Engineering 101 Terms Test
Term 1 2008

Equations that might be useful:

$$y = A\sin(\frac{2\pi x}{\lambda} \pm \frac{2\pi t}{T} + \phi) \qquad v = \frac{\lambda}{T} \qquad f = \frac{1}{T} \qquad \theta = \frac{H}{D}$$

1. Correct answer **B**

The result of the binary addition (all numbers are 7 bit binary plus a sign bit) 00010110 + 00111001 + 00001110 is

(a) 01101101
(b) 01011101
(c) 01110101
(d) 01100011

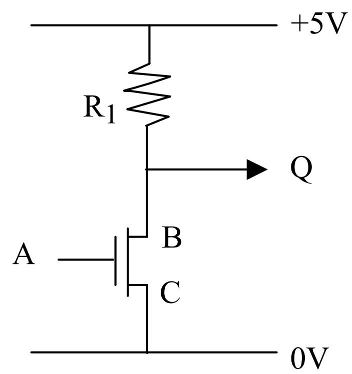
First sum:
00010110
00111001
01001111

Second sum:
01001111
00001110
01011101

(I suggest 4 marks for correct answer, 2 if the final answer is wrong but it is shown that the first part is correct)

2. The diagram at right represents an NPN MOSFET (Metal Oxide Semiconductor Field Effect Transistor) connected in a simple circuit. Which of the following is NOT true?

(a) When no voltage is applied to the gate terminal (A) the resistance between terminals B and C is very high.
(b) When a high positive voltage is applied to A a conducting "bridge" is induced between B and C.
(c) When the MOSFET conducts Q = 5 V.
(d) The MOSFET in this configuration is equivalent to a NOT gate (i.e. Q = NOT A).



[2 marks]

Correct answer **C**.

(All or nothing 2 marks)

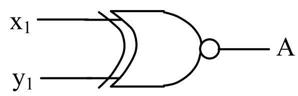
3. x_1x_0 and y_1y_0 are 2 2-bit binary numbers.
Design a logic circuit which has the two binary numbers as its inputs and gives an output of 1 if the two numbers are the same.

It is necessary to have a gate which will give an output of 1 when x_1 and y_1 are the same as in the truth table below.

x_1	y_1	A
0	0	1
0	1	0
1	0	0
1	1	1

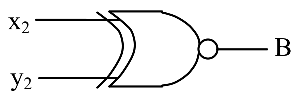
(3 marks)

This is the truth table for a XNOR gate. Thus a XNOR gate will correctly identify if $x_1 = y_1$.



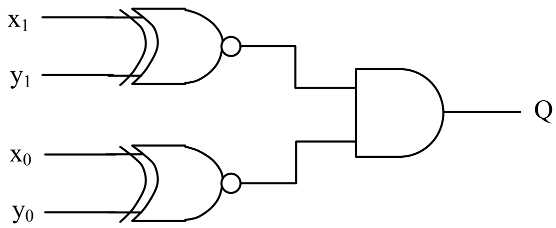
(3 marks)

Similarly, the XNOR gate on the right will identify if $x_2 = y_2$.



(1 marks)

The final design must give 1 as an output only when A = B = 1. An AND gate will achieve this. Thus the simplest circuit is as shown below.



(3 marks)

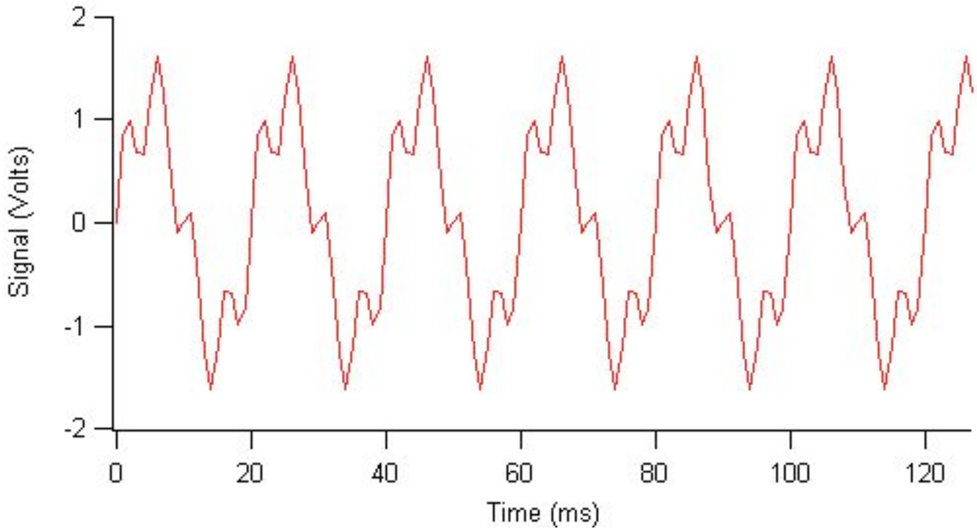
4. In computer technology "Bandwidth" usually means the number of bits per second. In physics bandwidth means the range of frequencies in a signal. Are these concepts related? If so, explain the connection.

