# SOLUTIONS MANUAL FOR:

# MEASUREMENT SYSTEMS APPLICATION AND DESIGN FIFTH EDITION

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CHAPTER 1
Problems

1.1 Depending on the available library resources and the previous preparation of the students, the instructor may have to give some initial quidance as to specific journal titles that might be good sources for this kind of information. The instructor may also wish to "steer" the students to certain topical areas (fluid flow, machine design, manufacturing, etc.) if the course has a certain focus, rather than being of a general measurement nature.

1.2. As in problem 1, the instructor can use hints to tailor this question to the needs of the particular course or lab.

1.3. a. While biomechanics has had some success in using theoretical models for the human body, this particular problem would require an experimental approach. Students might raise ethical questions about the use of human subjects, but in this case its seems unavoidable. Astronauts and test pilots regularly risk their lives as part of their jobs; so as long as "informed consent" is obtained, such research satisfies ethical considerations.

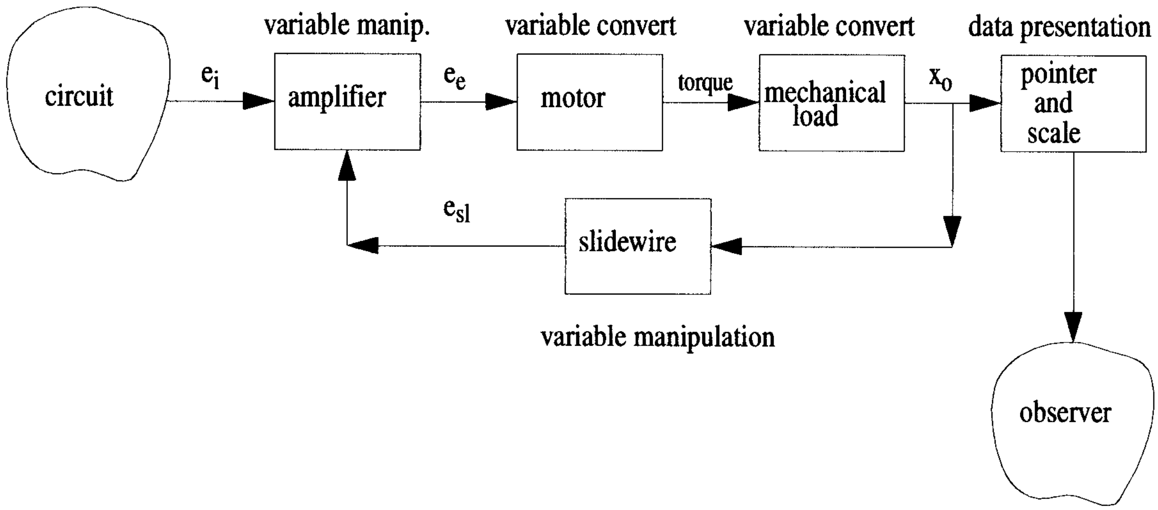
b. A theoretical approach to this problem is certainly possible and in fact found in most machine design texts. This problem is simple enough that students with only the usual physics (or perhaps engineering mechanics) preparation could deal with it. The theoretical approach brings out useful relations involving lever lengths, friction coefficient, and applied force. However, the normal force and friction force are actually distributed pressures rather than concentrated forces, thus assumptions about where the concentrated forces used in the analysis are sources of error. Also, the actual friction coefficient would not be the same as a "handbook" value used in the analysis, and might change with wear, temperature, sliding speed, etc. An experimental study woul yield information on such questions.

c. This is a thouroughly practical problem encountered often in all vehicle dynamics studies, not just rockets. When we have not yet built any prototypes and have to work from drawings, it is really impossible to theoretically compute inertial properties such as total mass, location of center of mass, moments of inertia, etc. There are just too many individual parts, complex shapes, and different materials. Some finite element software will compute inertial properties of individual odd-shaped parts from the CAD drawings, but this is not practical for an entire automobile or aircraft. The experimental approach requires only some weighing scales to locate the center of mass. Moments of inertia usually are found by creating a vibrating system by connecting the inertia to springs and measuring the natural frequency.[1]

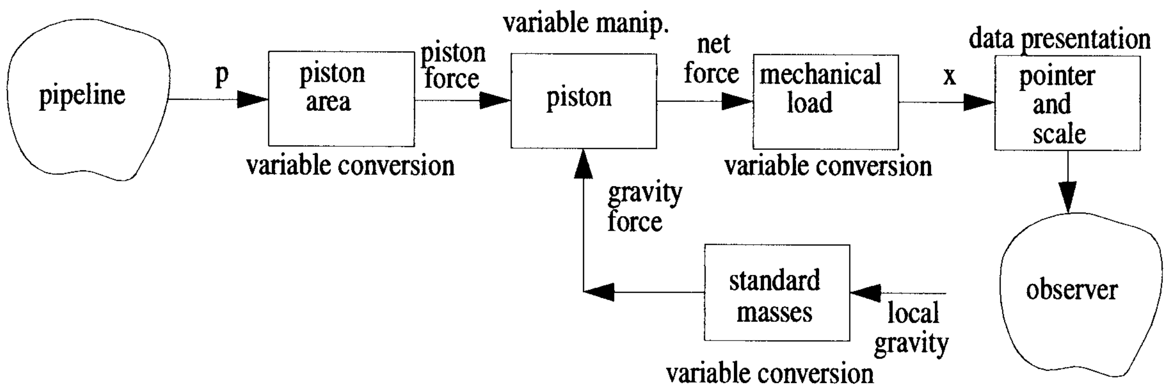
d. The simplest version of this problem neglects air resistance and considers only the gravity effects. Many students will have encountered it as an example of maximization in a calculus course. This theoretical approach is quite quick and easy and gives a specific result. When air resistance is added, it can become quite complex, depending on the model used. For example, the air resistance depends on altitude, not just projectile speed. The experimental approach could become quite complex and expensive but would allow study of the air resistance model.

