what voltage you want.

Off grid, use car or household batteries or a solar power system. To control speed, use a DC/DC car adapter from eBay. If you have no fan movement? Switch the +/– poles on the adapter or switch the positive and negative wires.

Blower fans are interesting. They overcome resistance in ducts and HRVs and move a ton of air. 120mm units on eBay are $10-20. They need silencers and more powerful adapters. Larger slower quieter ones would be better. I built one once. It took a lot of time!
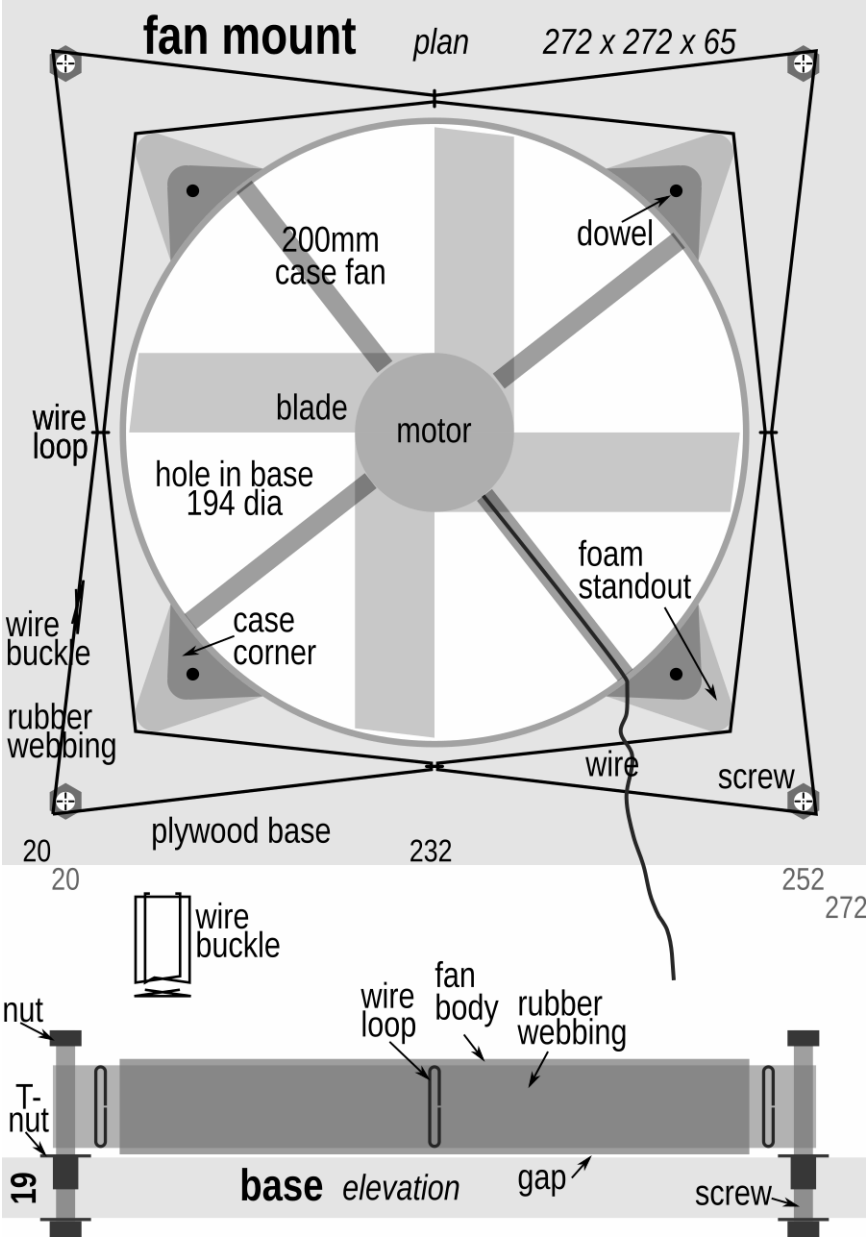
fan mount

The fan mount totally dampens vibration from the fan, already smooth and quiet. The silencer then absorbs airborne noise from the fan. It is inspired by studio microphones and tensegrity structures. It fits the silencer.

The design is fairly self-explanatory:

- description
    - a fan suspended in a web of 2 concentric rings of rubber, stretched between 4 screw posts, anchored in a wooden base
    - modular, fitting silencer in any configuration
- materials
    - base: 272 x 272 x 19 (center hole, 194 diameter). Cut precisely with jig, band, or coping saw; router; or have a carpenter do it for you. Screw hole centers 20 from corners
    - case fan: 200 (computer fan)
    - screws: 4@5 x 60 machine + 4 nuts + 4 T-nuts, 4 fender washers
    - rubber: 1-2 thick, 28 wide, 1700 long. Use inner tube of car, motorcycle, or bicycle wheel. It is tricky to work out distances between loops so that rubber has enough tension to suspend fan without too much movement. Loops and buckle make it all adjustable.

- **–** loop: wire, 1mm, bent to fit tight
- **–** gap: 0.5–1 between base and fan
- assembly
  - **–** lay out rubber strip.
  - **–** figure out order to slide loops on. Do so.
  - **–** add buckle
  - **–** tighten and adjust rubber
  - **–** fit fan with foam standouts into rubber
  - **–** align fan directly over the hole in base. Gravity may pull it to one side or another. Tug on fan or webbing to reposition fan.
  - **–** slide webbing up or down screws to adjust base-fan gap
  - **–** screw base onto silencer over a hole in any position

fan mount *plan* *272 x 272 x 65*

200mm
case fan

dowel

blade

motor

wire
loop

hole in base
194 dia

foam
standout

wire
buckle

case
corner

rubber
webbing

wire

screw

plywood base

20

20

232

252

272

wire
buckle

nut

wire
loop

fan
body

rubber
webbing

T-
nut

19

base *elevation*

gap

screw

plan: fan mount - <u>download</u>

power

In my first major darkroom in Guatemala, I had no electricity.

At first, to create a draft, I made lamps that burned cooking oil inside a lightproof chimney. It was a messy, unreliable, and labor-intensive process. No one should ever repeat it. But it worked long enough for my brain to make the leap to the 20th century and remember the existence of batteries.

AA batteries made a quick and dirty solution. One night requires 4-8 batteries, alkaline or rechargeable. Connect them in series: positive end of one to negative end of the next.

Voltage adds up like this. Each battery is 1.5V, so 4 batteries=6V. Some fans need 7V or 9V to start, thus 5 or 6 batteries. Increase fan speed by adding batteries to the pack, up to 8. Increase pack life by using bigger batteries or another series in parallel (fan wires contacting ends of both series).

