Laser Cutting & Engraving

What is Laser Cutting?

- Light Amplification by Stimulated Emission of Radiation
- Technology that uses a laser to cut materials
- Typically used for industrial manufacturing
- Increasingly used by schools, small businesses & hobbyists
- Focused laser beam directed at material, which either melts, burns or vaporizes away
- Optics to focus the laser & CNC for motion control
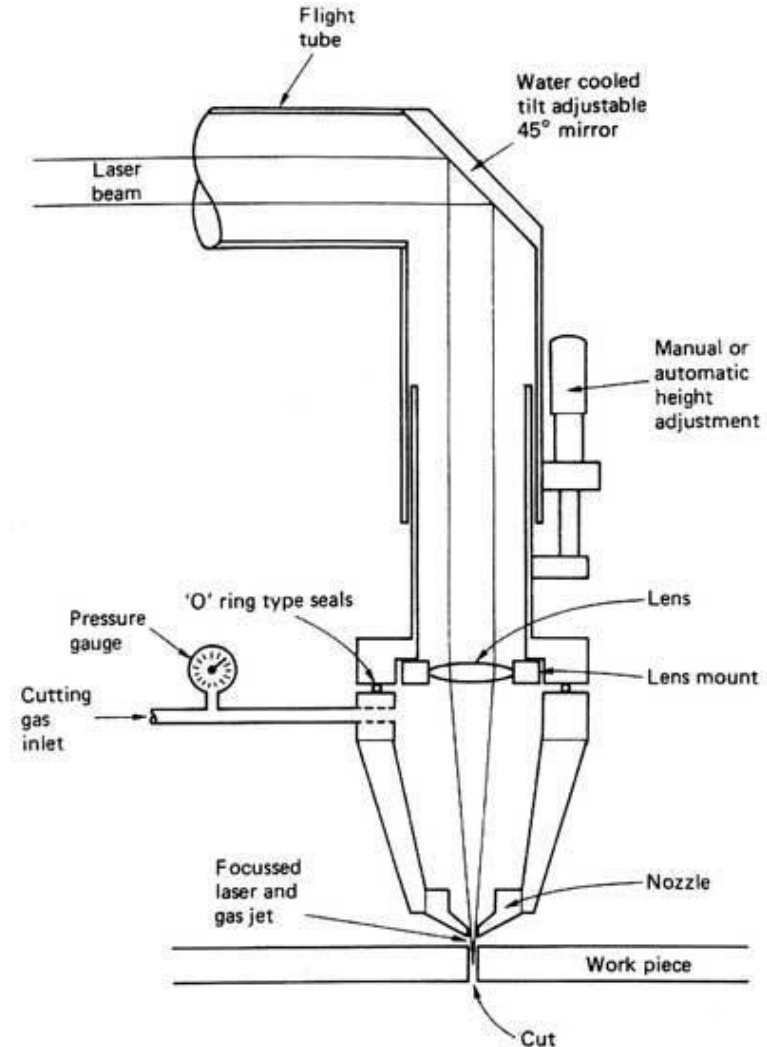
Other Forms of Computer Controlled Cutting

- Knife
- Waterjet
- Hot-wire
- Wire EDM
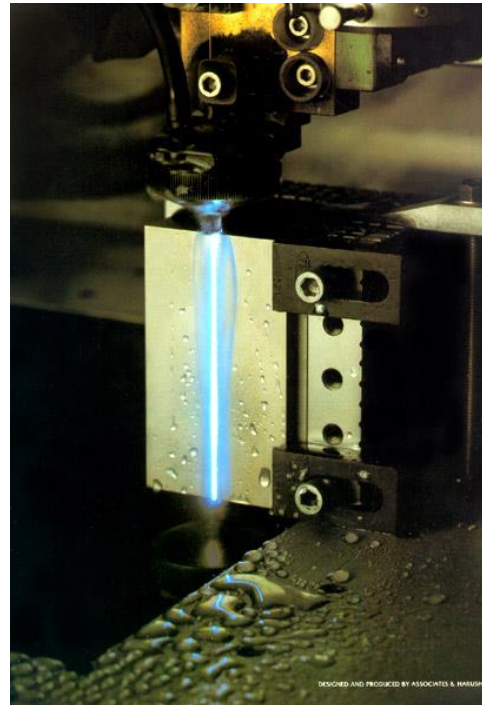
Software

