

Task04: Camera Sensor and Digital Image

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

Answer: Performance of an image sensor can be determined by a number of factors including dynamic range and signal-to-noise ratio. As the size of the sensor increases, both of these properties improve. It can be explained by the fact that the number of pixels in a captured image depends on the size of the sensor. A bigger sensor increases the resolution of the captured image and hence can be considered a "good" image sensor.

High-end DSLR cameras include high quality image sensors and other components (camera body, image sensor, lens etc.) of very high quality which aid in improving the quality of image they can capture. All of this has to be included while keeping the size and weight portable for the camera. These factors make high-end DSLRs expensive.

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

Answer: Optical Zoom: This can be thought of as "true zoom". It works by adjusting the focal length of the camera to increase or decrease the zoom level. It takes place with a physical change in the camera system while changing the magnification level. It produces much high quality zoomed images as compared to digital zoom.

Digital Zoom: Can be thought of as a "synthetic data augmentation" where a part/zone of an image is identified, cropped out and resized to the resolution of the camera sensor. If the camera is high quality, and the resolution is high, the loss in quality may be negligible. It is a post-processing step.

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



Answer: Apple introduced triple camera setup in a "stove-top" style layout for the iPhone 11 Pro and Pro Max. Each of the three camera sensors has a specific role to play and is unique in that purpose. The three sensors work with the software to determine which sensor has to be used when to determine the best usage of each. The sensors in the iPhone are mentioned below:

- 12-megapixel primary camera with a 26mm focal length and f/1.8 aperture
- 12-megapixel camera with a 13mm focal length and f/2.4 aperture- Ultrawide camera. This sensor enables to capture a 120° field of view.
- 12-megapixel 2x (Telephoto Camera) with a 52mm focal length and f/2.0 aperture. Higher the focal length (52mm), the camera can capture zoomed in images since the area which can be captured on the image plane reduces, i.e. , "zooming in" is caused.

Q4. Can you search for the unique design or function of the smartphone camera module (not software)? Please rank five cameras and make a short explanation of why they are unique or special.

Answer: *Note: The smartphones have been ranked according to the uniqueness of the feature and not the performance.*

1. **Oukitel WP7 with IR Night Vision Camera:** It is the only smartphone to feature an InfraRed night vision camera. It has the option of attaching modular accessories such as UVC sterilisation attachment and high performance flashlight to enhance its night vision abilities.



2. **Motorola Polaroid Mod for Moto Z:** As a part of its modular camera development for Moto Z, Motorola introduced the Polaroid Insta-Share Printer which attached to the Moto Z magnetically and can print instant pictures without any ink using special "Zink" paper from Polaroid. It can hold 10 sheets of paper and is compatible with any phone in the Moto Z family.



3. **LiDAR on iPhone 12 Pro:** Apple took the high road in depth sensing and portrait photography using the ultimate depth sensing tool: LiDAR (Light Detection And Ranging). It can be thought of as the Face ID sensor with a longer range. LiDAR can do so much more than better photos and has applications in 3D segmentation, architectural modelling, augmented reality to name a few.



4. **Asus Zenfone 7 and 7 Pro:** These phones have a primary rear camera which can pop up and rotate to take front facing selfies. It eliminates the need of including notches or punch holes to include selfie cameras. Additionally, better rear sensors can be used to take selfies.



5. **OnePlus 7T Pro:** OnePlus 7T Pro features an objectively top of the class pop up selfie camera and as a result does not feature any notches or punch holes.



Q5. What kind of phone cameras or phone camera technologies will be introduced in next five years? Talk freely

Answer: I believe that the following technologies have the potential to be the future of phone cameras:

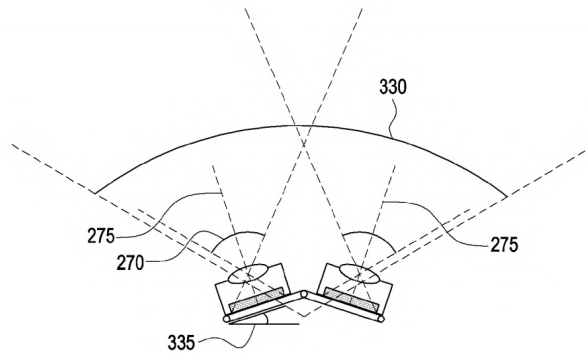
- **Modular phone cameras:** Removable and customisable camera sensors have been in the development for some time now. These cameras will have the potential to be connected, removed and replaced as and when required according to the scene being captured. This will be a step closer to removing the boundary between DSLR Camera and Phone Camera. *Note:* Motorola briefly introduced Hasselblad True Zoom in 2016 mod as a part of its Moto Mods program which could be attached to Moto Z with a magnetic back (image included below):



- **In-display selfie camera:** The ugly and distracting display notches and pop cameras can be a thing of the past if this technology is refined in the next few years. "ZTE Axon 20 5G" (image included below) managed to put out the phone with this technology amidst mediocre reviews. Photos taken with its selfie camera have been called "hazy, weak colors, and soft" by [reviewers](#). If behind-the-scenes technologies such as metamaterials, pixel demosaicing and pixel filters can be perfected, this can be the standard feature in all smartphones within the next 5 years.