I was isolated and just learning. This simple discovery encouraged me after weeks of the fascinating absurdity of oil lamp-driven convective ventilation. However, changing batteries every day also quickly got to be a pain. So I bit the bullet and got a proper solar power system for less than $100:

- solar panel: 12V. Size depends on location: 10W in Guatemala, 40W in rainy Oregon winter. ($10–$100 on eBay)
- charge controller: 12V, 4 or 6-pole ($35 on eBay)
- battery: 12V 7A, lead acid ($30 at a motorcycle shop)
- wire, 20 AWG, enough to connect everything ($0–10 from your shed, a dumpster, yard sale, or hardware store).

Once built, maintain by wiping dust off panel once a week. What a luxury! Of course, if you have reliable wind or hydro power, that's great, too.

heat

For heat, I often use a portable oil-filled electric heater. It is silent and can be positioned by a window or vent to warm incoming cold fresh air. Before buying, check that its indicator lights are easy to cover (not glowing from the interior through multiple cracks) and that it doesn't rattle or hum. Old or cheap ones often make noise. Buy it new.

If you live in a cold place, I highly recommend buying and installing a Heat Recovery Ventilator (HRV) for both health and economy. It conducts heat from return air to supply air while keeping airstreams separate using an exchanging core and fans.

Fine wire heat exchange (fiwihex) technology is my favorite. It is 15x more efficient than plate exchangers. It is compact. A low power fan will supply air to one person. So it can be installed at point of use with little to no ducting. Fiwihex cores have been available for $150 from Viking House and possibly Fresh-R. These companies' *Breathing Windows* embody an intriguing design for a complete ventilation system.

However, I lived with one for six months and found it too loud due to its small, high-RPM fans with no silencing. If fans were separated and silenced, fiwihex would be great. A 200mm axial case fan works (I tried it). DC blower fans could work with silencing. Building your own HRV is doable.

It also needs a filter despite the manufacturers' strange denials. Just a leg of a stocking inside a tube for each intake is enough. It's much easier to remove, clean, and replace than using the core itself as a filter (the manufacturer's strange instruction).

The most interesting plate exchangers use the Mitsubishi *Lossnay* core, found in ERVs (Energy Recovery Ventilators) such as Renewaire's. Made of high-tech paper, the Lossnay recovers heat-trapping water vapor as well as heat from air.

Lossnay's principle has DIY-potential, using non-siliconized parchment paper ("sandwich paper" in supermarkets). After years of contemplation, I have conceived a design for a convection-powered fiwihex ERV. It would take a small factory to produce. Maybe someday I will.

purity

In some cases, an air purifier becomes necessary. If your house is near a factory, busy roads, in a smoggy city, or near a smelly restaurant or neighbor, get one. Purification methods include:

- activated carbon
- HEPA
- Photo Catalytic Oxydation (PCO) is a new, interesting technology that destroys pollutants at the molecular level. Several companies make filters with it. Prices vary widely.
- UV-C light bulbs with 253.7nm wavelength destroys VOCS and germs and cost less than $10. These would use the regular case fan and just need a helix vent to stop light.

Do not use an ionizer. It produces toxic levels of ozone.

Recently, I upgraded the ventilation system of a darkroom in Czech Republic where people burn coal for heat. Coal smoke smells terrible. I installed an activated carbon filter into the silencer. The $50, 18 x 18 cm filter eliminated the smell. Catching the particles would require HEPA filtration, but it was less important at the time.

The filter also stops all light and some sound. It requires a fan more powerful than a case fan to overcome the resistance it presents. A blower fan does this. I have yet to test one with a silencer. If that works, I'll adapt the fan mount for one.

If air quality at your home is bad enough, consider moving. Lots of places in small towns and the countryside have clean air and are less polluted in general. It is a cheap and simple solution to multiple problems, some of which you may not know you have yet.

∼/∼

That's it for lightproof ventilation, silence, power, heating, and purification. On to darkening doors and windows.

darkness   *10*

There is darkness, and then there is *darkness*. We're going for the second kind: perfect and absolute. There is a 1,000,000% difference between 99% and 100% dark. In 100% darkness, the mind has nothing left to hold onto, no reason to resist. Finally it can let go, fall into the well of itself, and be renewed.

Light is easier to deal with than ventilation. There are fewer factors involved, and they are visible.

But light is relentless. It sneaks sideways through a single layer of clear plastic tape; through the fibers and weave of heavy fabric; around multiple, darkened corners; and at joints and edges of everything.

I have suffered many defeats at its hands. Eliminating it demanded equally formidable techniques. Now I bestow them upon you, oh, future Conan the Barbarian of lightproofing.

Generally, to darken a space,

1. use dense, inherently lightproof sheet material in 1-2 layers to cover area. Using few layers means:
   - simpler construction
   - better function
   - easier operation
   - neater appearance
   - greater need for precision
2. seal out light at edges with black polar fleece. Attach it to 2 sides, over an edge, forcing light around 1-2 corners.
3. make outer surfaces exposed to sun reflective: white or silver
4. in vents, channel light around 6 black-surfaced corners

If improvising for tonight *4*: use as many layers as necessary. If it is already night, turn on all your lights and check your work from outside. With each layer, block as much light as close to the source as possible. First, block 99% the light. Then 99% of what's left. The last 0.01% is easier to address or ignore. Close curtains over windows outside a darkroom's door.

Where possible, shade darkening measures made of paper from direct sunlight.

Edges were tricky till I tried black polar fleece. It's like a sponge for light. It is widely available, cheap, and forgiving. A knit fabric, its edges require no hem. Just cut and attach with school glue or masking tape.

We will start with the most portable and perhaps simplest design. It darkens the small space around the eyes: the mask.

mask

A good blindfold or sleeping mask is the quickest way to obtain a large measure of darkness wherever you are. It's like draping a dark shirt over the eyes, but it stays on all night.

Know that no mask is comfortable for long periods. None stays in place during all movement. And our skin has enough light-receptors for it to wake us up. A mask cannot replace a darkroom. And the double blind below may be just as easy to make.

A mask is cheap, accessible, discreet, and very effective for immediately improving sleep. It is a good first step toward the profound rest darkness makes possible.

No mask I've tried or seen satisfied my requirements. So I designed one. The strap design is very effective. It would improve most existing masks. Instant and standard versions are described.

constraints

- blocks all light
    - through the mask
    - at its edges
- comfortable for many hours
- stays in place during sleep and gentle activity
- cheap and simple to make
- easily replaced elastic (skin and hair oils seem to degrade it quickly)

Adjust the measurements as needed. The mask can cover your forehead, but not your ears, nor go below your nose. Adapt it according to its comfortability and light-blocking ability on your face. The drawing is of the mask that fits me.

instant

photo: sleeping mask, instant

I put this one together in a few minutes. It's like the standard mask below but without seals. Combined with a mostly darkened room, it blocks 95% of light and lets me sleep in and nap. (Later, I succeeded in stapling seals to it.)

- cut a piece from a black 100% cotton
    - T-shirt, 250mm x 440, folded the short way in 4 layers
    - or sweatshirt, 250mm x 330, folded in 3
- staple along its long edges
- 4 strap anchors - 3mm holes poked through with a ball-point pen tip, elastic going through them then knotted - or 2 staples each - knot where comfortable, endknots (overhand or figure-8) on one end, two half-hitches or slip knots on the other.

