

Guidelines for 6.163 Laboratory Memos

1. Collaboration Policy

While you will conduct your laboratory exercises in your four-person lab groups, you will prepare your laboratory memos in 6.163 as an individual effort. You, personally, are expected to:

- Write essentially all of the text on your own (and cite your source when quoting text written by someone else).
- Create *every* photographic print included in your report. (Under certain circumstances we will permit the inclusion of prints made by a commercial photo lab, but you must receive permission in advance to do so.) Note that this means you cannot submit prints in your report that another student created.
- Create your own diagrams of your apparatus. You may use images and diagrams from public sources, if you cite the source. However, it not permissible for one student to create a setup diagram for use by other students in the subject.
- Create your own graphs and tables based on your recorded data and images.

You are encouraged to discuss with others -- particularly your lab partners -- general topics such as what approach to take when analyzing data, how to improve a photographic print you have already made, or how best to present a calculated result. However, you may not seek out such advice until you have first made a substantive effort to answer your question on your own.

If you have any doubt as to whether a particular act of collaboration is allowed, please send an email to Dr. Bales and the TA for clarification.

2. Structure of the Memo

As this is a memo, your document should open with the transmittal block:

To: *name of recipient*

From: *your name*

Date: 7 February 2005

Subject: Example of a transmittal block

IM-123JWB

(Optional string identifying which memo this is)

The memo should contain the sections described below. If you find any of this description confusing, turn to the sample memo at the end for an example.

Summary and Recommendations

This section is for you manager or boss—they believe that you are competent, that your procedures were correct, and your conclusions are valid. They want to see

- A brief (yet *specific*) description of what you did and found
- Specific recommendations on what should be done next. Make the recommendations simple and clear—enumerating with bullet points is a good way of doing so.

Background

This section should tell your reader

- The significance of what you did
- Any information they need to understand your work
- The goals of your work (i.e., what you hoped to learn or accomplish)

As a general rule, if you know something before you walk into lab, it belongs in the background. This is a good place to introduce the answers to your pre-lab questions and the derivation of equations required for the pre-lab. You must number all of the equations you put into your memos. You can then refer your equations by number later in the memo, or in future memos.

Procedure

Your goal here is to describe what you did with enough detail that someone skilled in the art can replicate your work. You must include a *list* of the *equipment* you used to carry out the experiments, including the manufacturer, the model number, and a unique identifier such as a serial number, MIT property number, or Strobe Lab identifier (e.g., Photocell Dotty). If you forgot to record a serial number, put “did not record” in the table. If there was no serial number, put “not available” in the table. In addition, include set-up diagrams (and set-up photos, if you have them) to help us understand how you arranged your equipment.

Narrative text is strongly preferred over a numbered list of steps. If the procedure is long, use sub-headings to break it into logical chunks and provide an overview of the entire procedure before you go into full detail on the first chunk.

Results

This is where you tell us what you found. There should be no interpretation or discussion of the results. Results can include:

- Photographs
- Graphs of measured quantities
- Tables of measurements and descriptions of what you observed
- Text descriptions of your observations

For example, you may have taken a multi-flash image of a ball falling under the force of gravity. From your image, you measure the distance the ball falls between each flash. The image and the measurements go into the *Results* section. If you want to calculate the acceleration the ball experienced, or its velocity as a function of time, or any other quantity not directly measured, the result of those calculations go into the *Discussion* section.

There is an exception. If a single table presents both measured quantities (e.g., the positions and times from the example above) and derived quantities (e.g., the velocities and accelerations from the example above), the table should be placed in the *Results* section, but any references in your text to derived quantities should appear in the *Discussion* section.

Discussion

Here you want to tie your results back to the goals you stated in the *Background*. All of the results you present must be discussed. Among other things, you will want to tell us:

- What generalizations and conclusions (if any) you might make from your data
- What are the potential sources of error in your measurements, how might these errors be reduced?
- What is the magnitude of the error sources? Estimate these if you must. They might be a percentage of a value (e.g., $\pm 5\%$ of dial reading) or an absolute value (e.g., ± 20 milliseconds)
- If you were to do this over again, what would you do differently?
- What future work is required (if any)

If you need to perform calculations to go from measured quantities to the quantities of interest, the results of the calculations go here, not in the results section (see the explanation of the *Results* section, above).

