# Task4: Digital Image Processing & Camera Sensor and Digital Image

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## Problem 1:

**The main goal of this problem is to review a tutorial for Digital Image Processing. Copy this folder in your computer and run digital_image_processing.mlx in MATLAB (Note: If you do not find the sample images, you can download them from here). Please answer the following questions in 'digital_image_processing.mlx': Q.001, Q.002, Q.005, Q.008, Q.009, Q.010, Q.013, Q.016**

**Q.001: Print "info" and identify what kind of information (metadata) is stored in the image?**

width: 240, height: 291, and channel(depth): 1

```
                  FileModDate: '13-Apr-2015 13:23:13'
                     FileSize: 69296
                       Format: 'tif'
                FormatVersion: []
                        Width: 240
                       Height: 291
                     BitDepth: 8
                    ColorType: 'grayscale'
              FormatSignature: [73 73 42 0]
                    ByteOrder: 'little-endian'
               NewSubFileType: 0
                BitsPerSample: 8
                  Compression: 'PackBits'
    PhotometricInterpretation: 'BlackIsZero'
                 StripOffsets: [8 7984 15936 23976 32089 40234 48335 56370
64301]
```

```
              SamplesPerPixel: 1
                 RowsPerStrip: 34
              StripByteCounts: [7976 7952 8040 8113 8145 8101 8035 7931 4452]
                  XResolution: 72
                  YResolution: 72
               ResolutionUnit: 'Inch'
                     Colormap: []
            PlanarConfiguration: 'Chunky'
                      TileWidth: []
                     TileLength: []
                    TileOffsets: []
                 TileByteCounts: []
                    Orientation: 1
                      FillOrder: 1
                GrayResponseUnit: 0.0100
                  MaxSampleValue: 255
                  MinSampleValue: 0
                    Thresholding: 1
                          Offset: 69004
                ImageDescription: 'Copyright The MathWorks, Inc.'
```

Here, I will explain some parameters:

*FileSize:* An integer indicating the size of the file in bytes

*Format:* File format, for example, JPEG and TIFF files.

*Width:* An integer indicating the width of the image in pixels

*Height:* An integer indicating the height of the image in pixels

*BitDepth:* Number of bits per pixel

*ColorType:* Image type. ColorType includes 'truecolor' for a truecolor (RGB) image, 'grayscale' for a grayscale intensity image, or 'indexed' for an indexed image.

*PhotometricInterpretation:* The color space of the image data. According to the image, it has different values:

0 = WhiteIsZero. For grayscale images: 0 is imaged as white.

1 = BlackIsZero. For grayscale images: 0 is imaged as black.

2 = RGB. RGB value of (0,0,0) represents black, and (255,255,255) represents white, assuming 8-bit components. The components are stored in the indicated order: first Red, then Green, then Blue.

*XResolution and YResolution:* resolution in x-direction and y-direction. Pixels per inch describes the resolution. Here, because "ResolutionUnit" is "Inch", I used Inch in the definition of resolution.

**Q.002: Run the above code using the color image and compare their results.**

I used the code for reading color image ("autumn.tif"). The result for color image is:

width: 345, height: 206, and channel(depth): 3

```
                FileModDate: '13-Apr-2015 13:23:12'
                   FileSize: 214108
                     Format: 'tif'
              FormatVersion: []
                      Width: 345
                     Height: 206
                   BitDepth: 24
                  ColorType: 'truecolor'
            FormatSignature: [73 73 42 0]
                  ByteOrder: 'little-endian'
             NewSubFileType: 0
              BitsPerSample: [8 8 8]
                Compression: 'Uncompressed'
PhotometricInterpretation: 'RGB'
              StripOffsets: [1×30 double]
           SamplesPerPixel: 3
              RowsPerStrip: 7
           StripByteCounts: [1×30 double]
               XResolution: 72
               YResolution: 72
            ResolutionUnit: 'Inch'
                  Colormap: []
       PlanarConfiguration: 'Chunky'
                TileWidth: []
               TileLength: []
              TileOffsets: []
           TileByteCounts: []
              Orientation: 1
                FillOrder: 1
          GrayResponseUnit: 0.0100
            MaxSampleValue: [255 255 255]
            MinSampleValue: [0 0 0]
              Thresholding: 1
                    Offset: 213642
          ImageDescription: 'Copyright The MathWorks, Inc.'
```

I have listed some parameters of the color image which are different from the parameters in the grayscale image:

ColorType:  color image: 'truecolor' - graysclae image: 'grayscale'

PhotometricInterpretation:  color image: 'RGB' - graysclae image: 'BlackIsZero'

In the grayscale image, "BitePerSample" is scalar value 8 while for the color image, this value is the vector [8 8 8]. The reason is that in the color image, we have three components stored in the indicated order: first Red, then Green, then Blue.