- vertical strap: make a slipknot in each end of the vertical elastic piece that tightens around the horizontal straps.

standard
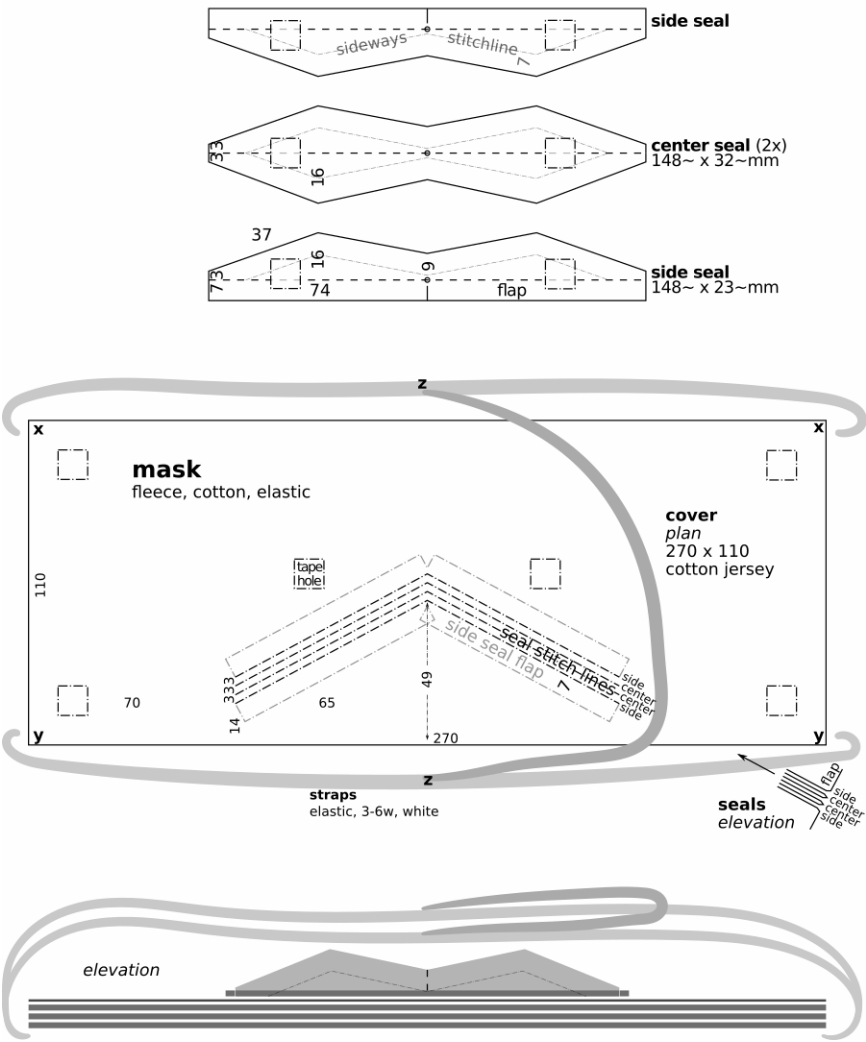
plan: sleeping mask - download

1. materials
   - soft black knit fabric:
     - 100% cotton sweatshirt fabric (French Terry cloth or loopback cotton)
     - 100% T-shirt fabric (cotton jersey)
     - polar fleece for the cold
     - cotton is cooler than fleece, which can feel scratchy, too. Avoid woven fabric. It frays and doesn't flex. A bright colored piece of cloth on the outside makes finding the mask in the light and in bags a lot easier.
   - elastic, 3-5mm, white, helps to find the mask and is much more common in stores
   - cord, 3mm polyester or nylon, white
   - thread
2. follow instructions in [fabricate](#) *9*
3. attach side seals to cover
   1. put cotton cover with plan still attached on 2-3 layers of cardboard
   2. each side seal has a 7mm wide flap divided by 5mm cut in middle and a small circle on dashed stitch line. Two side seals=4 divisions.
      1. align one division at a time to grey marks on cover
      2. tape in place
      3. sew on stitch line of plan to or from small circle
      4. tear plan in middle to bend seal
      5. repeat for other three divisions
      6. remove all paper from fabric
4. attach center seals
   1. fold center seals in half the long way and fit them between side seals, making everything symmetrical and even
   2. pin center seals to cover through their folds
   3. sew (maybe hand sew) center seals to cover
5. bind seals
   1. hand-sew seals together through sideways stitchline
   2. pull thread with minimal force, leaving seam neither loose nor tight.

   3. the stitchline is a little distant—7mm—from the zigzagging edges of the seals. This allows the seals to hold each other up to fill in the gaps on each side of the nose. Yet the unbound edges of the seals can fan out to more gently make contact with the face.

6. sew cover
   1. stack all cover pieces, matching up edges evenly
   2. fold seam allowance of cotton cover under and pin in place to other cover pieces
   3. sew around edge of cover to join all pieces

7. prepare straps
   1. cut elastic
      - 2 pieces 500mm long
      - 1 piece 250mm long
   2. cut cord, 4 pieces 30mm long
   3. melt all ends with flame to prevent fraying
   4. tie figure-8 knots in ends of elastic

8. attach straps
   1. fold cord in half, making a loop. Sew loop to front of mask at points **x** and **z** so loops stick out over corners from cover 1mm and cord ends are pointed toward center of cover
   2. tie one end of a 500mm piece to a loop at point **x** with a slip knot
   3. tie other end at other point **x** with taut line hitch
   4. repeat steps 2 & 3 with other 500mm piece at points **y**
   5. tie 250mm piece to 500mm pieces at points **z** with slip knots
   6. the taut line hitch, when tight, slides on the part of the strap it is tied to, then locks in place, creating a strap of adjustable length. Adjust straps for comfort. Bottom strap should go around neck, top strap should go high around back of head.

door seal

Black polar fleece makes darkening a door easy and quick. Use masking tape at first. Tack edge of fleece in position with 10mm pieces of masking tape every 400mm. Then put a continuous strip of tape over the edge. Once you get the hang of it and know where you want the fleece to stay, use glue where possible (glue removal described below).

1. sides and top: affix 50-70mm wide strips of black fabric to door jam with masking tape or white school glue. When closing, door should catch middle of fabric, pulling and bending it around one edge of the door and fill the gap between the door and jam.
2. hinges: make perpendicular cuts in edges of fleece to accommodate these
3. latch: make a parallel cut over the strike plate to accommodate the bolts
4. bottom: where no threshold vent is necessary, make a fleece baffle the width of the door. See threshold vent perspective drawing for baffle design. It is a half-tube of black fleece fabric that hangs from the bottom of the door on each side and touches the threshold or floor underneath. Tape a 100mm wide strip of black fabric to the threshold or floor under the closed door. Black fabric against black fabric makes a good light seal. Partially darken space beyond door with curtains or partitions to ensure darkness in the darkroom.
5. if light still leaks in the sides or top, affix a second strip to door, as in drawing
6. to remove glued-on fabric, wet it. This will dissolve the glue and the strips will peel off easily after a few minutes. As this happens, use a wet rag to wipe off glue residue before it dries again.

