

# Problem Set 5

Due 11:59PM ET on Thursday, November 12, 2014.

Staff email: [staff@dme10.org](mailto:staff@dme10.org)

Submit this problem set at <http://digitalphotography.exposed/submit>

By the deadline, type your answers in any word processing application you wish and export your document in Portable Document Format (PDF) for submission. If you prefer, you may write out the problems on a sheet of paper, scan that, and submit the scanned document as a PDF. Before the due date, visit the submission tool to upload to the staff.

**Unlike prior problem sets, this one is divided into two sections: one for undergraduates only and one for graduates only. If you are enrolled as a graduate student, you must complete the graduate section for full credit. If you are an undergraduate, you may choose to complete either section, but you must complete only one. No extra credit is offered for completing both sections. We will grade only one section that you submit to us.**

## Undergraduates

1. (5 points) What are two advantages of JPEG over RAW?
2. (5 points) Which color space should you employ for general use?
3. (5 points) Why is white balance measured in degrees Kelvin?
4. (5 points) List two reasons why batteries in digital SLRs tend to last longer than those in compact digital cameras.
5. (10 points) Why is calibrating your monitor important?
6. (10 points) What is a tone curve and why is it necessary?
7. (10 points) Explain what a crop factor is. What are the implications of having a small or large crop factor?
8. (10 points) Assume you have two sources of light: an incandescent light at an approximate color temperature of 3000 K, and the sun with an approximate color temperature of 6000 K. Which source produces warmer tones? Consider taking a properly-exposed photograph of a white sheet of paper in each of these two lighting situations with your camera set at a white balance of 4500 K; in which photo would the white sheet of paper appear warmer?
9. (10 points) Photons hit a photodiode on the sensor and this causes an increase in voltage. The task of an analog-to-digital converter (ADC) is to sample this data and convert it to a digital value. What are the differences between 8-bit, 10-bit, 12-bit, and 14-bit ADCs? More specifically, how does the number of ADC bits impact the dynamic range and tonal range of an image? Be sure to reference sensor linearity.
10. (10 points) Explain why the notion that compact digital cameras have a larger depth of field than digital SLRs is somewhat oversimplified.

11. (10 points) Explain (in a few sentences) what are the major theoretical advantages and disadvantages of the Foveon X3 sensor compared to sensors that use Bayer filters or other color filter arrays. Your response should include all of the major functions of a sensor: resolution, noise, and light gathering performance. You may use a diagram, but only to complement, not replace, your explanation.
12. (10 points) A CCD or CMOS sensor that uses a color filter array (*e.g.*, a Bayer filter) will typically have the following layers: photodiode, low pass filter, color filter array, microlens, and electronic/sensor well. What does each layer do? How does each layer impact image quality?

## Graduates

*Students registered as graduates must complete this section.*

The New Horizons probe was launched in 2006 to study Pluto and its moons. Onboard the craft is an imaging system called the Ralph telescope, which was responsible for this amazing image (among many others):

<https://www.nasa.gov/image-feature/the-rich-color-variations-of-pluto>

An in-depth scientific paper on Ralph's capabilities is available from the Southwest Research Institute's Department of Space Operations website at the following link:

<http://www.boulder.swri.edu/pkb/ssr/ssr-ralph.pdf>

Please download and read that document to help you answer the following questions.

1. (5 points) The Ralph instrument is made up of a telescope and two focal planes: Multi-spectral Visible Imaging Camera (MVIC) and Linear Etalon Imaging Spectral Array (LEISA). How does the instrument provide an image focused by the telescope to both of these imagers?
2. (5 points) What is the "equivalent" focal length of the telescope, in terms of a field of view comparable to a lens on a 35mm camera?
3. (5 points) As described in the paper, there are 7 CCD sensors in MVIC; six of them have a size of 5024 pixels by 32 pixels while another has a size of 5024 pixels by 128 pixels. What does each CCD do?
4. (5 points) It turns out that Ralph has another lens other than the main telescope. What is this lens used for?
5. (10 points) The MVIC imager in the Ralph telescope uses a clever mechanism to capture an image that is much taller than the 32 pixel height of the sensor. How does it work? Are there any consumer digital cameras that use a similar mechanism?
6. (10 points) Given the way MVIC captures an image, what is the advantage to giving each CCD 32 pixels of height, rather than only 1?
7. (10 points) How do the spectral capabilities (in other words, color detection) of the two imagers (MVIC and LEISA) compare to human vision?

8. (10 points) On page 6, the authors describe the optimal “integration times,” which we can consider analogous to shutter speed, of the various CCDs in the MVIC imager: 0.4 seconds for the “pan band” sensors but 0.6 seconds for the “color bands.” Since all of the CCDs in the MVIC are the same technology (and, therefore, the same sensitivity), why would the color CCDs require a longer exposure time than the panchromatic CCDs?
9. (10 points) Once New Horizons was in flight, scientists tested the camera to ensure proper operation. However, they found a problem with the system that they describe in section 6.4, “Anomalous Solar Light Leak.” What is the problem? What two methods do they describe to resolve it?
10. (10 points) New Horizons has been in flight for many years. The photographs we've seen of Pluto were taken from an imager that was not created the same year it captured those images, but instead from a time before the mission was launched. First, estimate the year that Ralph was designed. Identify a high-quality digital camera available to consumers at around the same time, and compare the capabilities of the two.
11. (10 points) Ralph is not the only imaging device on New Horizons. Find some information on a companion imager, LORRI, and briefly compare the capabilities of the two imaging instruments.
12. (10 points) List two things not discussed above that you consider unique to this imaging system compared to consumer digital camera systems we use on Earth. When you do so, provide a quotation from the paper with a reference to a page number that includes a description of the feature and describe why it is unique.