**Q.005: When do we use impixel?**

The built-in function "impixel" returns the value of pixels in an image.

We use built-in function "impixel", when we want to select pixels in the image using mouse. In fact, the "impixel" function displays the image and waits for you to select pixels in the image using the mouse.

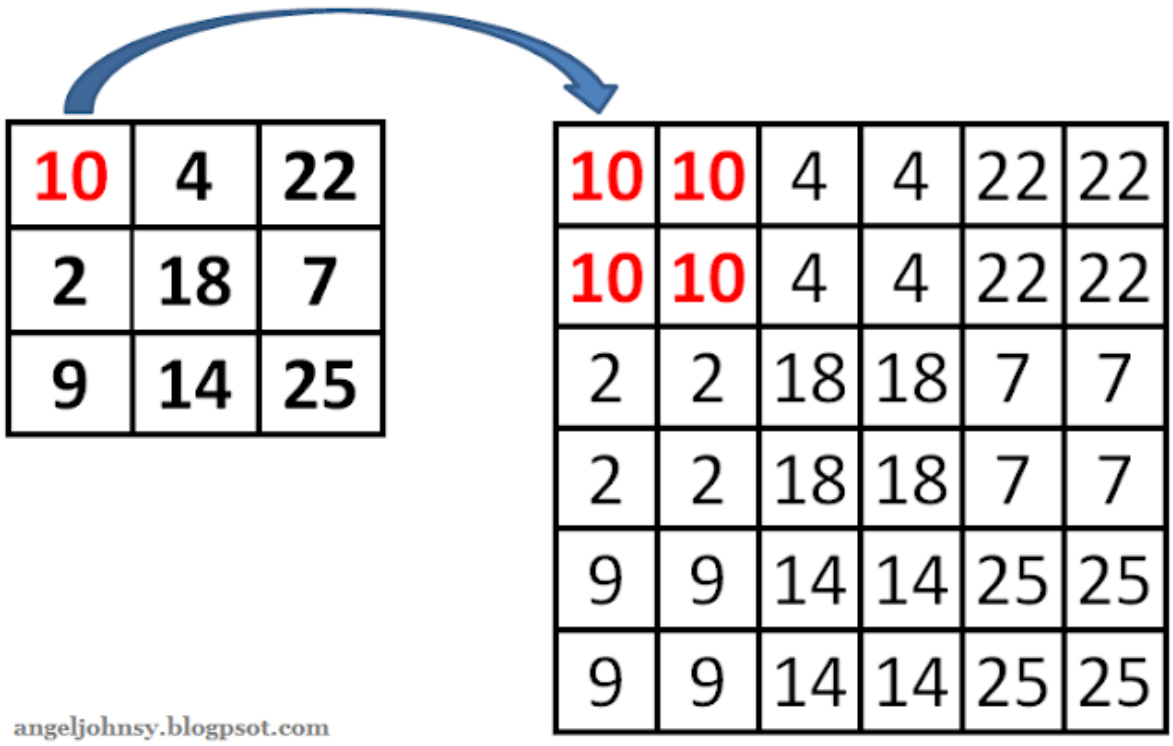
**Q.008: Please check what the 'nearest' option is.**

```
img1 = imresize(img,2,'method','nearest');
```

In "imresize" built-in function, the method for interpolation is "nearest" method. Nearest-neighbor interpolation method assigns the value of the pixel that the point falls within to the output pixel. No other pixels are considered.

In fact, this method is the simplest technique that re-samples the pixel values present in the input vector or a matrix. In MATLAB, "imresize" function is used to interpolate the images.

In the below example, nearest option is utilized to interpolate a 3x3 matrix to 6x6 matrix. As you can see, the values in the interpolated matrix are taken from the input matrix, and no new value is added.




**Q.009: Please check that how the code reproduce or reduce the pixels in the original image**

For reproducing the pixels in the original image, the code uses two different functions "imresize" and "repelem" as:

```
img1 = imresize(img,2,'method','nearest');
img1r = repelem(img,2,2);
```

The first is "imresize" built-in function by using scale=2 and interpolation method "nearest". So, in the new image, the number of pixels in the directions x and y (width and Height) would be twice the number in the original image.