If door has a window, cover it with plastic or a panel, described below.

plan: door seal - [download](#)
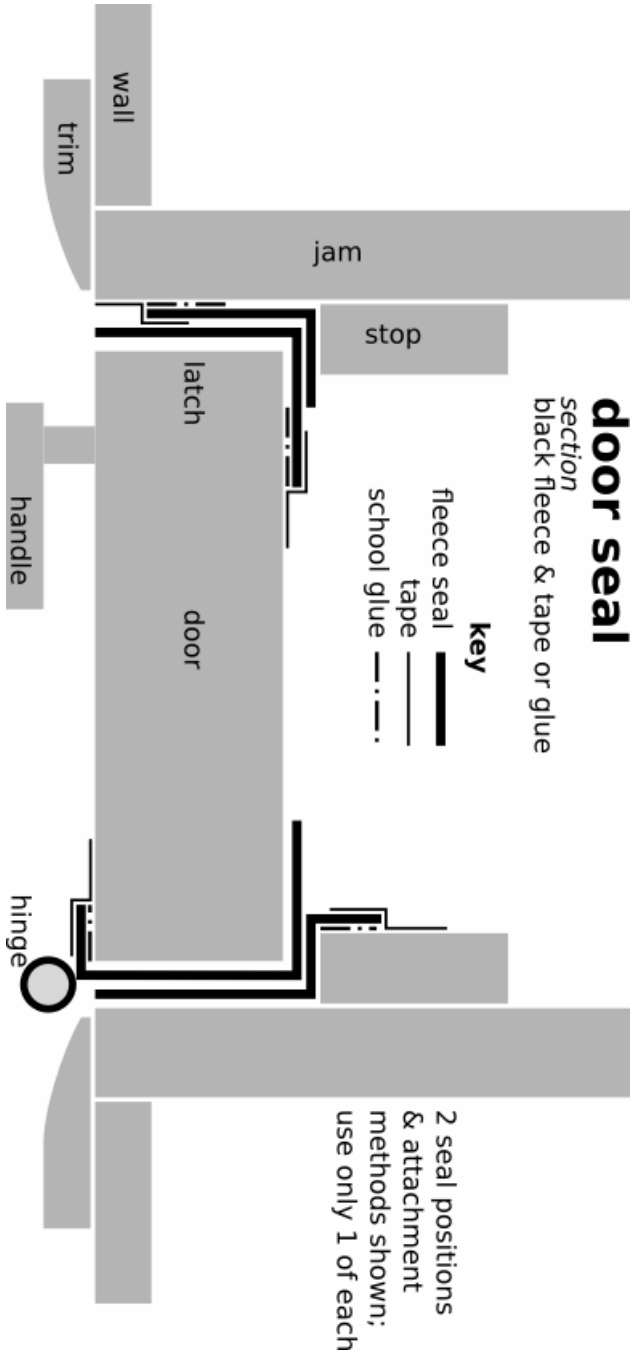
window cover

constraints

- perfectly darkening
- quickly and easily operated so it actually gets used
- good-looking
- discreet: looks like a blind or curtain from the outside
- accommodates lightproof vent
- window or trickle vent can be open behind it
- holds its shape over time in different temperatures and humidities
- durable
- of common, cheap materials
- easy to make
- easily uninstalled
- leaves few marks or holes

intro

I tried several methods of darkening windows in ~100 spaces. Two work well: double blind and panel. Plans and instructions follow.

Notes on others I tried—foil, velcro, roller blind—are below. Their descriptions, instructions, and drawings are archived in the zip file.

If your room's air supply comes through your window, attach a helix vent to the back of the blind. If the recess doesn't allow this, attach the vent to the front. Test position of vent before cutting a slot for it to make sure it clears the window frame and handles. The slot jig usually works. See helix vent parts *9*.

If both your supply and return air pass through your window, use two lightproof vents, one at the top, one at the bottom of a blind. Use fan mounts and silencers if necessary. Test without them at first. Some buildings have mysteriously good ventilation. Convection works in winter, when temperatures inside and out are different enough.

Some windows leave no space for a blind or vent because they are flush with the wall. In this case, either:

1. remove the window temporarily. Replace it with a panel with a vent
2. use a panel or traditional shutters outside, operable from the inside
3. or build a deep-set frame around window for a double blind or panel

A handful of companies make blinds for traveling (especially with children). They attach with suction cups. They are convenient and helpful. Some sell the fabric they use by the meter. I got several samples from one company. Mind you, none of it was perfectly lightproof in one layer.

lesson

Now for a quick lesson on window types and anatomy.

- types:
    - fixed
    - opening
        * sliding
            · double-hung (vertical)
            · horizontal
        * casement (hinged)
- anatomy, from center of window to wall:
    1. pane: the glass itself
    2. frame: holds pane, moving with it in opening windows
    3. sash: attached to wall, surrounds frame. In opening windows, the frame closes against the sash. With non-opening windows, sash is often the same as the frame.
    4. sill: holds sash; it's the surface where you put plants, candles, etc, and corresponding sides and top. Defines the recess.
    5. recess: entire opening in wall where window is installed. It is defined by the sill.
    6. trim: wooden border around window. Attaches to wall and edge of sill, covering the crack between them. Not always present. 40-100 wide, 10-20 deep.
    7. wall

double blind

This is my favorite method. One layer goes inside the window recess and one goes over. It is

- cheap, easy, fast to find materials for and do
- extremely effective and simplest overall
- durable, adaptable, and cleanable for reuse and travel.

It requires ordinary precision, much less than single-layer. Light can't leak past all its corners and narrow gaps. It blocks 99% of light even without taping the outer layer. This is much better than a mask for use at home.

It is usually of flexible plastic. Plastic is lightweight, holds its shape, making taping easy. The inner layer can be lightweight board: cardboard, foam board, or corrugated plastic sign board. It is usually for temporary use.

Fabric or paper could work. They are heavier. Fabric drapes. Paper warps.

I use masking tape. It sticks to it really well and causes the least damage everywhere. Magnets, tacks, nails, staples, poster tack, etc could work.

I'll talk about plastic. The technique is mostly the same for fabric and paper.

North Americans: 1 mil = 0.025mm = 25μ(microns).

Minimum total thickness of layers must be 0.25mm.

materials

- black
  - most common
  - construction sheeting, black polyethylene, 0.15 thick. Widely available in rolls or by the meter at building supply, variety, and department stores.
  - garbage bags. Package usually shows thickness in microns. Make two stacks, 0.125 each. Join with staples, tape, melting, or sewing
- white **important**
  - with black plastic, attach white material to outside layer. Use any thickness of plastic, fabric, paper. Leave 30-50mm of black edges exposed.

