

United States Naval Academy
Electrical Engineering Department
EE411: Electrical Engineering Design I

EXAM I

1. Put your name on the test.
2. There should be 7 pages including the cover sheet.
3. This test is open-book, open-note.
4. Show all your work to receive maximum partial credit. If you make an assumption, state it.
Express your answers with proper units.
5. You have 50 minutes to complete the exam.
6. Each page is scored as follows:

Page	Points	Score
1		
2	20	
3	10	
4	15	
5	25	
6	15	
7	15	
Total	100	

Name: SOLUTIONS

1. (20 points) Joe, a student at a liberal arts college, considers only two criteria when he picks his courses: his level of interest in the material and the cost of the course materials. He weighs these two requirements equally. He is trying to choose between three courses to fill out his senior spring: "physics for poets" (physics), "rocks for jocks" (geology), and "clapping for credit" (music appreciation). The textbook costs for the courses are as follows:

Physics	\$75	$\frac{75}{75}$	$\frac{1}{3} \rightarrow 0.444$
Geology	\$100	$\frac{75}{100}$	$0.75 \rightarrow 0.333$
Music	\$150 (includes several CDs)	$\frac{75}{150}$	$0.5 \rightarrow 0.222$
			2.25

To quantify his interest, he has constructed the following pairwise comparison matrix:

	Physics	Geology	Music	Sum	Weight
Physics	1	3	1/5	4.2	0.251
Geology	1/3	1	1/5	1.53	0.091
Music	5	5	1	11	0.658
				16.73	

Use this information to complete the following matrix and determine Joe's decision:

		Physics	Geology	Music	
Price	0.5	0.444	0.333	0.222	← 3 pts
Interest	0.5	0.251	0.091	0.658	← 10 pts
Score		0.348	0.212	0.440	← 4 pts

MUSIC 2 pts

2. (10 points) MIDN 1/C Dorothy Parker really doesn't want to get the flu. She plans to build system similar to night-vision goggles that will allow her to spot midshipmen who have a fever from a distance so that she can avoid them. For the following statements from her proposal, determine whether they most suitably express a "need" or an "objective."

a. "The use of night vision goggles will allow sick individuals to be identified from a distance."

Need

Objective

b. "During the 1918 flu pandemic, more than 3% of the entire world population died."

Need

Objective

c. "It is difficult to identify a contagious individual from a distance that is sufficient to avoid infection."

Need

Objective

d. "The body temperature of the subject will be determined from their infrared emissions."

Need

Objective

e. "Fevered individuals will be clearly identified in the user's visual display."

Need

Objective

3. (15 points) Which of the following statements from MIDN Parker's Requirements Specification appear to meet the criteria for an engineering requirement? For those that fail to meet the standard, explain why or restate the requirement in a way that would qualify.

a. The unit should consume less than 1 W of power at all times.

Yes

No (why?)

b. The unit should be small.

Yes

No (why?)

AMBIGUOUS
BETTER TO SPECIFY MAX DIMENSIONS

c. The system should have a single control to turn it on and off.

Yes

No (why?)

d. The unit should weigh less than 10 pounds.

Yes

No (why?)

e. The unit should be able to identify individuals with a fever from far away.

Yes

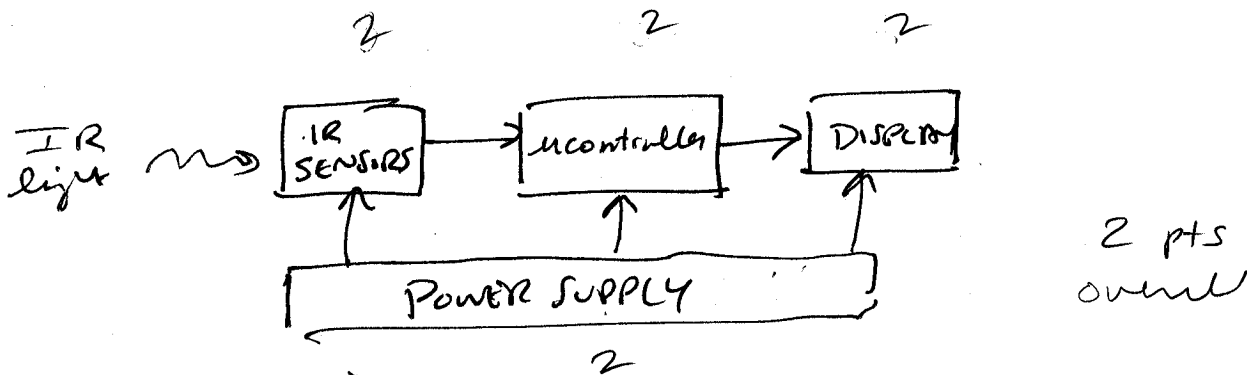
No (why?)