- **Multiple Sensors with Tilting Mechanism:** Samsung patented a technology which uses an array of 6 cameras with tilting capabilities. (Source: <https://www.androidpolice.com/2020/06/18/samsung-patents-a-crazy-6-camera-tilting-array-for-smartphones/>). The unique technology will be used to take panoramic landscapes with bokeh effect.




Q6. Shutter speed (Exposure time)

Answer: Shutter speed or exposure time as the name suggests indicates the duration for which the camera sensor is exposed to light, i.e, for how long the shutter remains open.

For example, 1/100 means 100th of a second. The higher this value is, the more light falls on the sensor (which is why Image 2 below is brighter). Longer shutter time is recommended for capturing still objects with very faint light, such as far away stars. Shorter shutter time is used to capture fast moving objects such as cars in Grand Prix.

METADATA IMAGE 1

IMAGE 2

METADATA IMAGE 1		IMAGE 2
Image		
Make	OnePlus	OnePlus
Model	KB2001	KB2001
Data and time	2021:02:21 17:58:30	2021:02:21 17:58:42
Image file type	JPEG (old-style)	JPEG (old-style)
Resolution	3000 x 4000	3000 x 4000
Focal length	4.7 mm	4.7 mm
Exposure	1/160	1/15
ISO	3200	3200
F-number	1.8	1.8
GPS	None	None
Flash	Off, Did not fire	Off, Did not fire

Q7. Aperture

Answer: The instructor's images have been used since my phone cameras (OnePlus 5 and OnePlus 8T) do not have an option to switch sensors (both phones have more than one camera sensor) while keeping other camera settings constant.

Aperture is the size of the opening in the lens. It determines the exposure. It also determines how much of an image is in focus.

A small F-Stop means a larger opening since $F \text{ number} = \frac{\text{focal length}}{\text{lens opening}}$. A larger opening means more light is captured, however, it also means that a part of the image is in focus and the background is unfocused. The converse of the previous statement also holds true.

Small apertures (large F-stop) can be used in scenes where more depth of field is required to be captured (more of image is sharp).

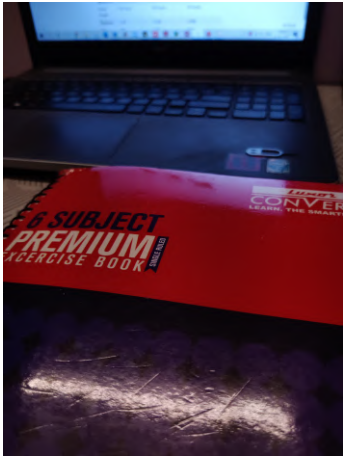
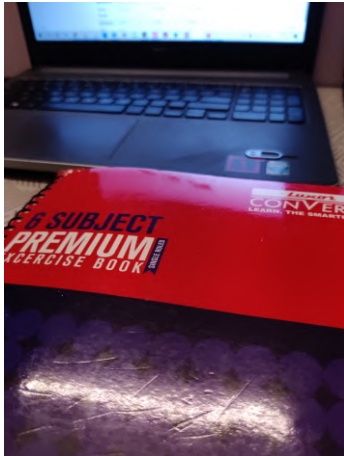

In the following demonstration, Image 1 (smaller F-stop, larger aperture) is brighter and the background is more blurred as compared to Image 2 (bigger F-stop, smaller aperture) because of the above mentioned reasons.

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 11:11:37
Image file type	JPEG (old-style)	JPEG (old-style)
Resolution	5184 x 3456	5184 x 3456
Focal length	49.0 mm	49.0 mm
Exposure	1/1000	1/1000
ISO	6400	6400
F-number	5.6	11
GPS	None	None
Flash	Off, Did not fire	Off, Did not fire

Q8. ISO

Answer: ISO determines how sensitive the camera sensor is to the light. Higher ISO is more sensitive and is hence preferred for night time photography. Conversely, lower ISO is recommended for daylight photography.

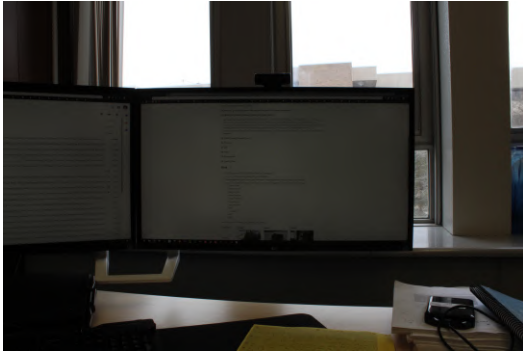

Generally speaking, higher ISO means brighter images as can be seen below where the ISO doubles from 800 to 1600 and then to 3200.