Also, the code uses another method for reproducing the image by "repelem" built-in function. This function ("repelem (v,n,m)") returns a matrix of repeated elements of v in such a way that each element of v is repeated n and m times in the x and y directions, respectively.

Also, the code checks that the results of these two functions are the same or not. It can be seen that the result is the same:

Are img1 and img1r equal? True

For reduction of the pixels in the original image, the code can only utilize the function "imresize" as:

```
img2 = imresize(img,0.5,'method','nearest');
```

As you can see, the scale is considered 0.5 here to reduce the number of pixels by half in the original image. In the following, we show that how function "imresize (img,0.5,'method','nearest')" works for a simple 4x4 matrix:

```
a =

     1     2     3    10
     1     2     3    20
     1     2     3    34
     1     2     3   435

     b = imresize(a,0.5,'method','nearest')

b =

     2    20
     2   435
```

You can see that the matrix b is created by selecting a(2,2), a(2,4), a(4,2) and a(4,4).

So, this is the way that the code reduces the pixels in the original image.

### Q.010: Are high resolution images always high quality? Do high-quality photos have high resolution?

High resolution images have not necessarily high qualities while high-quality photos have always high resolution.

Pixels per inch (PPI) describes the resolution of an image. An image with high resolution has high pixels per inch. Suppose, we have an original picture with 100 PPI resolution. If we change the resolution to 300 PPI, it means that we increase the number of pixels per inch from 100 to 300 (3 times). It does not mean that the quality of the picture has increased because the main picture has a lower value of resolution.

In contrast, if a picture has high-quality, it means that the picture has a large enough number of pixels per inch.

Also, it should be mentioned that the image quality depends on both of the size of the image and the image resolution. If we have very large images, we need to have very high resolution to achieve a high-quality image, but we should consider that the resolution of the screen or digital image has a limitation. So, it may lead to the low quality for very large images.

**Q.013: With this result, please estimate the filesize of a 8,688 x 5,792 image stored as tif (lossless compression)?**

We know that each byte is equal to 8 bits. The depth for the image is 1. So, bit depth is equal to 8. Therefore, the filesize in terms of bytes is equal to (Width) * (Height) * (bit depth)/8:

$$\frac{8688 \times 5792 \times 8}{8} = 50320896 \text{ bytes}$$

**Q.016: What is the difference between im2double and double?**

"im2double(img)" converts the image img to double precision. Also, "im2double" rescales the output from integer data types to the range [0, 1], which is convenient when working with built-in functions like "imshow()".

The function "double()" only converts the specified array to a variable of type double, keeping the same values. So, when we are dealing with uint8 images, if we want to work with double function and want to have the same functionality as "im2double" function, we need to scale it down afterward. So, we need to edit the function double as,

```
img1 = double(img)./255;
```

***An example of the functionality of "im2double" function:***

For example, suppose the output data of an image is like:

```
img =

  4×4 uint8 matrix

   49   43   33   44
   36   38   39   38
   34   30   36   37
   37   24   27   42
```

By using "im2double(img)", we have,

```
im2double(img) =

    0.1922    0.1686    0.1294    0.1725
    0.1412    0.1490    0.1529    0.1490
    0.1333    0.1176    0.1412    0.1451
    0.1451    0.0941    0.1059    0.1647
```

This means that each member of img data has been divided by 255. So, the result would be between 0 to 1.

# Problem 2

**The main goal of this problem is to learn a working principle of a digital camera and how to take quality photos using your camera. Students are encouraged to actively search for relevant information on the web, such as wiki, article, or tutorial videos. Please answer the following questions:**

**Q1. What is a good image sensor? Why are the high-end DSLR cameras expensive?**

The quality of image sensor is related to its size. As the size of image sensor increases, the number of pixels increases. Also, we can mention that the size of the pixels will increase, resulting in using more light to create an image. Therefore, a bigger sensor can gain more information than a smaller one and produce better images.

In fact, with a small sensor, the pixels can't capture as much light, so a pocket camera will produce images that have less dynamic range and never as clean as a DSLR. A camera with a larger sensor will also produce images with less noise, especially at high ISO.

High-end DSLR cameras are expensive because the camera's sensor and processor are made of expensive materials. In addition, for making DSLR cameras small, microchips and processors are used for them, leading to an extra fee in comparison to other cameras. The last reason is that the sensor for a DSLR camera is several times bigger than the ones used for other cameras.