CAD

- Fusion 360
- Rhino
- Blender
- 123d Make
- AutoCAD, QCAD
- Gimp
- Photoshop
- CorelDraw
- Illustrator

CAM

- Vendor printer driver
  - Epilog
  - Universal Laser Systems
  - Trotec
  - Full Spectrum Laser
  - GCC
- 3rd party & open-source
  - Fab modules
  - Image2Gcode

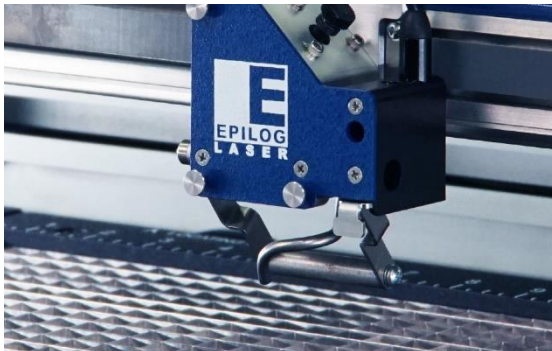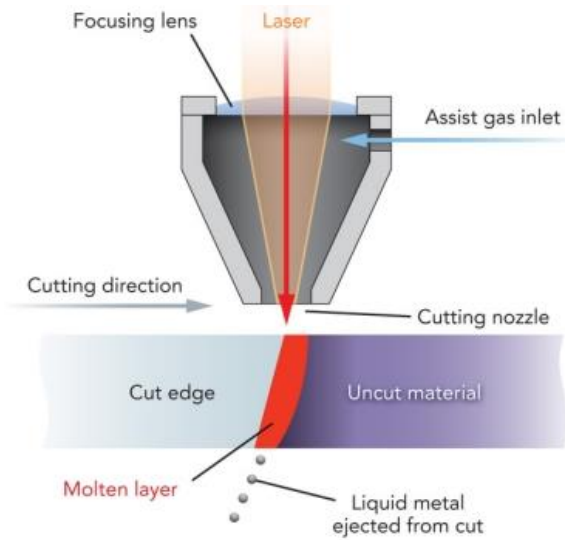# Types of Lasers (Gain Medium) & Mechanism

Gain Medium

- CO2 (10.6 u)
- Fiber (1-2 u)
- InGaAsP (1-2 u)
- Nd:YAG (1064, 532 nm)
- Ti:sapphire (650-1100 nm)
- Excimer (100-300 nm)

Cutting Mechanism

- Burning
- Melting
- Evaporation
- Ablation
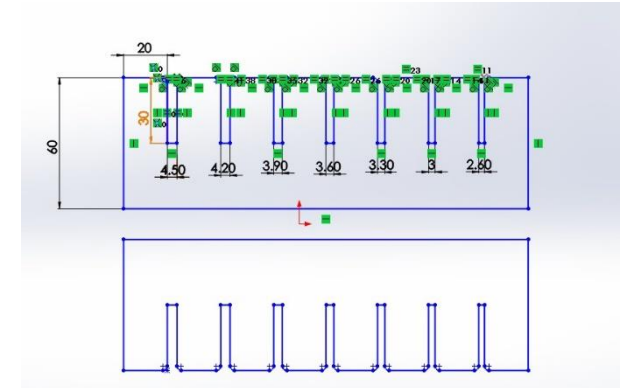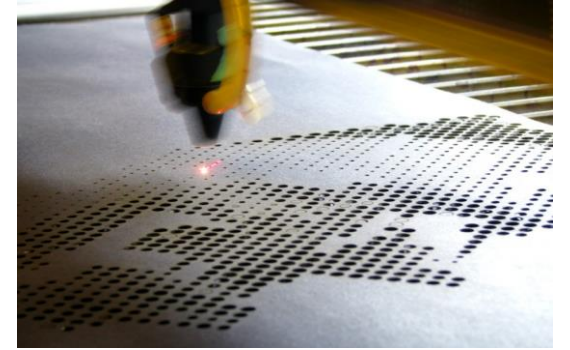
Airflow (air assist, exhaust, filter) is very important for safe laser cutter operation