1. E.O. Doebelin, System Dynamics, Marcel Dekker, New York, 1998, pg 80.

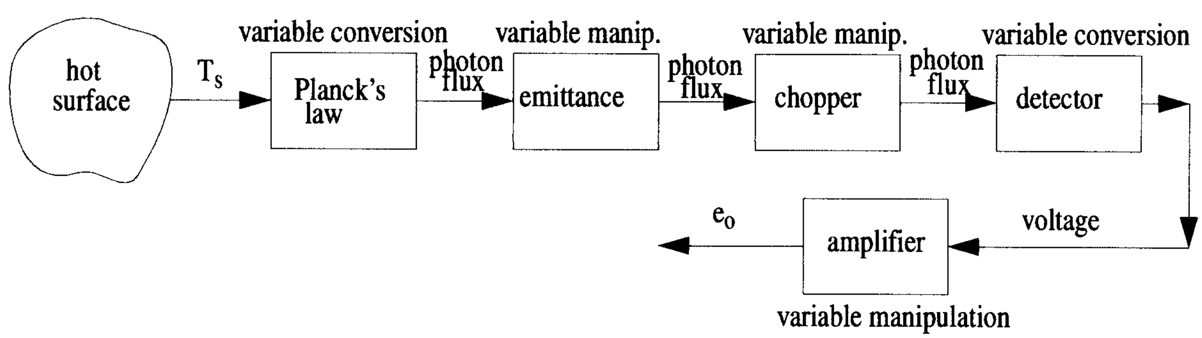
2.1 a. As noted in the text, such diagrams are somewhat a matter of opinion, so other versions may also be correct.




b.




e.



2.2 a. No active transducers.
b. No active transducers.
c. The bridge circuit battery provides power without taking it from the strain gage, so it is an active transducer.
d. No active transducers.
e. No active transducers.

2.3 a. The incoming light waves have only minuscule power while it takes significant energy to push the pedal through some distance, so the driver is functioning as an active transducer.
b. The car's motion is driven by the full power of the engine, whereas the energy taken from the human foot is small in comparison, so the engine is clearly an active transducer with a very large power amplification.

2.4 A laboratory beam balance is usually used to determine masses, but it can be used to measure forces by balancing the unknown force against the gravity force of known masses in the opposite pan of the balance.

2.5 The potentiometric method of voltage measurement is a null method. The unknown voltage is connected in series opposition with a known voltage picked off a slide-wire resistance. A galvanometer (current detector) is connected in the loop so formed. This current detector will read zero only when the slide-wire has been adjusted to the same voltage as the unknown. The slide-wire has a calibrated scale which gives its voltage, and thus the unknown.

2.6 One solution is to use 10-to-1 gearing between the measured shaft and the shaft shown in Fig. 2.4. Another way is to put 10 "bumps" on shaft. Students should provide neat sketches of these designs.

2.7. a. Modifying and interfering inputs must in general be divided into those felt to be significant and those which probably are not important. This classification is somewhat subjective and sensitive to the particular application and the accuracy required. Thus the lists now provided should not be considered definitive or exhaustive. In Fig. 2.2, some interfering inputs would include: temperature (thermal expansion and/or spring creep cause a zero shift), vertical acceleration (zero shift and/or dynamic error), vibration (causes jitter in pointer). Modifying effects include: temperature (changes the spring stiffness, changes the piston area, changes the frictional effects, changes lever ratio on pointer), pressure (changes the cylinder area), vibration (changes frictional effects).
d. Interfering inputs include: temperature (thermal expansion in optical system causes shift in the light spot position, expansion of paper chart), acceleration (inertia forces on mirror cause light spot deflection), imperfect tracking of the paper chart, humidity (causes expansion/contraction of paper chart). Modifying inputs: temperature (changes :spring stiffness, magnet field strength, coil resistance), time (aging effects magnet strength, spring stiffness, lamp brightness).

2.10 To compensate for the reduced spring constant, we need to decrease the moment of inertia. A method actually used in mechanical watches employs bimetallic strips which deflect in the desired direction when temperature changes. Various geometrical arrangements are possible; students should neatly sketch their concept. One possible solution is shown below.