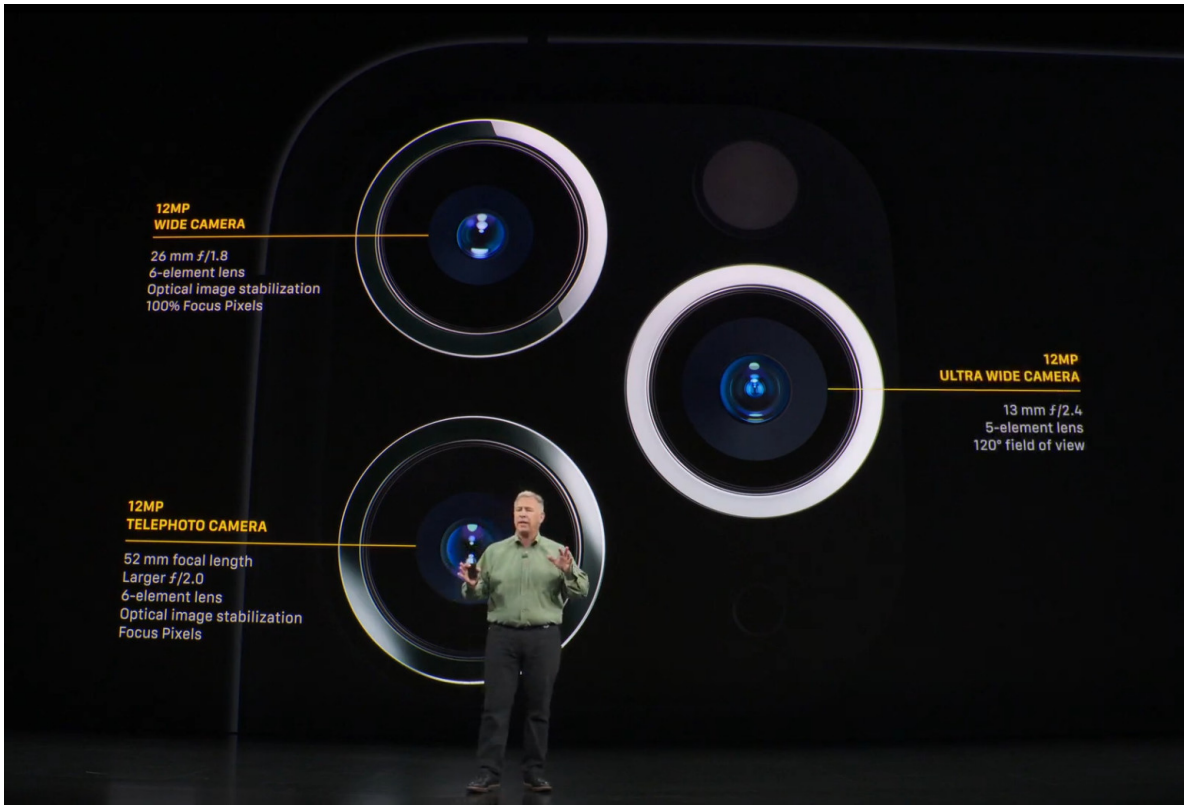
**Q2. What is the difference between optical and digital zooms?**

The optical zoom is achieved by using an actual camera's lens (see the below figure). So, we can change the zooming rate only before taking a picture. In contrast, the digital zoom is the result of cropping the image and enlarging the total number of pixels after it has been taken by the digital camera's sensor.


Also, digital zoom often results in lower quality pictures in comparison to optical zoom. You can see the difference between the quality of pictures for optical and digital zooming:


**Q3. Why did the apple make "stove-top" iPhone 11?**

Both the iPhone 11 Pro and Pro Max have three different camera lens configurations to capture different angles of the same view. There are a telephoto lens with an f/2.0 aperture and 52 mm focal length, a wide-angle lens with an f/1.8 aperture and 26 mm focal length, and an ultra-wide lens with an aperture of f/2.4 and 13 mm focal length. Each of these camera lenses is 12-megapixel cameras.




Why did the apple make this for iPhone 11? Because the more light you collect, the better your picture can be. One of the biggest drawbacks of older iPhone models is the drastic difference in quality if you're shooting in a dark space. According to Apple, you'll be able to take great pictures even if the sun isn't out with the new iPhones.

