YOUR NAME: ______________________ ID:_s__________ DOB: ____/____/19__

Department/Program: TN / N / TBK / BMT / …

# Final Exam
## Principles of Measurement Systems
### (NAPMS.2008-2009.1a)
### Friday 31 October, 2008 (9:00-12:00)

*Please write your name, student ID number and date of birth on this or the first page, only your name on all subsequent pages, and number the pages. Don't forget to hand in all relevant paperwork.*

*This is not an open-book exam, so please remove all other documents.*

*Read carefully. Pay attention to units. A numerical result without, or with wrong units, will be considered incorrect. You may assume that I know the answer to the questions posed; Therefore, give derivations and/or motivate your answers as appropriate! If you cannot answer the first part of a question, make a (educated) guess, and continue with the rest… Success!*

You may use the following table:

| time-domain $f(t)$ | $s$-domain $\tilde{f}(s)$ |
|---|---|
| $\delta(t)$ | $1$ |
| $1$ | $\frac{1}{s}$ |
| $t$ | $\frac{1}{s^2}$ |
| $e^{at}$ | $\frac{1}{s-a}$ |
| $1-e^{-at}$ | $\frac{a}{s(s+a)}$ |
| $\sin(\omega t)$ | $\frac{\omega}{s^2+\omega^2}$ |
| $\cos(\omega t)$ | $\frac{s}{s^2+\omega^2}$ |
| $e^{at}g(t)$ | $\tilde{g}(s-a)$ |
| $g(at)$ | $\frac{1}{a}\tilde{g}\left(\frac{s}{a}\right)$ |
| $f(t)$ | $\int_{0^-}^{\infty} f(t)e^{-st}dt$ *) |
| $f'(t)$ | $s\cdot\tilde{f}(s)-f(0^-)$ |

*) Note: The lower bound of the integral being equal to $0^-$ signifies that the origin is fully included in the evaluation of the integral.

**Question 1**

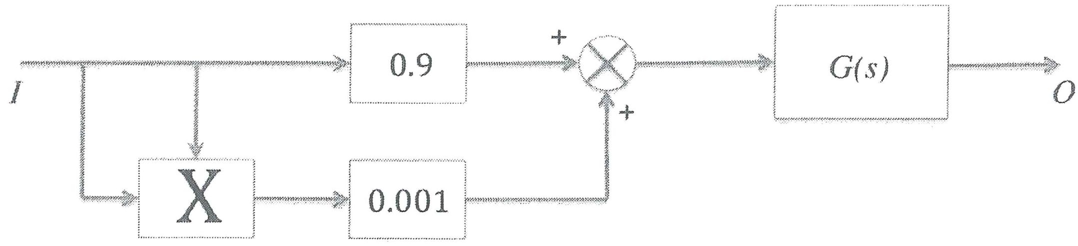
In the lectures we have seen that a measurement system can be divided into 4 constituent parts.

a) Name the 4 generalized subsystems.

b) Give 3 examples of different measurement systems and their respective subsystems.

**Question 2**

The following block diagram characterizes a pressure measurement system that is to be used over the range from 0 to 100 mbar:




Here, the transfer function *G(s)* is given by: $G(s) = \dfrac{1}{\dfrac{s^2}{\omega_n^2} + \dfrac{2\xi s}{\omega_n} + 1}$

with $\omega_n = 5$ rad/s and $\xi = 0.2$.

a) Determine the steady-state relation between input and output to a step input function, using the final value theorem.

b) Determine the ideal linear sensitivity (straight-line slope) and intercept for this pressure sensor.

c) Determine the maximum non-linearity of the system, both in absolute terms and as a percentage of full-scale deflection.

d) Sketch (qualitatively) the dynamic response of the system if the input pressure is suddenly raised from 25 to 60 mbar at t=0. The system is in equilibrium ("at rest") at $t=0^-$.

**Question 3**

A temperature measurement system consists of an NTC temperature sensor, a voltage divider network, and a recorder. The three elements are described by the following model equations:

$$R(T) = R_\infty e^{\beta/T}, \quad V(R) = V_0 \frac{R_0}{R_0 + R(T)}, \quad T_M(V) = K \cdot V(R) + a$$

| Parameter | Mean value | Standard deviation |
|---|---|---|
| | | |
| $\beta$ | 3965.0 K | 0 K |
| $R_\infty$ | 1.6770 $10^{-2}$ Ω | $10^{-5}$ Ω |
| $V_0$ | 10.000 V | 5 mV |
| $R_0$ | 10.000 kΩ | 0 Ω |
| $K$ | 8.9678 K/V | 0.001 K/V |
| $a$ | 253.315 K | 0 K |

Assuming all probability distributions are normal, calculate for an input temperature of 300 K:

a) the mean of the measured temperature, and

b) the standard deviation of the corresponding error probability density function.

c) Which parameter contributes most significantly to the measurement uncertainty?