WHAT DEFINES "FEVER"?
HOW FAR AWAY?
AMBIGUOUS & HARD TO MEASURE.

4. (10 points) The level 0 functionality for MIDN Parker's system is as follows:

Module	Remote Infectious Individual Identifier
Inputs	Infrared emissions from subjects in field of view
Outputs	Goggle-mounted, visual display
Functionality	Fevered individuals are highlighted in the display

Specify a possible level 1 system architecture (i.e. block diagram) for MIDN Parker's system. You need not detail the functional requirements of the subsystems.



6. (15 points) In background research related to her project, MIDN Parker determined that the skin temperature for a healthy individual is $33 \pm 1^\circ\text{C}$. The conversion factor for a particular infrared sensor she is considering is $100 \text{ mV}/^\circ\text{C} \pm 5\%$. The voltage output for the sensor is the product of the temperature and the conversion factor. Determine the expected voltage signal and error, in absolute terms (i.e. in units of V), for a healthy individual. Be sure to state your answer with the appropriate number of significant figures.

$$33 \pm 1^\circ\text{C} \xrightarrow{2 \text{ pts}} 33 \pm 3\%$$

$$(33 \pm 3\%)(0.1 \text{ V}/^\circ\text{C} \pm 5\%) = 3.3 \text{ V} \pm 8\% \quad 4 \text{ pts}$$

$$(8\%)(3.3) = 0.264 \text{ V} \quad 3 \text{ pts}$$

$$\boxed{3.3 \pm 0.3 \text{ V}}$$

FORM
3

5. (15 points) The infrared sensor subsystem consists of an array of 100 sensor units. Each sensor unit has a failure rate of 1 failure/ 10^6 hours.

a. Determine the reliability for a single sensor unit in 5 years.

$$\begin{aligned} R(t=5 \text{ years}) &= \exp\left(-\frac{1}{10^6 \text{ hours}} \cdot 5 \text{ years} \cdot \frac{365 \text{ days}}{\text{year}} \cdot \frac{24 \text{ hours}}{\text{day}}\right) \\ &= 0.957 \quad \boxed{95.7\%} \end{aligned}$$

b. Assuming that every sensor in the array has to be operational for the subsystem to be functional, determine the subsystem reliability in 5 years.

$$R_{\text{Sys}} = (R_{\text{ONE}})^{100} = 1.25\%$$

c. If only half of the sensor units need be operational for the subsystem to be functional (i.e. the subsystem can be modeled as having 50 sensor units each with a redundancy of 2), determine the subsystem reliability in 5 years.

$$R_{\text{PAIR}} = 1 - (1 - R_{\text{ONE}})^2 = 0.998$$

$$R_{\text{Sys}} = R_{\text{PAIR}}^{50} = 91.2\%$$

6. (15 points) Questions you really shouldn't get wrong:

- a. True False It is important to consider test procedures from the beginning of the design process.
- b. True False It is acceptable to criticize a fellow team member if he or she isn't present at a meeting.
- c. True False Most batteries do not pose a safety hazard
- d. True False A project management plan or work breakdown structure (WBS) is unnecessary for a one-person project.
- e. True False Data sheets do not contain any practical information.

7. EXTRA CREDIT John is driving down the road in his car on a wild, stormy night, when he passes by a bus stop and sees three people waiting for the bus: an old lady who looks like she is about to die, an old friend who once saved his life, and the woman of his dreams. Knowing that there can only be one **passenger** in his car, whom should he choose? Explain your answer. (Hint: there is a way to make everyone happy.)

JOHN SHOULD GIVE HIS KEYS TO
HIS FRIEND AND LET HIM
DRIVE THE OLD LADY TO THE
HOSPITAL.

THEN HE CAN WAIT AT THE
BUS STOP WITH THE GIRL OF
HIS DREAMS