- windows build up fierce heat when sealed with black plastic. It destroys the vacuum seal of dual or triple-pane windows. It even causes them to explode! The heat also damages paint and wood.
- black plastic looks spooky from the outside, attracting negative attention. White looks normal.

- black-white
  - easiest, coolest
  - laminated agricultural plastic. Called "light deprivation" tarp, used in greenhouses and for "pit tarps". I once got some for free from an agricultural plastic supply house. It was the end of a 1-ton roll of 0.125mm plastic. It was still a huge amount.

Amazing stuff. White looks nice. Use one layer for traveling. Use two (white sides visible) for perfect darkness. - lumber unit covers, discarded daily at lumber yards. They are big black/white-laminated woven plastic tarps for shipping. Graphics are printed on them. Rinse or wipe clean if necessary. Find punctures and patch them. Make white sides visible.

assembly

1. measure, cut, and tape first layer inside the recess against the sash or frame. Second, outer layer extends 100-200mm past recess and any trim. This catches light leaks between sill and wall.
2. When using 2 layers of black-white plastic, fold back edge of outside layer 20-50mm. This exposes black side for sealing against frame or wall.
3. first layer can also be cardboard or black foam board.
   - join multiple boards with 50mm wide strips of the same material.
   - fit a window perfectly with no measuring: enlarge the thick board with 50-200 wide strips of black poster-board glued to edge, extending to the sash or sill.
4. temperature control: protect your windows from heat damage!

- reflect heat with white paper, posterboard or fabric on outside, except 30-50 from edges to absorb light at the contact surface
- if window receives direct sun and gets especially hot, tape or glue aluminum foil to one side of it. Leave 10mm spaces between the strips of foil. Glue white fabric loosely over the foil at these strips. Set the cardboard in recess, white fabric and foil facing outward.
- if it is a cold room, face the foil inwardly to reflect heat back in
- in extremely hot areas, install an awning, exterior blind or shutters

5. For a handle, screw a small block of wood on the front from the back. Use a fender washer or stiff piece of plastic, like a bottle cap. Use as insulating insert described in #4 below.
6. For daily use till you make a panel
    - use tape just at top corners. Tape and untape blind layers in place
    - put a patch of tape on wall to tape to for longevity of adhesive
    - tape plastic to long board. Rest board on nails or screws beyond top corners of window

tape

1. use masking tape, 25mm wide. I like 3M construction grade, from a builder's supply. It is heavy and sticky. Masking tape is effective, cheap, sticks and conforms well to irregular wall surfaces, yet comes off easily without residue (unless you leave it up too long: months, maybe weeks).
2. black masking tape is interesting and fun. It is useful in some applications, but not essential. Brands and models are Intertape PF3 or PB1 and Shurtape T106. Local art and professional lighting supply stores carry it. For difficult surfaces, photographic masking tape or black kraft paper tape are stickier, thicker (more lightproof), stronger, and more expensive. Look for ProGaff (formerly Permacel) 743, Shurtape 724 or 743, and 3M 235.

3. avoid electrical tape and most duct and gaffer's tape. They are made of soft vinyl and obnoxious adhesives. They are toxic in their manufacture, handling, use, and disposal. One exception I know is Shurtape PC 657, a polyethylene coated gaffer's tape. Do research; the devil is in the details.
4. pro-tips
   - let tape relax between unrolling it and pressing it in place. Stretched tape peels off by itself!
   - for temporary seal, press in place with pad of finger.
   - for strong, more permanent seal, press in place with finger nail. You can see and feel the difference immediately
   - use sticky side to grab edge of applied tape to remove it
   - use small pieces to tack material in place, then long pieces to cover the whole edge
   - except for tacking and overlapped ends, use one layer of tape. Then it flexes with material as it expands and contracts with heat and moisture. Multiple layers rigidify tape and cause it to peel.

single

Single-layer: extra-thick (0.25mm) black polyethylene construction sheeting, available at concrete supply houses, or EPDM rubber, used for pond lining and roofs.

This is tricky. A single layer requires the most precision. You will need lightproof tape or especially careful taping. Maybe extend plastic far beyond trim (150-200mm) or fold edge under to create springy seal. Use fleece seals for rough surfaces. Avoid nicks and punctures. Repair with black tape or patch it.

panel

A panel is for permanent use. It has several benefits. It seals snugly inside a recess or outside as a shutter.

A panel is of exterior plywood inside or out, or melamine inside. These engineered woods are dimensionally stable.

A panel:

- is best for long-term use
- is lightproof in one layer
- seals well with fleece, which attaches well to the edges with various glues
- retains its shape and size
- easily takes cutting for a hole or slot to attach a duct or vent (unlike glass).
- adds soundproofing and thermal insulation
- looks good
- is easy to get free material for from discarded furniture
- removes with no trace, usually held in place by pressure.
- installable with hinges
- usable just for retreats or permanently
- adds security if installed outside and latches from the inside through the window

photo: panel, exterior

Seal exposed edges of melamine with varnish, glue, or tape. The smell from exterior plywood dissipates after three months. Meanwhile, mitigate it with foil or mylar over interior face of plywood.

Avoid interior plywood. Its glue is less stable and outgasses more and longer than that of exterior plywood.

I made my first panels with cardboard. But it warps and shrinks. Water damages it. It hasn't enough mass to stop noise.

Panels work for opening or fixed windows. Fill big openings with multiple panels. Add a flange of wood to the edge of one panel and fleece to the edge of the next one.

Remove an opening window at or from its hinges. Carefully trace its outline onto the board you will use. Or trace onto paper or cardboard if handles or hinges make tracing awkward or to test-fit the pattern. Tracing is better than measuring. It accommodates non-square corners that windows tend to acquire over time.

Cut 2-3mm inside the line to allow for fleece seal. Make sure it fits in the frame with 2-3mm around it. Fold fleece the long way so it attaches to the panel's edge and face. Use glue. Then it will make contact with window frame on two sides all the way around, sealing out light.

Determine where a vent or silencer will go so it clears the frame, the screen, and the window recess. Measure and mark a hole in the panel for the vent or silencer.

Cut out hole with a jig or coping saw. Or drill holes in the corners with a 4mm bit. For each hole, drill two more 8mm away. Then drill between them along the line at various angles until you cut a slot big enough for a keyhole or hack saw.

Attach a handle to the panel so you can lift it in and out. A 30 x 30 x 30 block of wood glued and screwed to the board is enough.

Fleece at edges usually holds the board snugly in place. If not, find attachment points on either side of the frame (or make them with screws). Stretch a wire or rope over the panel between them. Wedge a block of wood between wire and panel to keep panel pressed in place.

If panel warps, reinforce it with dimensional lumber to keep it flat. Add hinges, inside or out, to easily darken and silence a room.

