CMPSCI 145 MIDTERM #1

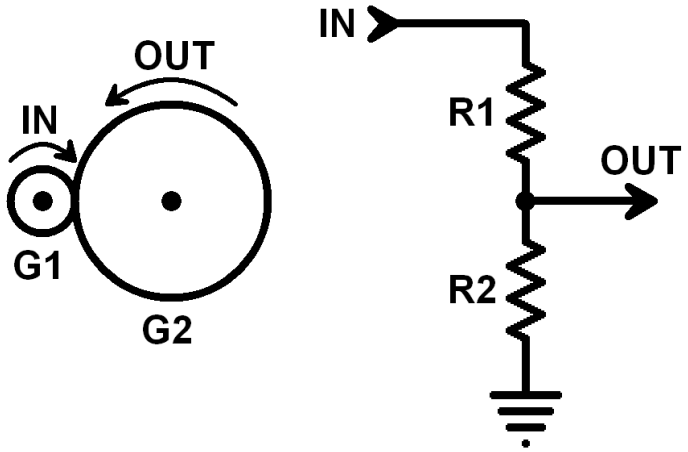
Solution Key

SPRING 2016

February 26, 2016

Professor William T. Verts

<1> 10 Points – Examine the following diagram of two systems, one involving gears and the other involving resistors. Gear **G1** has 18 teeth, and gear **G2** has 54 teeth. Resistor **R1** has a resistance of 2000 Ohms.



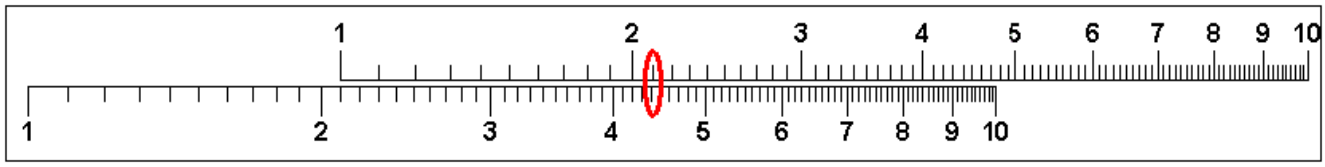
A. (5 points) What is the spin rate of gear **G2** relative to the spin rate of **G1** (your answer must deal with differences in direction)?

G2 spins at **-⅓** the rate of G1 (the minus indicates the opposite direction).

B. (5 points) What is the resistance of **R2** so that the voltage output of the resistor divider relative to its input is the same as the absolute value of the spin rate of **G2** relative to **G1**?

For the output voltage to be ⅓ the input voltage (absolute value, so no minus sign), ⅔ of the voltage must be across the 2000Ω R1, thus **R2 must be 1000Ω.**

<2> 10 Points – In the following image of a slide rule, the top slider is set to 2.1 on the bottom bar. Show where the answer will be for solving the multiplication 2.1 × 2.1 on the bottom bar. Does that answer fall exactly on one of the tic marks on the bottom bar? How many digits of precision is this device? Is that enough precision for the 2.1 × 2.1 problem?



(1 point) For indicating the answer on the slide rule diagram above.

(3 points) **No**, the answer does not fall exactly on a mark.

(3 points) The device has **two digits** of precision. (Accept the answer if students say there is only one digit to the right of the decimal point.)

(3 points) That is **not enough** for the given problem, where we need three digits of precision.

The problem 2.1 × 2.1 = 4.41, but the closest mark we can hit is 4.4 (shown in the red ellipse above).

<3> 15 Points (1 point each box) – Solve each sum below, and then tell me, ***yes or no***, if it exhibits ***unsigned overflow*** or ***signed overflow***. For problems that use ***four-digit decimal*** arithmetic (base 10), the left-most digit is the sign digit, and you are to write down only the right-most four digits of the sum even if a carry to a fifth digit is generated. For problems that use ***eight-bit binary*** arithmetic (base 2), the left-most bit is the sign bit, and you are to write down only the right-most eight bits of the sum, even if a carry to a ninth bit is generated.

