Preliminary Results of an Online Mathematics Testing Program for Engineers

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It is well documented that there is currently an unsatisfied need in industry for more qualified engineers, and a disturbing decline in college students opting for technical degrees. Part of the problem is the high attrition rate among engineering majors, which can be attributed in part to problems with mathematics. We are currently developing a strategy using web-based mathematics examinations, tutoring and advising to help improve retention of engineering students and to address ABET's outcomes-based assessment.

In the past, about 50% of engineering students at the University of Nevada dropped out or changed majors in the first two years of study, some without actually taking a single engineering class. This high dropout rate can be attributed in part to a misunderstanding of what a career in engineering involves and a realization that such a career does not meet the expectations of the student. Nevertheless, many of these students drop out because of problems with mathematics. In addition, the current educational environment does not allow them to remedy their deficiencies in mathematics at their own pace.

The University of Nevada and the South Dakota School of Mines and Technology have received NSF funding to develop a strategy using web-based mathematics examinations and tutoring to diagnose deficiencies in mathematics and, we hope, help students achieve correct them.

Drs. Jeff McGough of the South Dakota School of Mines and Technology and Jeff Mortensen of UNR have written a prototype program that presents randomly generated questions to build an exam, which is then delivered to the student through a browser. The student answers the questions and submits the responses. The system will grade and record the results. It does not require any special software for the student; all of the processing is done on the server.

One of the goals of the program is to include mathematics problems in the context of engineering applications. Colleagues in the College of Engineering have observed that students who have otherwise successfully completed a mathematics course have difficulty applying it in engineering classes. It is believed that this is partly because the students are seeing the mathematics in an unfamiliar setting with different notation. The web-based tests are designed to couch mathematics in engineering terminology. Here is a simple example:

The resistance of an electric wire depends on its material and geometric properties. The resistance is directly proportional to the length of the wire and inversely proportional to the cross sectional area of the wire. What happens to the resistance of a piece of wire if it's length and diameter are both doubled?

(a) it is quadrupled (b) it is doubled (c) it stays the same (d) it is half as much (e) it is 1/4 as much.

During October 2000, March 2001 and September 2001 an exam consisting of eight questions was administered to a total of 121 pre-electrical engineering majors in an orientation class, Electrical Engineering 101.

The first seven questions required no mathematics beyond simple algebra, while question No. 8 required knowledge of Sin 30^{o}. The overall average was 4.0. The scores were as follows:

4.1% scored 8, 5.8% scored 7, 19.0% scored 6, 12.4% scored 5, 14.0% scored 4, 17.4% scored 3, 19.8% scored 2, and 6.6% scored 1. Overall, 58.7% got 4 or less out of 8.

(Only 18.2% of them got the resistance problem above correct.)

Percentage of correct answers by question:

	Q1 Sqrt sum Of sqrs	Q2 Rational exprsn	Q3 Kirchoff 2 equs	Q4 Ratio/ Proportion Wire	Q5 Ratio/ Proportion Capac	Q6 I=V/R	Q7 angular speed	Q8 Snell's Law
fall 2000	57.1%	40.5%	61.9%	23.8%	59.5%	88.1%	42.9%	28.6%
spring 2001	60.0%	43.3%	50.0%	16.7%	56.7%	80.0%	50.0%	36.7%
fall 2001	66.7%	47.1%	68.6%	15.7%	60.8%	78.4%	56.9%	17.6%

It illustrates the fact that the students are not well prepared (or else that they were not trying very hard). There were 49 students in the group tested this fall. Unlike the other two semesters, these students were told that if they scored less than 4/8 they would receive a zero on one of the homework assignments in the course. 27 students scored four or less and as of six weeks later none of them has yet come back for a retake. Furthermore, a sample of students interviewed following the test showed that even students who scored poorly were convinced that they had no problems with math and required no remediation. Therefore, a continuing problem is how to deal with this student mind set.

In the spring of 2002 the students will be told that if they score less than 4/8 they would receive an "incomplete" in the course. It will be interesting to see reactions again from the students under these conditions.