Air Assist and Exhaust Pump

Laser Cutter Applications

- Cutting, marking or engraving
  - Raster (e.g. photos)
  - Vector
- Screen printing
  - Halftone
  - Holes
  - Path
- Press-fit construction
- Factors to consider
  - Kerf
  - Chamfer & joints
  - Parametric design
- Flexures & living hinges

Laser Safety

- Ensure Class 1 w/safety interlock
- Venting of fumes
- Regular cleaning of laser optics
- Supervision at ALL times
- Adequate air/gas flow
- Prohibited materials
- Fires during operation
- E-stop & fire-extinguisher

The laser cutter is a potentially dangerous machine. It is very easy to start fires with the laser cutter. The laser cutter can also produce dangerous fumes (e.g., chlorine) if used with improper materials.

People **must** receive training prior to use of the laser cutter. The cutter must also remain under constant supervision while in use. This document is very partial, and does not constitute training. Please contact shop-admin@cba.mit.edu for further information.

What can happen when you leave a laser cutter unsupervised

Particular warnings:

Never cut PVC, or other chlorinated plastics (Lexan and PC board are also strongly discouraged). PVC in particular will give off chlorine gas, which is not only highly corrosive to the machine, but also dangerous for any nearby people.

Constant machine supervision really is a must. E.g., with our own machine, in the middle of a cut, I observed the laser begin etching the internal walls of the machine, and igniting the rubber rollers of the laser cutter head. It turned out that a primary mirror had fallen off, and the 100 watt laser beam was reflecting off the skewed and moving mirror. Had the machine not been under supervision, this might have resulted in a serious fire.

Materials

Laserable

- Cardboard
- Wood
- Acrylic
- Delrin
- Fabric
- Ceramic
- Glass

- Flame test: if it flames, it should not be cut

Prohibited

- PVC
- Pleather
- Moleskin
- Polycarbonate/Lexan
- HDPE
- Polystyrene foam
- Fiberglass
- Carbon fiber
- Butane/Gas

Epilog Approved Materials

Material	Engrave	Cut
Wood	X	X
Acrylic	X	X
Fabric	X	X
Cloth	X	X
Ceramic	X	
Delrin	X	X
Linoleum	X	X
Leather	X	X
Marble	X	
Matte Board	X	X
Coated Metals	X	
Paper	X	
Cork	X	X
Tile	X	X
Glass	X	
Chocolate	X	X

Epilog Forbidden Materials

Material	Danger	Consequence
PVC (Polyvinyl Chloride)	Emits Pure Chlorine Gas	Gas will ruin lense, corrode Metal, and ruin motion control system.
Pleather / Artificial Leather	Emits Pure Chlorine Gas	Gas will ruin lense, corrode Metal, and ruin motion control system.
Moleskin Notebooks	Emits Pure Chlorine Gas	Gas will ruin lense, corrode Metal, and ruin motion control system.
Polycarbonate / Lexan	Cuts poorly, Discolors, Fire	This Material absorbs infared Radiation so the laser is very ineffective.
ABS	Emits cyanide gas and melts	ABS tends to melt, making a mess. It also has a higher chance of catching fire.
HDPE / Milk Bottle Plastic	Catches fire and melts	It melts, tending to make a mess and ruin the material tray.
Polystyrene Foam	Catches Fire	It catches Fire and melts. #1 material to cause laser fire.
Fiberglass		Like Polystyrene, it metls, catches fire and the melted drops continue to burn and turn into rock-hard drips and pebbles.
Coated Carbon Fiber	Emits Noxious Fumes	A mix of two materials. Thin carbon fiber can be cut, with some fraying - but not when coated.
Any Powder		Compressed Air will blow it away.
Butane Lighters	Explode / Catch Fire	
Gasoline or other Liquids	Explode / Catch Fire	
People	XX	
Animals	XX	

Laser Settings

- Power
  - Higher burns deeper
  - Too much or too little sacrifices detail
- Speed
  - Higher saves time, burns shallower
  - Too high or low speeds reduces detail
- Frequency (PPI)
  - # pulses per inch of travel
  - Higher increase burning/melting effect
  - Acrylic: 500 ~ 1000
  - Wood: 100 ~ 500
- Rule of Thumb:
  - Doubling power doubles depth of cut
  - Halving speed doubles depth of cut
- Use vendor recommended settings as starting point

Machine Settings (Epilog, acrylic)

Fusion Series Suggested Material Settings (CO2)