While the regular iPhone 11 has both an ultra-wide and wide-angle lens, it's missing a telephoto camera — which is why the Pro models have much better zoom features. While the iPhone 11 has 5x digital zoom, the Pro has 10x digital zoom. That means that you can capture an image from a distance and still have it look good.

The biggest new feature is the addition of a wide-angle lens. It sees double that of the main camera, meaning an equivalent focal length of 13mm. That's really wide, 120-degrees wide, which is about equal to human vision flattened into an image.

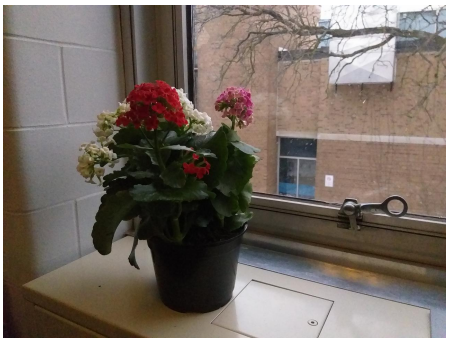

**(Q4~Q9) Please explain and demonstrate the following functions/effects using your own images. Also, you can also explain when you change their values on a camera. Your answers are graded based on both the correctness and extensively considering various potential situations. Your answers do not have to be lengthy but should not be short. Note that you are allowed to use the DSLR images provided but you need to provide a suitable reason for why your smart phone camera cannot take the corresponding images. You can download the instructor's images from here.**

**Q4. Shutter speed (Exposure time)**

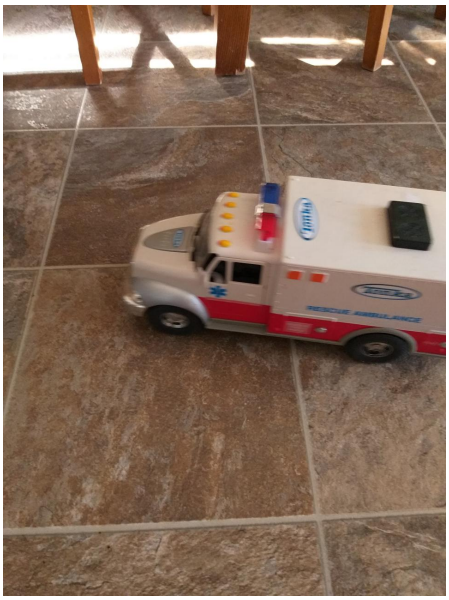
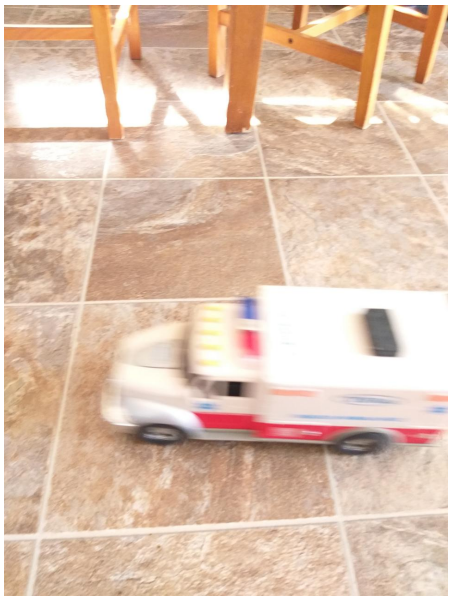
**I used my smart phone camera to take these photos.**

It will happen when a camera's shutter is open when taking a photograph. Shutter speed or exposure time is the length of time when the sensor is subjected to the light. In other words, the amount of light that reaches the image sensor is related to the exposure time. As the exposure time increases, the amount of light will increase, leading to brighter images.

For comparison, the exposure time in image 2 is about 5 times greater than the exposure time in image 1. It means that more light is exposed to the sensor for this case, making the image brighter. Also, it should be mentioned that when the sensor is exposed to more light (image 2), some details, like the outline of the objects, are missing.

| Metadata | Image 1 | Image 2 |
|---|---|---|
| Image |  |  |
| Make | samsung | samsung |
| Model | SM-A605G | SM-A605G |
| Data and time | 2020:02:20 14:00:24 | 2020:02:20 14:00:37 |
| Image file type | JPEG | JPEG |
| Resolution | 4608 x 3456 | 4608 x 3456 |
| Focal length | 3.9 mm | 3.9 mm |
| Exposure | **1/5712** | **1/1277** |
| ISO | 800 | 800 |
| F-number | 1.7 | 1.7 |
| GPS | 43.47112, -80.54019 | 43.47112, -80.54019 |
| Flash | No Flash | No Flash |