[5 marks]

To a computer scientist or to a computer user, "bandwidth" is related to ones and zeros per second. To a physicist "bandwidth" means the range of frequencies in a signal. Whether we are thinking of pulses of radiofrequency signal or light pulse or something similar, short pulses contain a wide range of frequencies. Similarly, a square wave – like digital signal in a computer contains higher frequencies if the individual ones and zeros are shorter duration. So more ones and zeros per second means a wider range of frequencies and the two concepts of "bandwidth" are very closely linked.

5. Consider the signal below which a customer has asked you to digitize. Design an analogue to digital conversion suitable for this and similar signals: a suitable digitization rate, range, and resolution. We want to save money and reduce the data rate as much as possible as per the customer's request. So we do not want to go faster than necessary to safely get the signal, and we do not want higher resolution the necessary. The customer needs to be able to detect 0.3 volt changes in the signals. Make the first measurement at time t = 0. Note there is more than one suitable design, but explain your reasoning.

[10 marks]



Answers will vary. But the highest frequency component of the data has a period of 5ms, and thus a frequency of 200 Hz. So the digitization rate must be at least faster than 400 samples/sec, perhaps 500 samples/sec might be reasonable as we are asked to make the digitisation inexpensive. We need a voltage resolution of 0.3 volts with a range of about -2 V to 2 V. So we need at least 4/0.3 or 13.3 subranges, suggesting 4 bit digitisation (16 subranges). The first reading, assuming 16 subranges, is 7 or 8 (on the border line).

4 Marks for rate, 5 for resolution and range, 1 for first digitisation.

6. **a.** If no compression is used, how many bytes are in the video of a 60 minute movie with frames of size 800 x 600 if there are 25 frames per second and the colour data is 24 bit? The sound is stereo, 16 bit, 44,100 samples per second. How many bytes in the sound data?

Video: We have (600*800 pixels)*(25 frames/sec)*(60 minutes)*(60 sec/min)*(3 bytes/pixel) = 129×10^9 bytes or about 1×10^{12} bits. Answers in bits or bytes are good.

Sound: We have (44,100 samples/sec)*(2 bytes/sample)*(3600 seconds)*(2 channels) = 635×10^6 Bytes or 5.1×10^8 bits.

b. Describe lossless and lossy data compression. Why are both particularly suitable for movies? Explain.

Lossless data compression takes advantage of redundancies to reduce the number of ones and zeros (data) with no loss of information. The exact original data can be recovered. Thus lossless compression is useful for almost any kind of large data set. Lossy compression yields a further reduction in the amount of data by giving up some information. This information may not be important. Often a .jpg which has been subjected to lossy compression looks pretty much identical to the original on a computer screen or even when printed. The lost information was apparently not important. But since information is lost, it is not possible to recover the original data exactly.

c. If the human eye's angular resolution is $3x10^{-4}$ radians, design a screen size (width and height) that can be viewed from half a metre and still give an image that appears continuous. The image is 800 x 600.

$3x10^{-4}$ radians = H/0.5m so H = $1.5x10^{-4}$m. The screen size is then $800x1.5x10^{-4}$m x $600x1.5x10^{-4}$m or 12 cm by 9 cm.

4 marks for part a, 3 for b, 3 for c.

[10 marks]

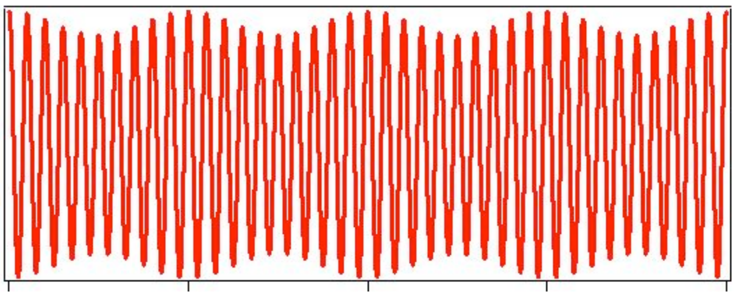
7. a. A wave is described by the equation below. Find the wavelength, frequency, and speed of the wave.

$y = 15\sin(0.5x - 3t + 3.14)$ where t is in seconds and x is in metres.

The wavelength is obtained from $0.5=2\pi/\lambda$ so $\lambda = 4\pi$ metres; the period is obtained from $3 = 2\pi/T$ so $T = 2\pi/3$ seconds. The frequency is obtained from $f=1/T = 3/2\pi$ sec^{-1}. The speed is obtained from $v=\lambda/T = 6ms^{-1}$**. 3 marks for part a**.

b. Describe how analogue AM radio signals encode information.

The sound is encoded as slow variations in the amplitude of the signal. Something like this:



3 marks for part b. [6 marks]