References

List any references you cited in your text.

Laboratory Notes

Attach the copy (or a photocopy) of your lab notes at the end of your memo.

3. Style

The memo is meant to be less formal than a research paper, so you may use pronouns such as “you,” “I,” and “we” as you see fit. There are a few common issues relating to style.

Inserting Photos

Photographs must be mounted onto the page. You may use tape, self-adhesive corners, staples, or clear plastic sleeves. Each photo must be a Figure in the memo, complete with Figure number (see the section on Figures below for details on how to label figures). Note, your prints need not be 8" by 10", and, in fact, are sometimes more effective if they are smaller.

Inconsistent Tenses

If you change the tense of the verbs partway through your text, you will confuse your reader. For example, “Attach the lens to the camera, then the tripod was positioned, and finally focus the camera” incorrectly goes from present tense to past and then back to present tense.

Spelling

Your memo may be handwritten, but if so, it must be neat and legible. Use white-out to correct errors. If your report is printed from a computer, you are assumed to have a good spell checker and know how to use it. In either case, we will mark off for spelling errors.

Figures and Figure Captions

A figure caption goes below the figure and has two or three parts. The first part is the word “Figure” followed by the *figure number*. The second part is the *title* of the figure, which (although it is not a sentence, as it has no verb) begins with a capital letter and ends with a period. The title should not be “Plot of Intensity vs. Time.” – we can tell that by reading the axes. Instead, the title should indicate the significance of the plot, such “Light Intensity Curve for Strobotac #4.” Look at the figure captions in the sample memo.

The last part of a figure caption is the optional *description*, where you write text to describe the figure. In general, you should make your descriptions more complete rather than less complete. I recommend that you assume that some readers will only read the figure caption and not the full text of your memo. So, you want a knowledgeable reader to be able to look at the figure, read the caption, and understand the point you are trying to convey. (Again, look at the sample memo.)

If the figure is a photograph, then I strongly recommend that the description include the details on how the image was taken (*f*/stop, lens, film speed, shutter speed if appropriate) and how the print was made (enlarger, enlarger *f*/stop, exposure time, paper type, and any additional efforts such as burning or dodging). If this information is not in the caption, it *must* be in the text where you refer to that figure. (It is OK to have a Table in the results section listing the photos, their figure numbers, the camera settings, and the enlarger settings. The Figure Caption can then include a statement like "See Table X for details on how this print was created".)

Each figure *must* be referred to in the text of your document. If your text doesn't refer to a Figure, then it is not needed. A reference to a figure should read "Figure 1", "Fig. 3", etc. Notice that "Figure" (or "Fig.") is always capitalized when followed by the figure number.

Your figures should be large enough to read clearly. If in doubt, make them too large rather than too small. This does not mean that all prints should be 8" x 10" – often you will get a more aesthetically pleasing image at a smaller enlargement. Similarly, if you have four images showing the time evolution of an event, it is much more effective to put the four prints on the same page (and hence they can't be 8" x 10"!).

You should provide set-up diagrams. It is generally best to mark the distances between components on the diagrams themselves. Your figures may be hand-drawn as long as they are neat. If you hand draw them, and you are not using a straight-edge, they are probably not neat! Sometimes, you may want to photograph your setup instead of drawing the diagrams—use your judgment in deciding which is better at explaining that particular setup. If you photograph your setup, you may find it helpful to write on the photo (a pen with white or silver ink can help).

Table Captions

A table caption goes above the table and has two parts. The first part is the word "Table" followed by the *table number*. The second part is the *title* of the table, which begins with a capital letter and ends with a period. The title should be informative—"Comparison of Strobotach Dial to Oscilloscope Measurement of Flash Rate." not "Results of the Experiment." Note that (unlike a figure caption) a table caption has no description.

3. Sample Memo

A sample memo follows. Each author (or each organization) creates their own scheme for assigning a unique identifier to each memo. Your memos concerning your labs will typically be longer than this one, as you are doing more work than was done for the sample.