In addition, fast shutter speeds are used to photograph quickly moving objects, achieving sharp focus, without motion blur, with less ambient light in the scene. I used a moving object (toy car) to show the effect of shutter speed on the image. You can see more motion blur in image 2.

| Metadata | Image 1 | Image 2 |
|---|---|---|
| Image |  |  |
| Make | samsung | samsung |
| Model | SM-A605G | SM-A605G |
| Data and time | 2020:02:23 13:14:51 | 2020:02:23 13:14:36 |
| Image file type | JPEG | JPEG |
| Resolution | 4608 x 3456 | 4608 x 3456 |
| Focal length | 3.9 mm | 3.9 mm |
| Exposure | **1/100** | **1/25** |
| ISO | 200 | 200 |
| F-number | 1.7 | 1.7 |
| GPS | 43.47112, -80.54019 | 43.47112, -80.54019 |
| Flash | No Flash | No Flash |

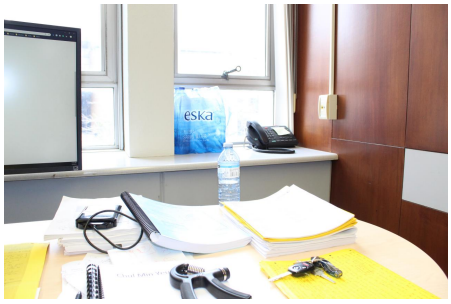
**Q5. Aperture**

**I utilized the instructor's images because the aperture is unchangeable in my smart phone camera (SM-A605G).**

Aperture is an opening in a photographic lens that admits the light to reach the sensor. Changing the aperture can affect the brightness (exposure) and the depth of field.

As the aperture increases or the f-number decreases, more light will reach to the sensor, making the photo brighter. Speaking about the field of depth, the decrease in the amount of aperture leads to an increase in the amount of field of depth (wider field of depth). This means that the image would be blurrier and more unclear outside the depth of field.

In image 2, the f-number is 5.6 which is about 4 times smaller than the one in the image 1. It means that the aperture in image 2 is about 4 times greater than the aperture in the image 1. As you can see, when the aperture increases, the image is brighter and the field of depth becomes narrow.

| Metadata | Image 1 | Image 2 |
|---|---|---|
| Image |  |  |
| Make | Canon | Canon |
| Model | Canon EOS Rebel T6 | Canon EOS Rebel T6 |
| Data and time | 2019:02:04 11:52:44 | 2019:02:04 11:52:36 |
| Image file type | JPEG | JPEG |
| Resolution | 5184 x 3456 | 5184 x 3456 |
| Focal length | 18.00 mm | 18.00 mm |
| Exposure | 1/200 | 1/200 |
| ISO | 1600 | 1600 |
| F-number | **22** | **5.6** |
| GPS | None | None |
| Flash | On, Fired | On, Fired |

**Q6. ISO**

**My friend helped me to take the images with different ISO because my smart phone camera (SM-A605G) changes the exposure time when I am manually changing ISO. I tried to keep the shutter speed constant when I am changing the ISO, but my camera changes the shutter speed automatically.**

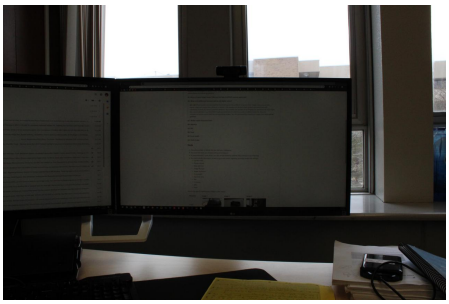
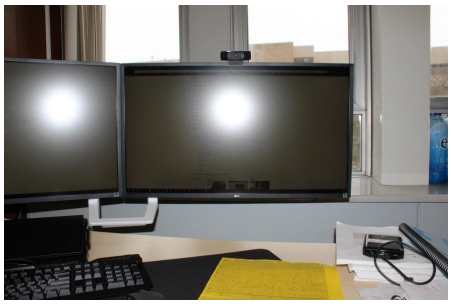
ISO is one of the three factors of exposure, along with shutter speed and aperture. When you change the ISO on a digital camera, you're rendering the sensor more or less sensitive to light. As the ISO increases, the image would be brighter. In digital cameras, raising the ISO means a similar decrease in quality, with an increase in what's called "noise."
In addition, for photographing quickly moving objects requiring a fast shutter speed, we can use higher ISO.