Material	DPI/Freq.	30 watt	40 watt	50 watt	60 watt	75 watt	120 watt
Acrylic							
Photo Engraving	300 DPI	90s 60p	90s 55p	90s 50p	90s 45p	90s 40p	90s 30p
Text/Clipart Engraving	300 DPI	90s 80p	90s 75p	90s 70p	90s 65p	90s 60p	90s 55p
Text/Clipart Engraving	600 DPI	90s 75p	90s 70p	90s 65p	90s 60p	90s 55p	90s 50p
Cutting 1/8" (3 mm)	100 f	5s 100p	6s 100p	7s 100p	8s 100p	10s 100p	12s 100p
Cutting 1/4" (6 mm)	100 f	2s* 100p	3s* 100p	1s 100p	2s 100p	3s 100p	7s 100p
Cutting 3/8" (9.5 mm)	100 f			2s* 100p	3s* 100p	1s 100p	3s 100p
Cutting 1/2" (13 mm)	100 f						1s 100p

Cutting Note: Adjusting the standard focus distance so it is closer to the lens by about .080" (2 mm) will produce better edge quality when cutting 1/4" (3mm) acrylic and thicker. Two passes can be used for cutting thicker materials. There are two types of acrylic: cast is better for engraving (it creates a frosted look when engraved) and extruded acrylic produces a much better flame polished edge.

* The Fusion has two sets of Speed control for vector cutting applications. Checking the Speed Comp selection box in the print driver will reduce the speed setting you have selected by one half. Speed Comp is most useful for speeds of 1 to 10. Example: Cut a square at 5% speed. Then repeat the job at 5% speed and also select Speed Comp. The second square will take twice as long to cut as the first square. Speed Comp gives you more slower speed setting to work with. Always use Air Assist when cutting.

Machine Settings (Epilog, Wood)

Wood					60W		
Photo Engraving	600 DPI	30s 100p	40s 100p	50s 100p	60s 100p	70s 100p	100s 100p
Clipart/Text Engraving	300 DPI	25s 100p	30s 100p	35s 100p	40s 100p	50s 100p	60s 100p
Clipart/Text Engraving	600 DPI	20s 100p	30s 100p	40s 100p	50s 100p	60s 100p	90s 100p
Deep Engraving	600 DPI	5s 100p	10s 100p	20s 100p	25s 100p	30s 100p	60s 100p
Thin Veneer (Cutting)	10 f	30s 100p	30s 80p	40s 100p	40s 100p	50s 80p	50s 60p
Cutting 1/8" (3 mm)	10 f	3s 100p	6s 100p	8s 100p	10s 100p	20s 100p	40s 100p
Cutting 1/4" (6 mm)	10 f	3s* 100p	1s 100p	2s 100p	3s 100p	5s 100p	12s 100p
Cutting 3/8" (9.5 mm)	10 f			2s* 100p	3s* 100p	1s 100p	8s 100p
Cutting 1/2" (12 mm)	10 f						3s 100p

When cutting wood, multiple passes may allow cutting of thicker materials. Using Color Mapping you can adjust the focus point between passes down to the center point of the cut for the best results.

* The Fusion has two sets of Speed control for vector cutting applications. Checking the Speed Comp selection box in the print driver will reduce the speed setting you have selected by one half. Speed Comp is most useful for speeds of 1 to 10. Example: Cut a square at 5% speed. Then repeat the job at 5% speed and also select Speed Comp. The second square will take twice as long to cut as the first square. Speed Comp gives you more slower speed setting to work with. Always use Air Assist when cutting.

Reference: Epilog Fusion M2 Laser

Exercises

Rules for Laser Engraving (Photo)

- Always work in grayscale (continuous tone) or BW (1-bit)
  - Fine (non-porous) material: half-toning (grayscale)
  - Coarse (porous) material: error diffusion
- Know the materials you want to work on
- Know your laser (speeds, power, frequency/ppi)
- Work only with good photos
  - Shows only subject (focus)
  - No background (noisy) images
- Know your adjustment commands
- Crop to subject

Laser Engraving (Steps)

- Step 1: convert to grayscale

- Step 2: crop to focus

- Step 3: contrast enhancement
  - How well does material hold small dot
  - How well does material display image
  - How consistent is the material