The oldest solution proves the most elegant: exterior shutters, operable from the inside. Traditional architecture worldwide uses them. They are common in Europe. Rollerblinds like this are standard on the Mediterranean. They operate with interior straps. It's so nice! The French still like shutters hinged, as do Latinos.

Alas, most Americans, Canadians, and Australians miss them without knowing it. People of Protestant countries are less

aware of their bodies. And we cling to big windows as symbols of space and freedom we are fast losing. Ironically, the first step to regaining these is to cover up the windows.

zip

Here are notes on techniques I don't use anymore. But I've kept their, photos, plans and instructions in the zip file

foil

If all you have is foil and electrical tape, this technique will do. The trick is to remove the roll from the box and unroll it directly onto the glass. This prevents bending, cracking and resulting light leaks. Tape it up with black electrical tape. One-time use. Doesn't work with vent. It is wasteful and toxic but better than psychosis.

velcro

Blackout fabric + adhesive velcro = 1-hour blind. This technique isn't bad. It is promising. Maybe it's for you. Good fabric must be found. The adhesive was not secure. It can delaminate the fabric's lightproof coating. It mucks up sewing needles. Non-adhesive, sewn-on velcro might be better than adhesive velcro. Commercial versions of this blind exist.

roller blind

Custom blackout roller blinds with lightproof rails are cool, especially with automating motors. Watch them on YouTube.

They are pricey! I wanted to see how cheaply I could do it. I reduced the cost of materials 90%. But labor was too much. The result was not as durable, effortless, or sleek as a high-quality manufactured blind. Compatibility with motors is uncertain.

If you want a rollerblind, buy one custom made from an established local blind shop. Let a technician come and measure your windows. Buy only top-quality national or international brands. These cause the least complaints.

Get a guarantee of absolute lightproofness of the entire installation. Tell them you will be testing it with advanced sensors: eyes adjusted to darkness for days.

Foamed acrylic coating is the industry standard. Look for it. Avoid fabric with PVC (polyvinyl chloride) coatings. It is toxic. Get full disclosure of material content.

water   *11*

If you already have a bathroom and kitchen you can darken easily or mostly, and you can get to it, at least with a blindfold, great. If not, make the quick, cheap, portable fixtures below. If basic versions are too punk rock for you, try the upgrades. You can incrementally improve them as you find out for yourself the value of retreating.

sink

basic

- bucket with lid, 10-25L
- 1-2L soda bottle with cap, filled with water
- loosen cap slightly
- squeeze bottle over bucket, with or without lid. Use one hand or put it between your knees for hands-free use
- wash hands or food
- slide lid off bucket to drain water into bucket
- putting food waste in the bucket helps keep the smell down

upgrade

- table
- rectangular plastic basin, like a restaurant bus tub
- short stand, 30h x 30 x 40cm, behind basin
- 10 or 20L bottle with valve-cap on stand
- drinking water (if separate from wash water): in 20L bottle with valve-cap
- waste (water and food): two, 20L buckets with lids

deluxe

- salvaged sink set in a counter-height table
- drains directly into waste bucket
- upgrade again by adding a drain tube to outside.

toilet

basic

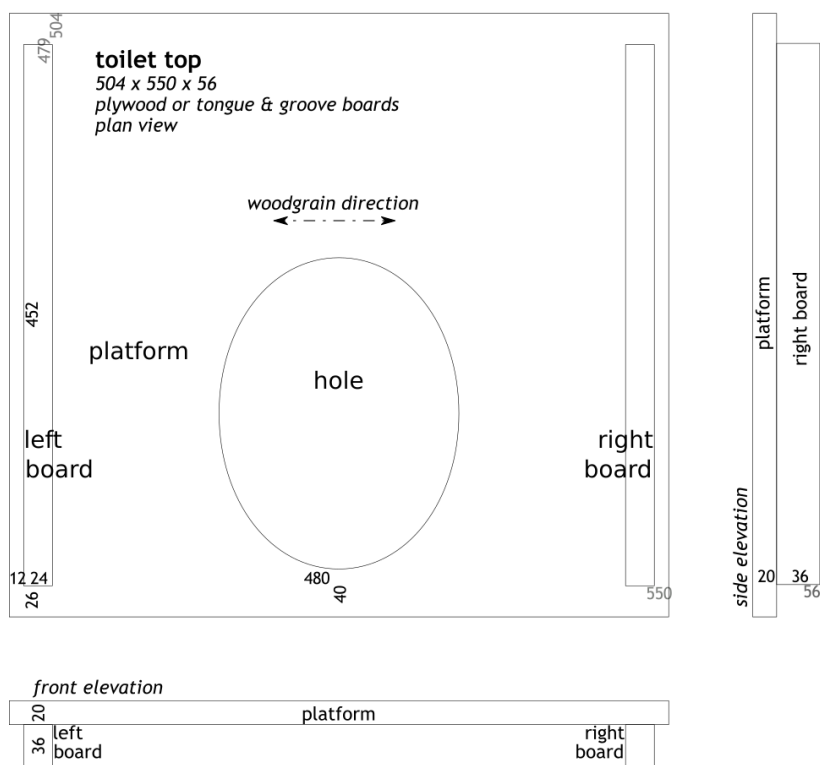It's a 20L bucket with a toilet seat on top. No kidding.

- put 2 liters of sawdust in the bottom
- put 15 liters more sawdust in another bucket by the toilet
- with a scoop, put a 0.5L of sawdust in toilet after each use
- place toilet away from bed and close to return vent
- dispose of in a covered compost pile:
    - include food scraps
    - alternate with layers of carbonaceous material like leaves, straw, sawdust
    - let it sit for a year before use
    - cover with dirt and plenty of carbonaceous material
- replace toilet paper with water to ensure cleanliness and prevent abrasion and infection
    - fill a 0.5–1.5L soda bottle with water
    - loosen the lid slightly
    - hold upside down, with lid against lower back
    - squeeze to get a small stream of water that runs straight down crack over anus
    - wet fingers of free hand and wash anus
    - wonder how you ever accomplished this task any other way

upgrade

Here are two similar toilet designs. The first is non-separating for sitting and squatting. The second is separating and just for squatting. Features could be combined. Many instructions for first apply to second. More for second are in drawing.

The first is a wooden box with a hole in the top and maybe a toilet seat attached over the hole. A 20L bucket sits inside to poop and pee into. The room's ventilation return duct attaches to a hole in the side of the box. So all air exits the room through the toilet, removing all odor. Empty it every 3-5 days.