| Metadata | Image 1 | Image 2 |
|---|---|---|
| Image |  |  |
| Make | Canon | Canon |
| Model | Canon EOS 60D | Canon EOS 60D |
| Data and time | 2020:02:20 10:30:00 | 2020:02:20 10:31:00 |
| Image file type | JPEG | JPEG |
| Resolution | 5184 x 3456 | 5184 x 3456 |
| Focal length | 59.00 mm | 59.00 mm |
| Exposure | 1/6 | 1/6 |
| ISO | **200** | **800** |
| F-number | 32 | 32 |
| GPS | None | None |
| Flash | No Flash | No Flash |

**Q7. Flash**

**I utilized the instructor's images because my smart phone camera (SM-A605G) changes the ISO and exposure time when I am turning the flash on or off. I tried to keep them constant when I am using flash option, but my camera changes them automatically.**

For illuminating a dark scene, a flash is used. In fact, flash is a device used in capturing images by adding artificial light to the scene. Also, flash is utilized in capturing quickly moving objects or changing the quality of light.

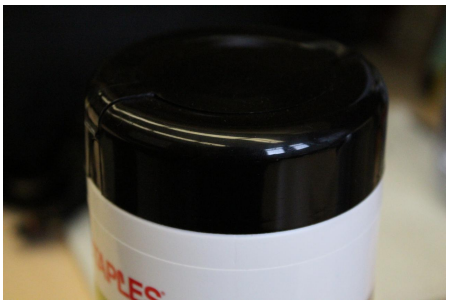
| Metadata | Image 1 | Image 2 |
|---|---|---|
| Image |  |  |
| Make | Canon | Canon |
| Model | Canon EOS Rebel T6 | Canon EOS Rebel T6 |
| Data and time | 2019:02:04 11:54:59 | 2020:02:20 10:31:00 |
| Image file type | JPEG | JPEG |
| Resolution | 5184 x 3456 | 5184 x 3456 |
| Focal length | 18.00 mm | 18.00 mm |
| Exposure | 1/200 | 1/200 |
| ISO | 1600 | 1600 |
| F-number | 20 | 20 |
| GPS | None | None |
| Flash | **No Flash** | **On, Fired** |

**Q8. Focal length**

**I utilized the instructor's images because my smart phone camera (SM-A605G) cannot change the focal length. In fact, focal length is related to the optical length and most of the smart phone camera cannot change the optical zoom before taking images.**

Focal length, usually represented in millimeters (mm), is the basic description of a photographic lens. The focal length is the distance between the aperture and the point where all the light beams converged to.

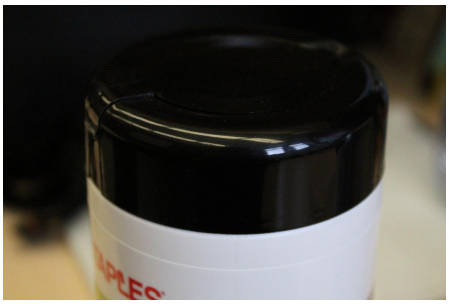
The focal length of lens tells us the angle of view and the magnification. The angle of view means how much of the scene will be captured and the magnification means how large individual elements will be. The longer the focal length, the narrower the angle of view and the higher the magnification. The shorter the focal length, the wider the angle of view and the lower the magnification.

| Metadata | Image 1 | Image 2 |
|---|---|---|
| Image |  |  |
| Make | Canon | Canon |
| Model | Canon EOS Rebel T6 | Canon EOS Rebel T6 |
| Data and time | 2019:02:04 11:10:54 | 2019:02:04 11:10:46 |
| Image file type | JPEG | JPEG |
| Resolution | 5184 x 3456 | 5184 x 3456 |
| Focal length | **49.00 mm** | **18.00 mm** |
| Exposure | 1/1000 | 1/1000 |
| ISO | 6400 | 6400 |
| F-number | 5.6 | 5.6 |
| GPS | None | None |
| Flash | No Flash | No Flash |