Sample Memo

To: Dr. Bales, VP for R&D
From: Strobe Student
Date: 11 February 2009
Re: Method for measuring strobe intensity in the lab
IM151-SS

Summary and Recommendations

We tested a new method of measuring the intensity of a strobe in the lab by comparing the laboratory measurements of one of our strobes against earlier photographic measurements made with the same unit. We found that this method (using one of the old vacuum photocells we recently rediscovered) is accurate enough for our purposes, and is significantly easier than our previous methods. Additionally, we found that our Acme Products, Ltd. HUMS electronic flash unit does not meet the manufacturers specifications. The intensity of the flash is only 2/3 of the specified value, and the flash duration is four times longer than specified.

We recommend that:

- The method presented here become the standard method for measuring the BCPS of a strobe
- We test (and calibrate, if need be) the rest of the vacuum photocells
- We disseminate the procedure for measuring BCPS to all strobe users
- We tell our legal and purchasing departments about the deficiencies in the HUMS unit

Background

We need a simple, reasonably accurate method of measuring the BCPS output a strobe in the laboratory. The BCPS of a strobe is a parameter that characterizes the intensity of the strobe in the center of the beam of light it emits. The BCPS is used to determine the correct camera settings when using that strobe by applying the relationship

$$D \times A = \sqrt{\frac{BCPS \times s}{c}}, \quad \text{Eq. 1}$$

where D is the strobe-to-subject distance in feet, s is the speed of the film (in ASA number), $BCPS$ is the intensity of the strobe in Beam Candlepower-Seconds, and c is a constant equal to 20 for the units above.

Until now, when we wanted to measure the BCPS output of a strobe we used this procedure:

1. Set up a static test subject
2. Place the strobe a fixed distance away from the subject (usually 1' for strobes that appear to be weak, 5' for strobes of average intensity, and 10+ feet for strobes that appear to be unusually intense)
3. Lighting the subject with only the strobe under test, take a series of photographs that span the range of f/stops available.
4. Develop the film
5. Select the best-exposed negative, and back calculate the BCPS from the aperture setting for that exposure and Equation 1.

This is a laborious and time-consuming process, which we can avoid if we have a method of directly measuring the BCPS in the laboratory.

In a recent clean-up of our storage spaces, we found a set of vacuum photocells, each integrated into an enclosure (Figure 1), designed for measuring the instantaneous light intensity from a strobe – i.e., $BCP(t)$. These units are labeled “Dottie,” “Dolly,” and “Diana”. We opened the enclosures and found labels stating that they had been built by the late Professor Edgerton and his assistant, Mr. Bill McRoberts. We then turned to Edgerton’s text on strobes [1] and found a schematic diagram for these devices and a description of their operation.

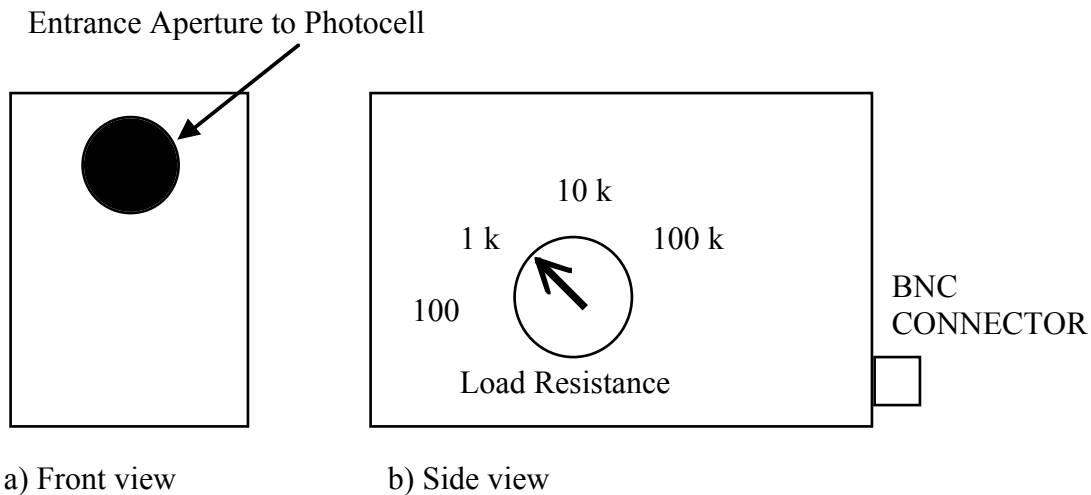


Figure 1. Front and side views of the photocell Dottie. The entrance aperture is covered by a Kodak Wratten filter (#106).