A vented urinal works for men and adventurous women. A toilet that separates liquid from solids is ideal. The styrofoam "Separet" seat is common in Swedish outhouses. I saw a porcelain separating composting toilet there, too. It was simple. It cost about the same as a flushing system. It was 1000x cheaper and less trouble than a septic system (one of industrial design's biggest failures).

toilet top
504 x 550 x 56
plywood or tongue & groove boards
plan view

woodgrain direction

platform

hole

left board

right board

side elevation

platform

right board

front elevation

platform

left board

right board

plan: toilet top - download

- top
  - platform made of 15–20 tongue and groove boards or 12–20 plywood

- left and right boards, attach to bottom of platform and fit on top of left and right frame pieces between frame legs
- hole is at least 20mm smaller than bucket opening all the way around
- attach toilet seat to top
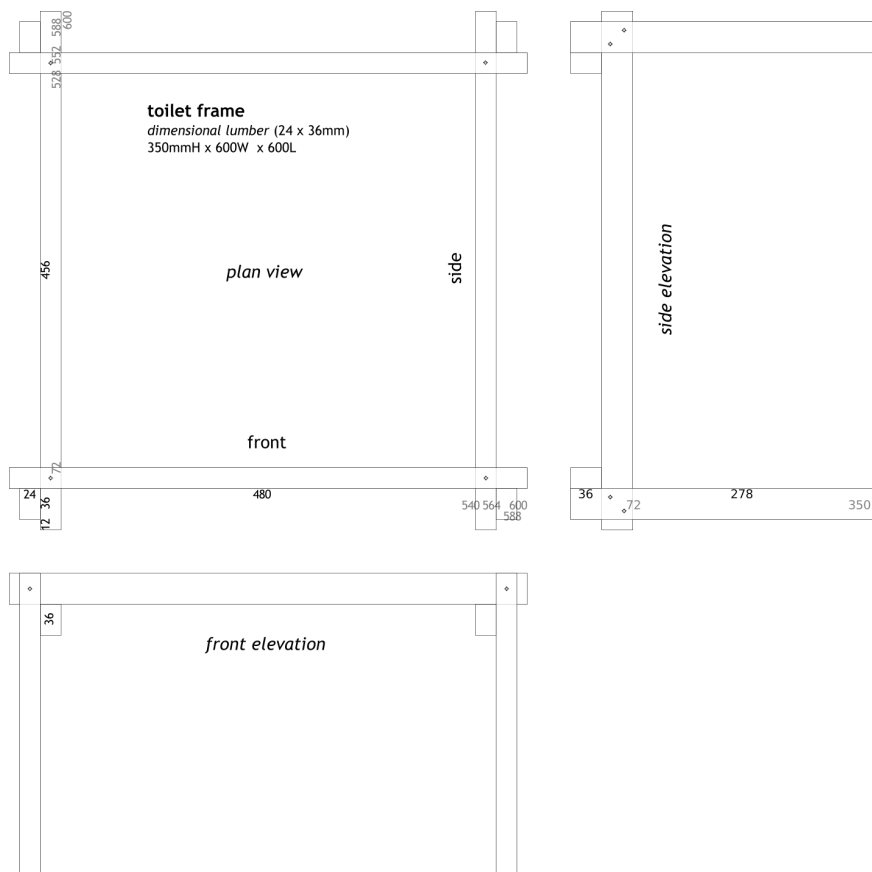
plan: toilet frame - download

- frame
  - made of 24 x 36 lumber
  - joint is extra strong, non-planar joint (see gridbeam.com)
  - black dots indicate heads of screws. Always drill pilot holes for screws.

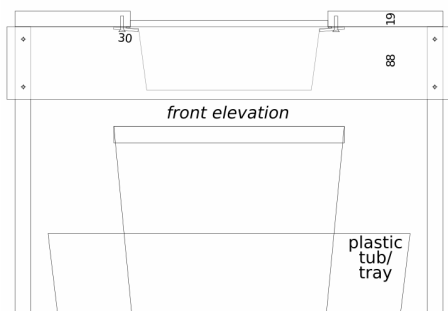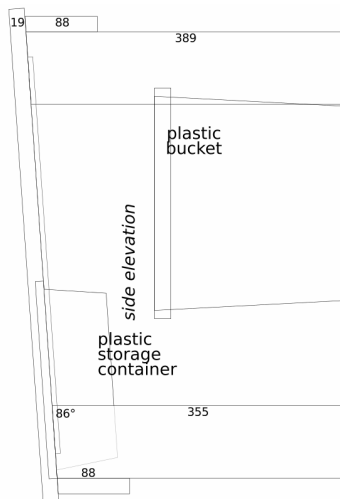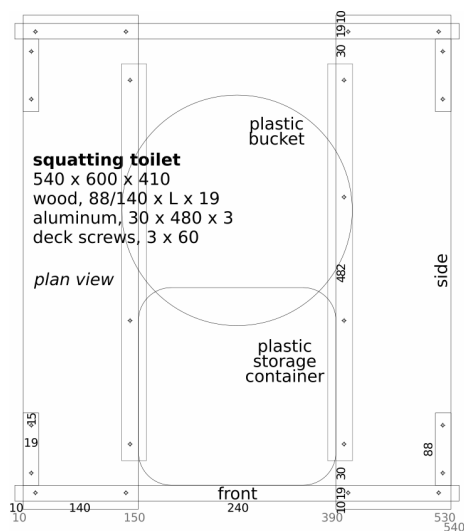– adjust leg height to allow a 15mm space between top of bucket and underside of toilet top

toilet liner
plastic sheeting (0.2mm)
1326 x 1350mm

bottom

side

flap

front
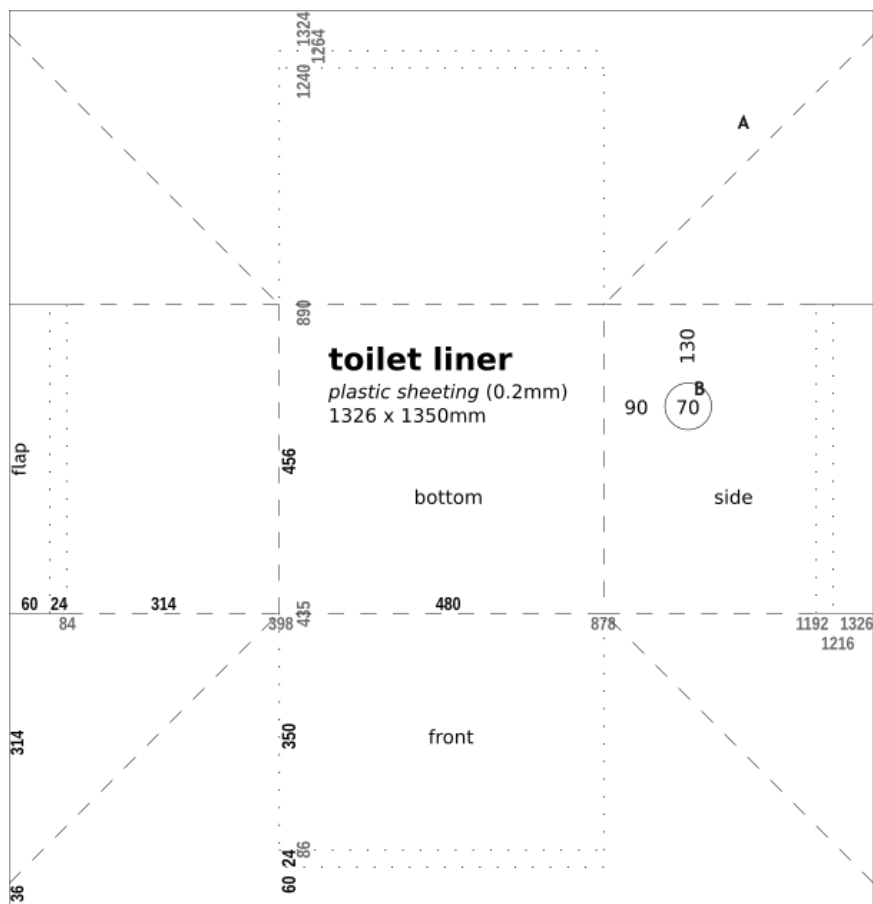
plan: toilet liner - <u>download</u>