**Q9. Field of view**

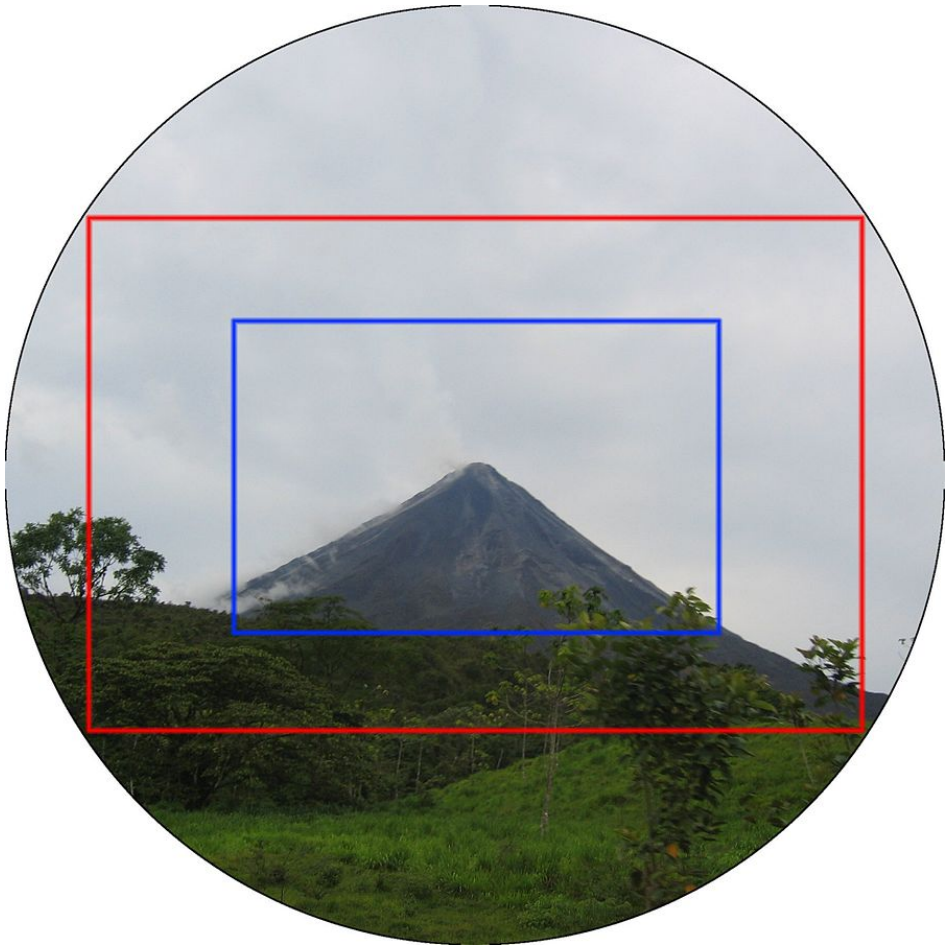
In photography, the field of view is the part of the scene which is observable by the camera. There are two factors that affect the field of view: 1. The focal length and 2. The size of the sensor.

As we discussed in the previous part (Q8), the longer the focal length, the narrower field of view (see image 1). In fact, image 1 has a greater focal length in comparison to image 2, resulting in a narrower field of view.

| Metadata | Image 1 | Image 2 |
|---|---|---|
| Image |  |  |
| Make | Canon | Canon |
| Model | Canon EOS Rebel T6 | Canon EOS Rebel T6 |
| Data and time | 2019:02:04 11:10:54 | 2019:02:04 11:10:46 |
| Image file type | JPEG | JPEG |
| Resolution | 5184 x 3456 | 5184 x 3456 |
| Focal length | **49.00 mm** | **18.00 mm** |
| Exposure | 1/1000 | 1/1000 |
| ISO | 6400 | 6400 |
| F-number | 5.6 | 5.6 |
| GPS | None | None |
| Flash | No Flash | No Flash |

Also, speaking about the size of sensor, as the size of image sensor increases, the field of view would be wider. I found an image in Wikipedia website to show the effect of the size of sensor on the field of view.

The outer, red box, displays an image related to a 24×36 mm sensor, and the inner, blue box, displays an image related to a 15×23 mm sensor.

| Metadata | Image 1 |
| --- | --- |
| Image |  |
| Make | N/A |
| Model | N/A |
| Data and time | N/A |
| Image file type | N/A |
| Resolution | N/A |
| Focal length | N/A |
| Exposure | N/A |
| ISO | N/A |
| F-number | N/A |
| GPS | None |
| Flash | N/A |