The vacuum photocell unit produces a voltage that is proportional to the instantaneous light intensity that strikes the photocell. The relationship between the output voltage V and the incident, instantaneous light intensity $BCP(t)$ is given by

$$BCP(t) = \frac{KV(t)D_{PHOTOCELL}^2}{R_L}, \quad \text{Eq. 2}$$

where $BCP(t)$ is the incident light intensity (in Beam Candlepower) $D_{PHOTOCELL}$ is the distance from the strobe to the photocell (in feet), $V(t)$ is the output voltage (in volts), K is a calibration constant (37.3×10^6 BCP-Ohms/volt/ft² for Dottie) and R_L is the load resistance (in ohms), as set by the knob on the side of the photocell.

Figure 2 shows a typical $BCP(t)$ curve for a strobe. According to Edgerton [1], the BCPS of the strobe can be estimated as

$$BCPS = BCP_{PEAK} \times \Delta t_{1/3}, \quad \text{Eq. 3}$$

where BCP_{PEAK} is the maximum BCP output from the strobe and $\Delta t_{1/3}$ is the time during which the strobe intensity exceeds 1/3 of its peak value (Figure 2).

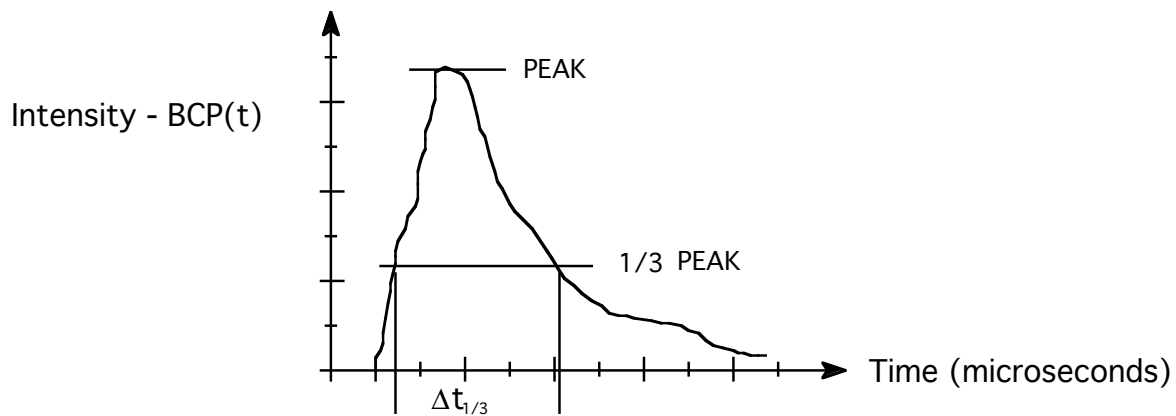


Figure 2. A typical intensity curve for an electronic flash. The BCPS is approximately equal to the peak BCP times $\Delta t_{1/3}$.

There is a chart on the top of the photocell that lists the maximum voltages that can be considered valid for each setting of the load resistor. If a voltage is observed that exceeds these values, either the load resistance must be reduced, or the strobe moved further away from the photocell. Similarly, for each load resistance, there is a minimum value for $\Delta t_{1/3}$ that can be reliably measured. (The minimum value for $\Delta t_{1/3}$ increases linearly with the load resistance.) If the observed $\Delta t_{1/3}$ is less than five times the time response listed for the load resistance in use, the photocell must be switched to a lower load resistance.

According to Edgerton's text, by following the procedure laid out in the next section, we can measure the intensity of a strobe in the lab in just a few minutes using the strobe under test, a vacuum photocell, an oscilloscope, and a tape measure. This would represent a major improvement over our previous method.