- liner
    - made of thick plastic sheeting (0.006" or 0.02mm)
    - folds into an open box
    - resulting triangular gussets in corners **A** fold against outside of liner
    - liner fits inside frame
    - top edges fold over horizontal frame pieces and get thumbtacked or taped in place on outside
    - toilet bucket goes inside

  – cut hole **B** for return duct:
    * 30mm smaller than return duct to stretch and fit over it snugly
    * so duct is 50–100mm off floor and next to a frame leg (to attach a bracket to to support duct if necessary)
    * fold nearest gusset away from hole
    * hole **B** in plan is just an example: 70mm diameter hole for 100mm diameter duct
  – liner can also just be a skirt with no bottom, cut exactly at floor level. Put a pan, tray, paper, or towel on the floor under the bucket to catch spills.

squatting toilet
540 x 600 x 410
wood, 88/140 x L x 19
aluminum, 30 x 480 x 3
deck screws, 3 x 60

plan view

plastic bucket

plastic storage container

side

front

side elevation

plastic bucket

plastic storage container

86°

front elevation

plastic tub/ tray

Squatting toilet has liner or skirt with plastic tub/tray like other toilet.

Plastic storage container catches pee. Then it slides back on aluminum rails and catches water from bidet. Bidet is a 0.5-1L soda bottle with angled hole in cap made with a medium needle. Empty into a ventilated bucket or pee bottle.

If skirted, lift whole toilet to remove bucket. Or hinge one platform at one end, put pins at the other, not screws. Or just pins at each end. Lift platform out of the way to remove bucket. Empty into compost bin and cover with dirt then leaves, straw, etc.

If bucket lid has airtight seal, fan can be switched off between uses.

plan: squatting toilet - download

bath

basic
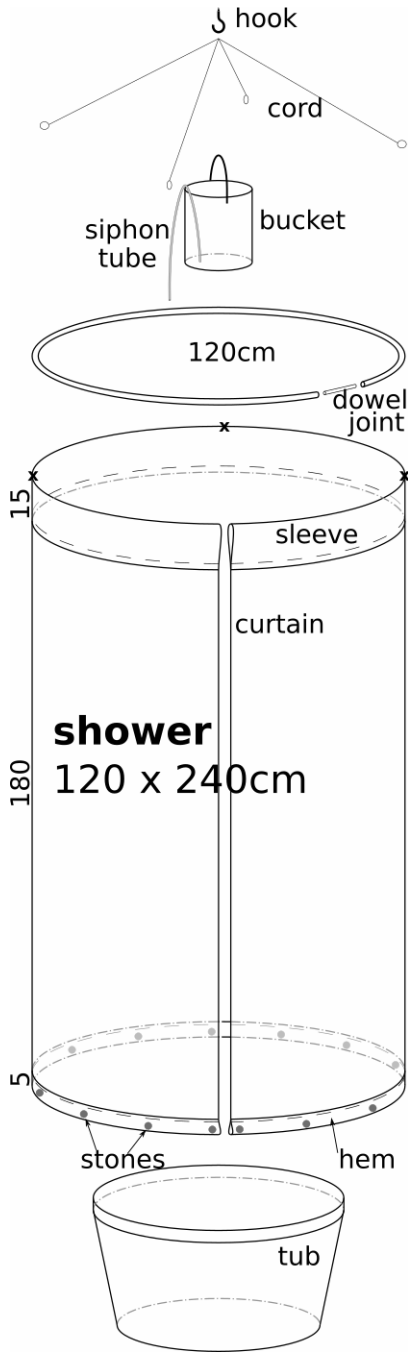
A sponge bath.

upgrade

- on waterproof floor or large plastic sheet, make a 2m diameter border of towels. Sit in the middle
- put warm water in 2, 1.5L soda bottles, with loose lids or nearly closed drinking spouts
- hold a bottle above yourself with one hand and wash with the other
- wipe up water with towels and squeeze it out into bucket
- hang towels to dry or give them to supporter

deluxe

This is portable shower. It collapses for storage, requiring no pipes and only 4-10L of water.

hook

cord

siphon
tube

bucket

120cm

dowel
joint

15

sleeve

curtain

shower
120 x 240cm

180

5

stones

hem

tub

plan: shower - download

Parts, top to bottom:

- hook (in ceiling, 50mm)
- bucket or bottle (4-10L, hangs from hook by handle)
- siphon tube (polyethylene, 4mm ID x 50cm, bent near its middle with heat to hook over rim of container)
- 4 cords (hung from hook, tied to curtain rod)
- curtain rod (common irrigation tubing, black polyethylene, 30mm OD, circular, 375cm long for 120cm diameter, dowel inside ends for smooth joint)
- curtain (polyester or plastic sheeting, with 15cm sleeve for rod (as shown) or grommets and rings, 5cm bottom hem with small river rocks inside to weigh it down)
- **x**=holes in curtain for cords to tie around curtain rod
- large tub (90L+, from garden supply store, catches everything at the bottom) or deep tray or pan.

Solar water heating method: nearly fill clear 4-8L bottles with water. Put rectangles of black plastic sheeting inside as elements. Put bottle in sun. Have supporter give it to you when warm. Or, with dark clothing and mask on tight, grab it from a sunny spot.

Adjust water temperature with cold water to suit yourself. Hang it from the hook. Suck on the tube to start the siphon action. Water flows for 8 minutes. Not bad. Dump used water into a 20L bucket with a lid for later disposal. Yes, all this is possible in darkness. I did it.

Adjust shower length and water flow with different size containers and tubes. Make sure hook can hold the weight.

$\sim/\sim$

That's the state of my art of low-cost DIY darkroom design and construction. Check back for the latest developments. If you design something simpler, faster, cheaper, more effective, more elegant, or just different, please let me know. See open-source *e*.

$\sim/\sim$

That's also the end of the body of my book. Thank you for reading. I hope it helps you find yourself, recover your health in body and soul, feel joy, and be successful and free.