- Rule of thumb:
  - More detail in image if lasering on good material; use half-tone, small adjustment in contrast enhancement
  - Get rid of detail, larger adjustment in contrast enhancement for porous material

- Use unsharp mask to sharpen fuzziness, get rid of details that cannot be reproduced by laser

Laser Engraving (Demo)
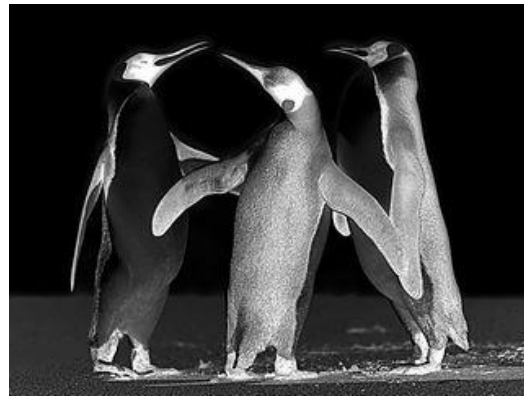

Original image

Crop to focus

Grayscale

Adjusting levels

Contrast enhancement

Inverted (acrylic)

Error diffusion (wood)

Engrave filter

Laser Engraving (sample)

Grayscale (S70/P60) Error Diffusion (S70/P60) Engrave filter (S70/P60)

Grayscale (S100/P30) Error Diffusion (S100/P30) Engrave filter (S100/P30)
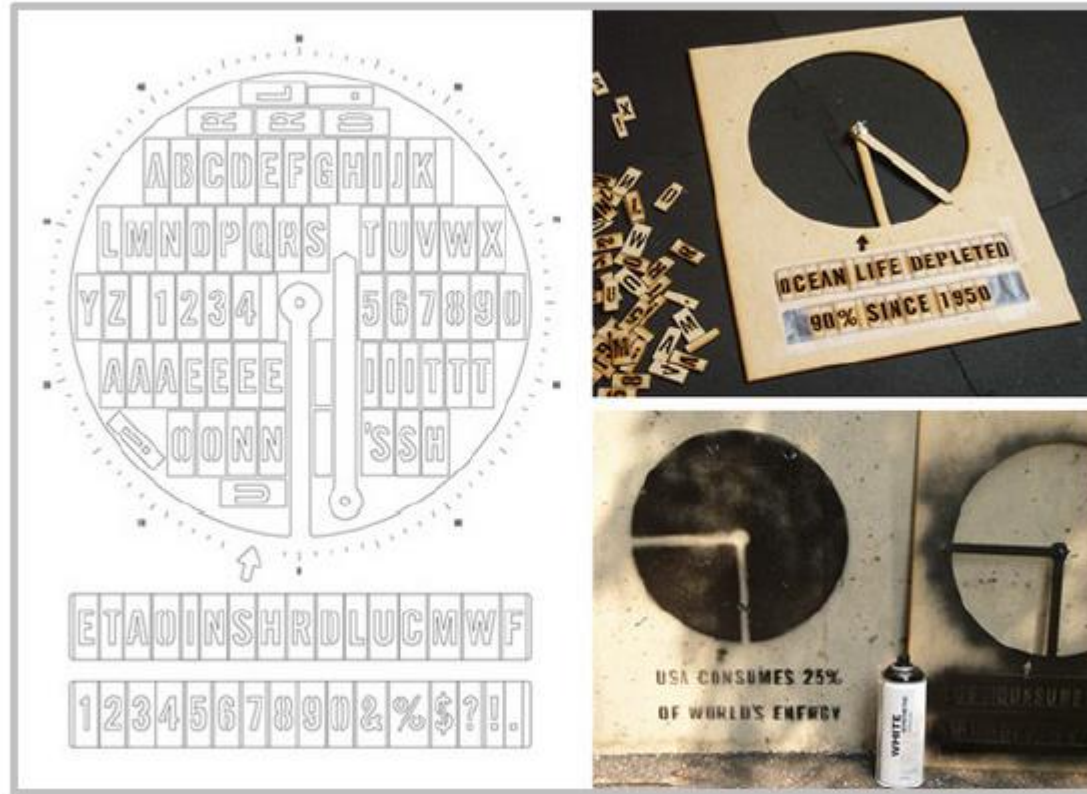
Samples

What can we do?