We used our Acme Products, Ltd., Hyper-Ultra-Mega-Strobe (HUMS) as the test strobe, as we have recently used the old method to determine its $BCPS$ to be 50 $BCPS$. This much less than the manufacturer's specification of 75 $BCPS$ [2]. The manufacturer also specifies that the HUMS has a flash duration ($\Delta t_{1/3}$) of 1 μs , and a flash-to-flash repeatability of +/- 10% for the $BCPS$ [2]. We can use the measurements from the photocell to compare the true performance of the HUMS against these specifications as well.

Our goals were:

- To determine if any of these vacuum photocells can be used to measure the $BCPS$ output of a strobe in the laboratory
- To calibrate at least one vacuum photocell for use in the lab
- To write a procedure for measuring the $BCPS$ of a strobe using a vacuum photocell
- To evaluate if the HUMS electronic flash unit meets manufacturer's specifications.

Procedure

Table 1. Equipment used to measure the BCPS of a strobe

Item	Manufacturer	Model	S/N
Strobe	Acme Products, Ltd.	Hyper-Ultra-Mega-Strobe	0001
Tripod	Silk	9710	n/a
Vacuum Photocell	MIT Strobe Lab	n/a	Dotty
Oscilloscope	Boondoggle Electronics	X-101	5321-0746

Set-up

The equipment used to conduct this experiment is listed in Table 1. Figure 1 shows a front and side view of a vacuum photocell. We placed the photocell on a bench, with the side containing the entrance aperture lined up with the edge of the bench. This prevented light reflected from the bench from entering the photocell, which would lead to an over-estimate of the strobe intensity.

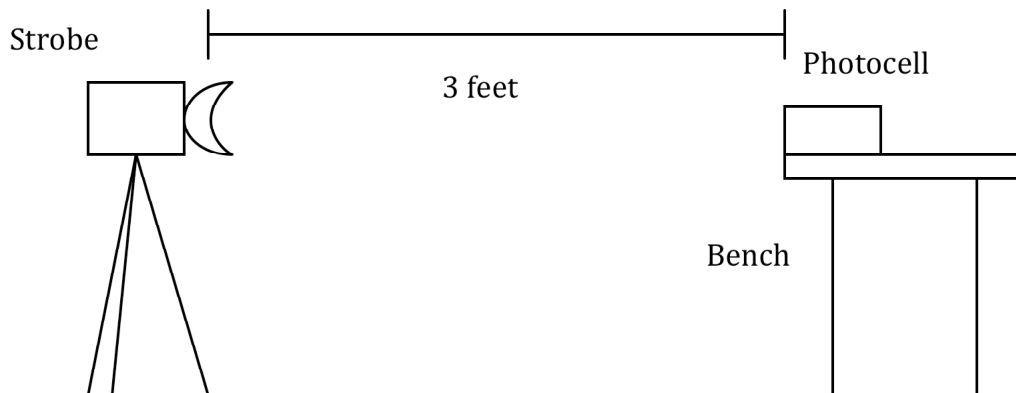


Figure 3. Setup for measuring the BCPS of a strobe. The strobe and photocell are the same height from the floor. The leading edge of the photocell is lined up with the edge of the edge of the bench to avoid reflections from the top of the bench.

We set the Acme Hyper-Ultra-Mega-Strobe (HUMS) on its tripod and positioned it 3 feet from the photocell, as shown in Figure 3. We adjusted the tripod so that the axis of the beam of light from the strobe was parallel to the floor and its brightest portion (the "hot spot") was centered on the entrance aperture of the photocell. We adjusted the photocell so that its entrance aperture was perpendicular to the beam from the strobe. The output from the photocell was connected to input channel 1 of the oscilloscope (Figure 4). The oscilloscope was set to trigger off of channel 1, and was in the normal triggering mode.