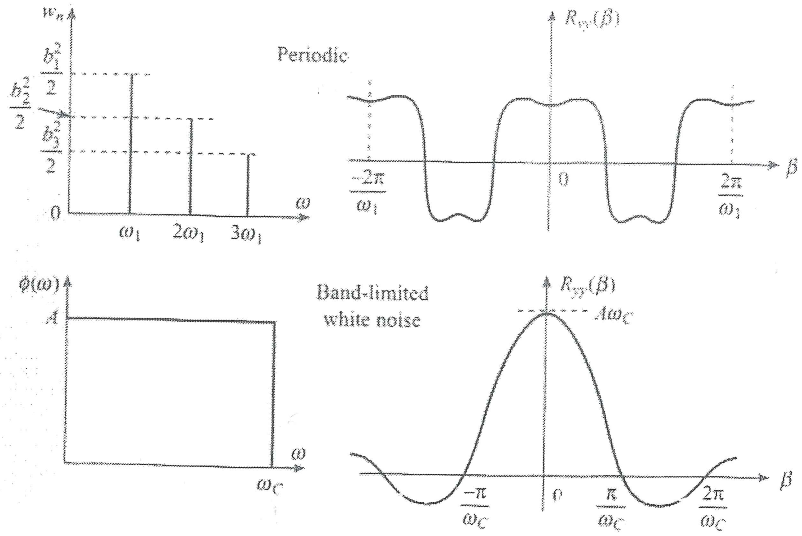
## Question 4

The autocorrelation of a continuous signal is given by:

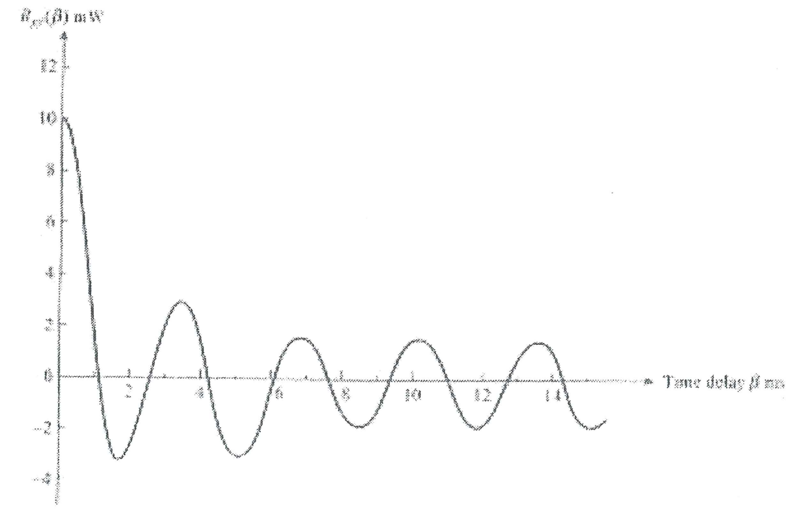
$$R(\beta) = \lim_{T\to\infty}\frac{1}{T}\int_0^T y(t)y(t-\beta)dt = \int_0^\infty \phi(\omega)\cos(\omega\beta)d\omega$$

a) Evaluating the above expression, derive an analytical formula for the autocorrelation function if $y(t)=b\,\sin(\omega t+\varphi)$. Remember that $\sin(a)\,\sin(b) = (\cos(a-b)-\cos(a+b))/2$.

b) Bentley discusses the autocorrelation function of periodic functions in paragraph 6.2.5 and illustrates this with Figure 6.6, reproduced here below. The figure contains a very obvious mistake. Which one?




c) The following figure represents the autocorrelation (unit is mW) as a function of the time delay $\beta$ (ms) of a sinusoidal signal after its transmission over a noisy transmission link. From the figure, estimate the signal power, the noise power, the signal-to-noise ratio (in dB), the signal frequency, and the noise standard deviation (assuming zero mean).



*... End of the Exam.*