Problem	**Sum (in 4 digits or 8 bits)**	**Unsigned Overflow?**	**Signed Overflow?**
Decimal: 2604 + 4975	**7579**	**NO** (No Carry)	**YES** (Pos+Pos=Neg)
Decimal: 9904 + 8769	**8673**	**YES** (18673)	**NO** (Neg+Neg=Neg)
Decimal: 3704 + 9904	**3608**	**YES** (13608)	**NO** (Pos+Neg=Pos)
Binary: 10010001 + 01110011	**00000100**	**YES** (100000100)	**NO** (Neg+Pos=Pos)
Binary: 01100011 + 01101010	**11001101**	**NO** (No Carry)	**YES** (Pos+Pos=Neg)

<4> 20 Points (1 point each box) – Show the ***decimal*** (base 10) value of the eight-bit binary numbers interpreted in each of the following ways. One problem has been done for you. For signed interpretations, the left-most bit is the sign bit.

The Number	**01110101**	**10000000**	**10111001**
Unsigned Binary	**117**	**128**	**185**
Sign & Magnitude Signed Binary	**117** or **+117**	**-0**	**-57**
One's Complement Signed Binary	**117** or **+117**	**-127**	**-70**
Two's Complement Signed Binary	**117** or **+117**	**-128**	**-71**
Unsigned BCD	**75**	**80**	**Illegal**
Unsigned Fixed-Point (4 bits whole number, 4 bits fraction)	**7.3125** or **7 5/16**	**8.0**	**11.5625** or **11 9/16**
Unsigned Rational (4 bits numerator, 4 bits denominator)	**7/5**	**8/0**	**11/9**

<5> 15 Points – Convert the decimal number **39.1875** into True Binary and Binary Scientific Notation. Show your work for partial credit.

$39_{10} \rightarrow ?_2$
39 ÷ 2 = 19 R 1
19 ÷ 2 = 9 R 1
9 ÷ 2 = 4 R 1
4 ÷ 2 = 2 R 0
2 ÷ 2 = 1 R 0
1 ÷ 2 = 0 R 1
$39_{10} \rightarrow 100111_2$

$.1875_{10} \rightarrow ?_2$
.1875 × 2 = 0.375
.375 × 2 = 0.75
.75 × 2 = 1.5
.5 × 2 = 1.0
$.1875_{10} \rightarrow .0011_2$

True Binary (10 points):	**100111 . 0011**
Binary Scientific (5 points):	**1.001110011×2^5**

For the first part, remove 1 point for each bit in error.
For the second part, the significant bits must match the first part, even if the first part is wrong; remove 2 points if they are different. Remove 1 point if the sig bits aren't normalized to a 1.xxxx pattern. Remove 2 points for an exponent inappropriate to the sig bits (i.e., the exponent can be different from 5 if the sig bits aren't normalized).

<6> 10 Points – Consider a binary number of the form **`xxxx.yyyy`** (where **`x`** and **`y`** are bits with the value of either **`0`** or **`1`**)

A. What happens to its numerical value if the number is left-shifted by one bit, to become **`xxxxy.yyy`** ?

(5 points) The value is multiplied by two.

B. What happens to its numerical value if the number is right-shifted by one bit, to become **`xxx.xyyyy`** ?

(5 points) The value is divided by two.

<7> 10 Points – SHORT ESSAY – In the video I had you watch of the Navy Fire-Control Computers (1953), they were using gears, cams, differentials, and mechanical multipliers to solve the fire-control problems of naval gunnery. How would the ***quality of the machining*** of these devices affect the answers that they produce? How ***reproducible*** are the answers given the same inputs on different days? Use the **TOP HALF** of the back of this page for your answer.

The answers are entirely dependent on the quality of the machining. If the machining is poor, the answers may have a large range of error due to the sloppiness in each device, accumulated over the process of the calculation.

Because these are analog devices, inherent slop in the machining, regardless of the quality, means that two attempts to do the same problem will always result in slightly different answers. . The error range would be smaller for better machining.

Accept anything reasonable. Score as "10: yes they get it", "5: some good ideas but not complete", or as "0: completely bogus".

<8> 10 Points – SHORT ESSAY – Consider the following devices:

1: A pair of gears where the driving gear is four times larger than the driven gear.
2: A lever built so that it is four times longer on one side of the fulcrum than the other.
3: A hydraulic ram where the driven piston has four times the area of the driving piston.
4: A vacuum tube where the electron flow from cathode to plate is four times the electron flow to the grid.

How are these systems all similar? How are they different? Are they analog or digital systems? Use the **BOTTOM HALF** of the back of this page for your answer.

All are analog multiply-by-four devices. Each uses a different technology, exploiting different properties of materials to do the same math.

Accept anything reasonable. Score as "10: yes they get it", "5: some good ideas but not complete", or as "0: completely bogus".