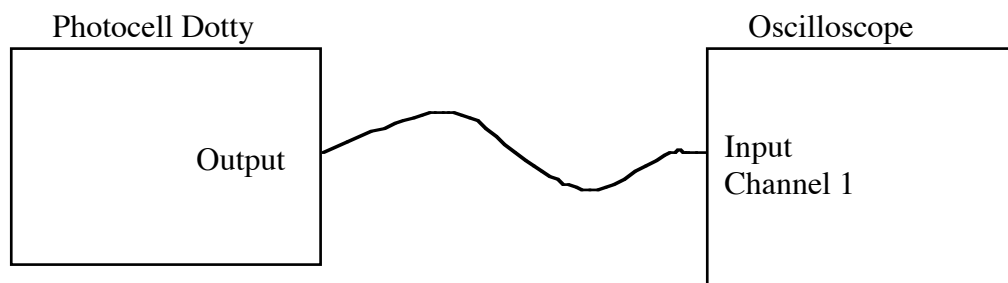


Figure 4. Electrical connections measuring the intensity of a strobe. The oscilloscope was triggered from Channel 1, in the normal trigger mode.

Data collection

We set the load resistor on Dotty to its lowest value (100 ohms) and fired the strobe several times while adjusting the voltage sensitivity and trigger level on the oscilloscope. As we had difficulty obtaining a good trace on the oscilloscope, we changed the load resistance to 1 k Ω and quickly found a signal. Next, we fired the strobe several times, adjusting the aim of the strobe and the photocell until we found the greatest peak voltage on the oscilloscope. We then considered the two units to be pointed directly towards each other.

We fired the strobe one last time, and found that voltage was greater than the maximum reliable voltage as listed on Dotty, so we reset the load resistance to 100 Ω . With the improved alignment, we had no trouble obtaining a usable trace. We recorded the results for 10 successive flashes to get some sense of the reproducibility of the measurement.

Results

Table 2 presents the results of our measurements on the HUMS unit.

Table 2: Results of vacuum photocell measurements of HUMS

Flash Number	V_{PEAK}	$\Delta t_{1/2}$	$D_{PHOTOCELL}$
1	3.3 V	4.3 μ s	3 feet
2	3.4 V	4.2 μ s	3 feet
3	3.4 V	4.4 μ s	3 feet
4	3.2 V	4.3 μ s	3 feet
5	3.3 V	4.2 μ s	3 feet
6	3.2 V	4.3 μ s	3 feet
7	3.3 V	4.2 μ s	3 feet
8	3.3 V	4.3 μ s	3 feet
9	3.2 V	4.4 μ s	3 feet
10	3.2 V	4.4 μ s	3 feet

Discussion

Calculations

From our results, we used Equation 2 to calculate the peak intensity (BCP_{PEAK}). Inserting the peak intensity and flash duration into Equation 3, we calculated the integrated BCPS output of the strobe for each flash. We then averaged the BCPS and the flash duration measurements over the 10 test firings of the HUMS unit.

Table 3 summarizes our findings. The average flash duration ($\Delta t_{1/2}$) is 4.3 μs , over four times longer than the specified 1 μs . The average flash intensity of the unit is measured to be 49.3 BCPS. This is very close to the 50 BCPS result obtained from film, and is only two-thirds the manufacturer's specification.

Table 3: Calculated BCPS measurements compared to manufacturer's specifications

Average measured BCPS	Accepted BCPS (from photos)	Specified BCPS	Measured Flash Duration (μs)	Specified Flash Duration (μs)
49.3	50	75	4.3	1.0

Evaluation of Method

Even though the photocell Doty has not been calibrated since the mid-1970's, we found that its results are sufficiently accurate for our purposes. The calculated BCPS values are within a few percent of that determined from photographs. The variation from flash to flash was less than 5%, well within the manufacturer's 10% specification for the HUMS electronic flash unit.

We found this method to be easy to use, once we got the hang of getting the oscilloscope to trigger reliably. We recommend that it become the standard method for determining strobe BCPS in the lab.

Evaluation of HUMS Electronic Flash Unit

This piece of equipment does not perform to its stated specifications, as demonstrated in Table 3. The intensity of the flash is significantly weaker than the manufacturer claims and the duration of the flash is four times longer than specified. We suggest that the matter be referred to our legal department, and that you suggest to your counterpart in purchasing that we stop doing business with companies represented by a coyote.

References

[1] "Electronic Flash, Strobe," H. E. Edgerton, 3rd Ed., MIT Press, Cambridge, pp. 235-247, 1987.

[2] "Specifications of the Hyper-Ultra-Mega-Strobe (HUMS)," W. E. Coyote, Acme Products, Ltd., Nowhere, NM, 16 July 1996.