METADATA	IMAGE 1	IMAGE 2	IMAGE 3
Image			
Make	OnePlus	OnePlus	OnePlus
Model	KB2001	KB2001	KB2001
Data and time	2021:02:21 18:18:39	2021:02:21 18:18:35	2021:02:21 18:18:30
Image file type	JPEG (old-style)	JPEG (old-style)	JPEG (old-style)
Resolution	3000 x 4000	3000 x 4000	3000 x 4000
Focal length	4.7 mm	4.7 mm	4.7 mm
Exposure	1/125	1/125	1/125
ISO	800	1600	3200
F-number	1.8	1.8	1.8
GPS	None	None	None
Flash	Off, Did not fire	Off, Did not fire	Off, Did not fire

Q9. Flash

Answer: The instructor's images have been used since my phone cameras (OnePlus 5 and OnePlus 8T) do not have an option to force-change flash option in professional mode.

Flash helps to illuminate scenes with artificial light in cases where there is not sufficient natural light available to capture certain details in an image.



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	2019:02:04 11:53:00
Image file type	JPEG (old-style)	JPEG (old-style)
Resolution	5184 x 3456	5184 x 3456
Focal length	18.0 mm	18.0 mm
Exposure	1/200	1/200
ISO	1600	1600
F-number	20	22
GPS	None	None
Flash	Off, Did not fire	On, Fired

Q10. Focal length

Answer: The instructor's images have been used since my phone cameras (OnePlus 5 and OnePlus 8T) do not have an option to switch sensors (both phones have more than one camera sensor with different focal lengths) while keeping other camera settings constant.

Focal length for a camera with lens is the distance between the aperture (lens) and the point at which parallel rays intersect.

When focal length is reduced (lets say halved), it can capture more scenes/objects (zoom out effect) and all the light becomes concentrated in a smaller area. Thus, reducing focal length results in zooming out and brighter image. The converse is also true. These effects can be seen below where Image 1 is zoomed in and darker (higher focal length) when compared to Image 2 which is zoomed out and brighter (because of lower focal length).



METADATA IMAGE 1		IMAGE 2
Image		
Make	Canon	Canon
Model	Canon EOS Rebel T6	Canon EOS Rebel T6
Data and time	2019:02:04 11:55:33	2019:02:04 11:55:37
Image file type	JPEG (old-style)	JPEG (old-style)
Resolution	5184 x 3456	5184 x 3456
Focal length	55.0 mm	18.0 mm
Exposure	1/200	1/200
ISO	1600	1600
F-number	20	20
GPS	None	None
Flash	Off, Did not fire	Off, Did not fire

Q11. Field of view

Answer: The instructor's images have been used since my phone camera (OnePlus 8T) does not have an option to switch sensor to wide angle in the professional mode while keeping other camera settings constant.

Field of view in camera terminology is defined as the extent (range) that can be observed by the camera. It is affected by the focal length and the sensor size.

By increasing the focal length (Image 2), the camera observes less of a scene (narrower viewing). A larger sensor size facilitates broader viewing since more of the scene can be mapped on the sensor.



METADATA IMAGE 1		IMAGE 2
Image		
Make	Canon	Canon
Model	Canon EOS Rebel T6	Canon EOS Rebel T6
Data and time	2019:02:04 11:10:46	2019:02:04 11:10:54
Image file type	JPEG (old-style)	JPEG (old-style)
Resolution	5184 x 3456	5184 x 3456
Focal length	18.0 mm	49.0 mm
Exposure	1/1000	1/1000
ISO	6400	6400
F-number	5.6	5.6
GPS	None	None
Flash	Off, Did not fire	Off, Did not fire

Q12. Aperture and shutter speed priority (A- and S-mode)

Answer: The instructor's images have been used since A- and S- are DSLR Camera options not available in my phone cameras (OnePlus 5 and OnePlus 8T).

In **aperture priority mode (A- Mode)**: The depth of field is chosen by the user by adjusting the aperture size, i.e, the user can set the aperture size such that the background is blurred and the object in the foreground is sharp (example: portrait mode). The camera automatically decides the shutter speed to be compatible with the user chosen aperture size. In Image 1, the background is heavily blurred by choosing the aperture size accordingly and the camera automatically set the shutter speed (exposure) as 1/100 s.

In **shutter priority mode (S- Mode)**: The user determines the shutter speed and the camera adjusts the aperture size accordingly to capture an image. It can be used to capture fast moving objects such as athletes competing in the Olympics. It can also be chosen to capture according to the light available to capture a scene (as discussed in Q6). In Image 2, the exposure mode is manual which means that the shutter speed (1/1000) was chosen by the user depending on the lighting conditions to capture the scene.

METADATA	IMAGE 1	IMAGE 2
Image		
Make	Canon	Canon
Model	Canon EOS Rebel T6	Canon EOS Rebel T6
Data and time	2019:01:30 11:11:43	2019:02:04 11:10:54
Image file type	JPEG (old-style)	JPEG (old-style)
Resolution	5184 x 3456	5184 x 3456
Focal length	55.0 mm	49.0 mm
Exposure	1/100	1/1000
ISO	200	6400
F-number	5.6	5.6
GPS	None	None
Flash	Off, Did not fire	Off, Did not fire
CanonExposureMode	Aperture-priority AE	Manual