Sample Web Exam

Problem 1

Which of the expressions equals the one given? $(1/x^2 + 1/y^2)^{(1/2)}$

(a) $1/|x| + 1/|y|$; (b) none; (c) $1/(1/|x| + 1/|y|)$; (d) $|x+y|$; (e) $|x|+|y|$;

Problem 2

Which of the expressions equals the one given? $(x+p)/(x-q)$

(a) $p/-q$ (b) $x/(x-q) + p/(x-q)$ (c) $(x+p)/x - p/q$ (d) $(1+p)/(1-q)$ (e) none of these

Problem 3

Khirchhoff's laws allow electrical engineers to write equations for combinations of electrical elements. The Current Law states that the sum of the currents flowing into a node is zero. Applying Khirchhoff's law to a circuit we obtain two equations governing currents i1 and i2 in the circuit:

$$3i_1 - i_2 = -15$$
$$2i_1 - 4\,i_2 = -10$$

Solve the two equations for the unknown currents.
$i_1 =$ $i_2 =$

Problem 4

The resistance of an electric wire depends on its material and geometric properties. The resistance is directly proportional to the length of the wire and inversely proportional to the cross sectional area of the wire. What happens to the resistance of a piece of wire if it's length and diameter are both doubled?

(a) it is doubled; (b) it is quadrupled; (c) it stays the same; (d) it is halved; (e) it is quartered;

Problem 5

Capacitance is a circuit property used to model the storage of energy in an electrostatic field by a device called a capacitor which has two conductor plates separated by an insulator. The capacitance is directly proportional to the area of the plates and inversely proportional to the distance between the plates. What happens to the capacitance if the area of the plates is doubled and distance between the plates is cut in half?

(a) it is quadrupled; (b) it is doubled; (c) it stays the same; (d) it is halved; (e) it is quartered;

Problem 6

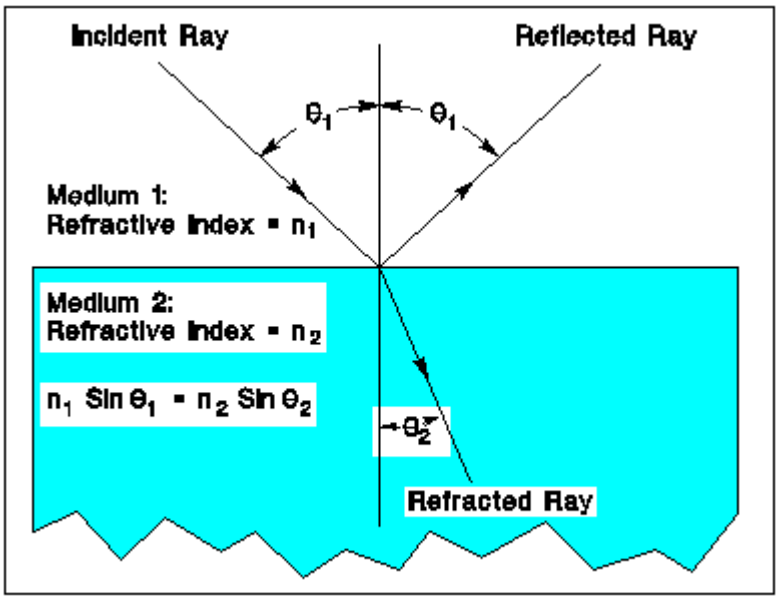
For a voltage V volts across a resistance, the current through it is given by $i = V/R$
where R is the resistance in ohms and i is the current in amperes. If a current of 8 amperes passes through a resistance of 489 ohms, what is the voltage across the resistance? V= ____ Volts (don't type the units)

Problem 7

Let w stand for the angular speed of operation of a motor. The torque T supplied by an electric motor must decrease with increasing w because of the limit on the energy delivered by the motor. If K and Tn are positive constants, only one of the following functions can possibly be a torque-speed relation. Which is it?

(a) T=Tn - Kw
(b) T=Kw^2
(c) T= Kw/Tn
(d) T=Kw - Tn
(e) T=Kw

Problem 8



Snell's law

The amount of bending that takes place when a light ray strikes a refractive boundary (e.g., an air-glass interface) at a non-normal angle is governed by Snell's law. It states that n1 sin (θ1) = n2 sin (θ2) where n1 and n2 are numbers called the indices of refraction of the two media respectively. Suppose the angle θ1 = 30 degrees and the index of refraction of medium 2 is 3.76 times that of medium 1. What is sin(θ2) within three decimal places?