Invitations

Just an example of the very precise details you can get with a laser cutter.

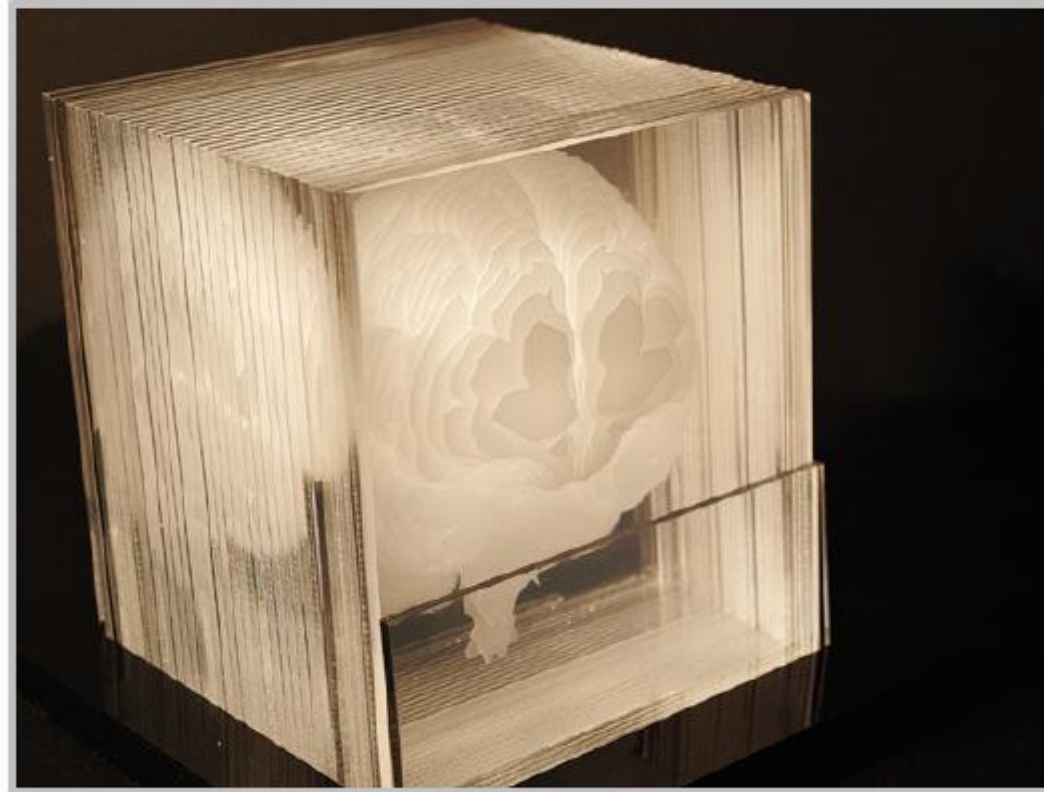http://blog.ponoko.com/2011/08/28/laser-cut-silhouettes/

Lasercut stencil for adjustable infographic graffiti

An adjustable lasercut stencil pattern for pie-chart graffiti. The pattern includes a complete set of re-arrangeable letters and numbers.

http://fffff.at/infoviz-graffiti-stencil/

Laser etching a 3D model

Using the transparency of each panel as a layer in the 3D space...

http://makezine.com/2010/05/26/laser-etched-brain-model/

Alphabet Topography

In this monotype typeface, the height of the letterforms is determined by how often a letter is used. This typeface maps the rhythmic ebb and flow of English.

http://www.synopticoffice.com/project.php?projectid=1&selectedcol=1

Lasercut nori for designer sushi

Developed by international ad agency I&S BBDO for the umino seaweed shop, 'design nori' is a series of intricately laser-cut seaweed for rolling sushi.

http://www.designboom.com/weblog/cat/8/view/20710/lasercut-nori-for-designer-sushi.html

You can etch your own MacBook

Have a look at this tutorial, and don't blame us, you did it!

http://makezine.com/2008/02/29/how-its-made-laser-etchin/

Some interesting blogs and sites

http://fslblog.tumblr.com/

http://lauraslaser.tumblr.com/

https://www.epiloglaser.com/resources/sample-club.htm

http://makezine.com/2013/10/23/tutorial-laser-cutting-techniques-and-projects/

http://www.instructables.com/id/Laser-Cut/