Part 1
2). 0.016322
3). 0.001153
4). 750 x 1500 x 3
6). 5

Part 2
1). If the filters is separable, you can convolve all rows, then all columns. This is great because it allows us to do filtering with much less memory usage.
2). [0 1 1 1 1 1 1 1]
3).
    a). Apply smoothing using a Gaussian filter before running the edge detector. We can change the window size and standard deviation of the gaussian in order to get greater/smaller amounts of smoothing.
    b). Apply thresholding gradient to throw away less "important" edges.

Part 4
B).
• Mall
- **Energy:** This picture is rather self-explanatory. Wherever there exists a sudden change in gradient, the energy function will mark that pixel as a high energy position. As we expect, the edges of objects are the most heavily emphasized.
- **Vertical CMEP:** The vertical CMEP shows that lowest energy vertical seams in this image are in the trunk of the tree (where the texture and color is fairly consistent). Other areas, such as the bottom left corner have very high cumulative energy, probably owing to the building detail that any seam in that area would have to cross.
- **Horizontal CMEP:** The highest energy portions of the image lie on the right middle edge of the image, next to the heavily detailed buildings that lie directly in its path. The bottom of the image-- where the relatively smooth surface of the grass is-- is one of the lowest parts of the image.

• Prague
- **Energy:** This picture is rather self-explanatory. The boat and parts of the water seem to have especially high energy.
- **Vertical CMEP:** As expected, the bottom of the image shows rather high cumulative costs in almost the entire bottom portion. The detail in that water drives the energy up considerably except in a small gap from 100 to 200. Parts of the

clouds also are visible as noticeably increasing the energy in the otherwise low-energy sky.

- **Horizontal CMEP:** The bottom of the image, near the boat and water have exceptionally high energy values. The sky— in the upper half of the image— is very low in energy. The buildings and leaves from the tree overhead make a stripe of low energy pixels that will likely constitute a majority of seams in the horizontal direction.

C).

- **Prague**
  - **<u>Vertical Seam</u>**
    - The seam starts at the bottom right of the image and continues to make its way up through the water in a particularly shadowy region. This makes sense, because the light causes noticeable ripples that increase the energy in the more sunny portions of water. The seam proceeds upwards making its way across a tree and then up a building (once again in shade). The seam concludes by meandering around the sky, avoiding the high contrast clouds.
  - Horizontal Seam
    - As suspected, the seams starts in the upper part of the image, meandering its way across the mostly dark leaves, and then across the sky (avoiding clouds) and finally into a building.
- **Mall**
  - **<u>Vertical Seam</u>**
    - The seam avoids the sunnier (more contrasting bits) of grass as it makes its way upward. It then lingers upward across some branches of a tree, and then finally into the sky, tracing a gap between the branches that illuminates a band of sky.
  - **<u>Horizontal Seam</u>**
    - The seam stays in the lower part of the image, and especially across the shadowed regions.

D).

- **<u>NASA</u>**
  - **Original Size:** 960 x 650
  - **Change:** Reduce the width by 75 pixels
  - **New Size:** 885 x 650
  - **Explanation:** The seams remove two people from the image almost entirely, with the exception of their face (which are very high energy). After this, the seams proceed to tear the VAB's eastern face (which is very uniform in color).
- **<u>Wimbledon</u>**
  - **Original Size:** 720 x 960
  - **Change:** Reduce the height by 100 pixels
  - **New Size:** 720 x 860

- **Explanation:** The most apparent change are those that are made to the stands in the background. Much of the plain black sides of the neighboring stadium were removed, along with almost all the empty seats from the audience. Novak Djokovic also seams to have lost his head (which was blurred with motions, and pretty low energy. Also, much of the tennis racquet handle seams to have gone, along with the left arm.
- **Belgium**
  - **Original Size:** 960 x 720
  - **Change:** Reduce the width by 200 pixels
  - **New Size:** 760 x 720
  - **Explanation:** Shrinking the width removes almost all of the dark building in the background along with two people (including my twin brother). This makes sense, because the buildings are reflected in the water, a fact which significantly degrades the amount of energy needed to cross in that region. A look at the vertical cumulative image shows this to be true.