



New Mexico State University  
Klipsch School of Electrical Engineering

EE589 - Digital Speech Processing  
Spring 2008 - Exam #1

Name: \_\_\_\_\_

Prob. 1	/	25 points
Prob. 2	/	25 points
Prob. 3	/	25 points
Prob. 4	/	25 points
Total	/	100 points

## Prob. 1

The waveforms and spectrograms in Figs. 1.1 and 1.2 (next two pages), were made from recordings ( $f_s = 16$  kHz, 16 bit resolution) of a single, spoken phoneme. Using these figures, determine the type of phoneme which was spoken:

- Vowel
- Nasal
- Voiced fricative
- Unvoiced fricative
- Voiced plosive
- Unvoiced plosive
- Diphthong

Note some phoneme types may occur more than once, some phoneme types may not occur. Providing comments regarding your decision may lead to partial credit.

(a) The phoneme in Fig. 1.1(a) and (b) is a \_\_\_\_\_ .  
Comment:

(b) The phoneme in Fig. 1.1(c) and (d) is a \_\_\_\_\_ .  
Comment:

(c) The phoneme in Fig. 1.1(e) and (f) is a \_\_\_\_\_ .  
Comment:

(d) The phoneme in Fig. 1.2(a) and (b) is a \_\_\_\_\_ .  
Comment:

(e) The phoneme in Fig. 1.2(c) and (d) is a \_\_\_\_\_ .  
Comment:

(f) The phoneme in Fig. 1.2(e) and (f) is a \_\_\_\_\_ .  
Comment:

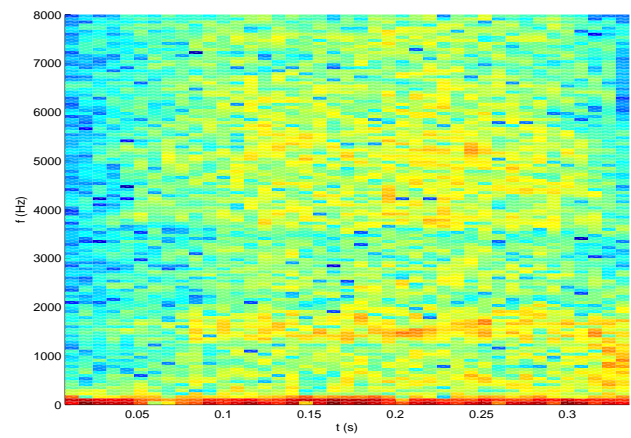
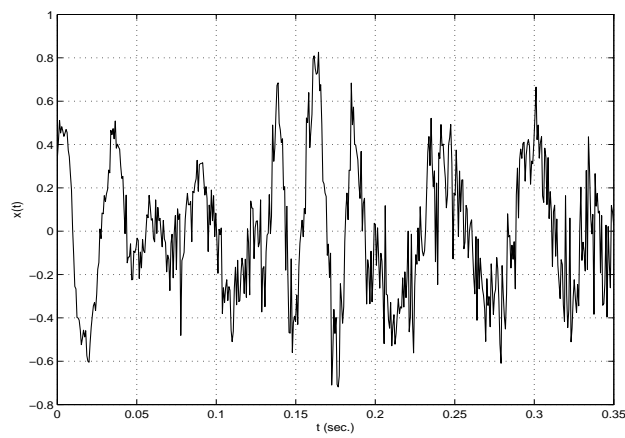
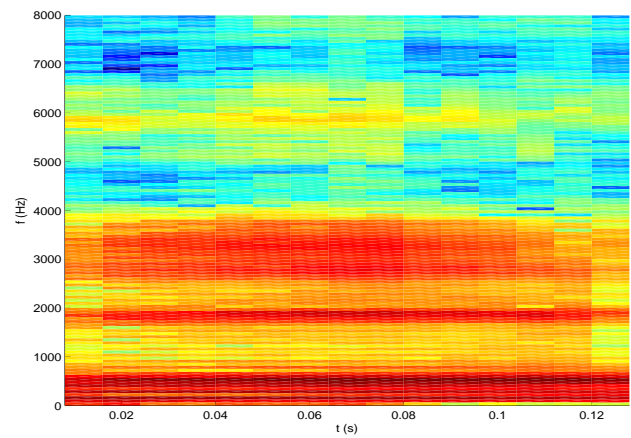
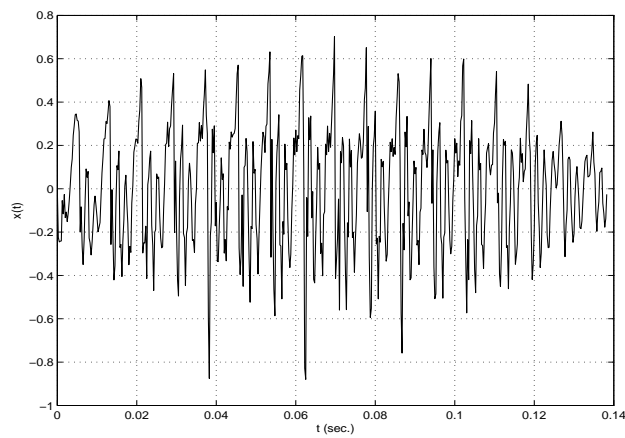
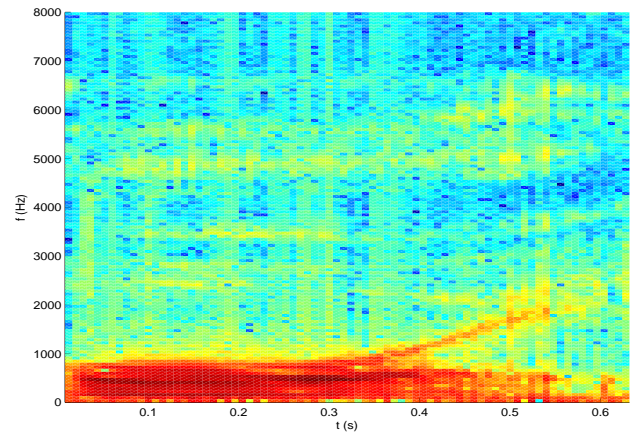
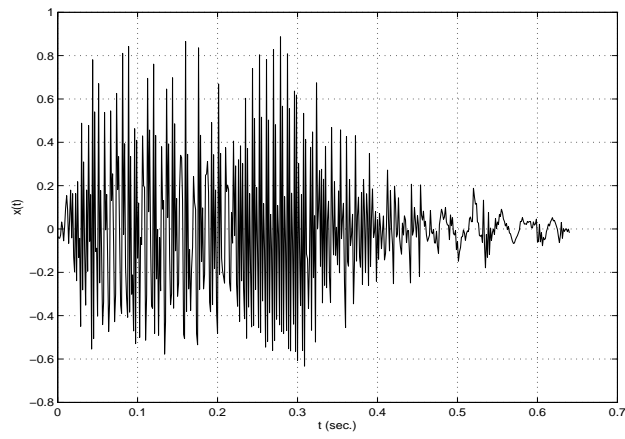
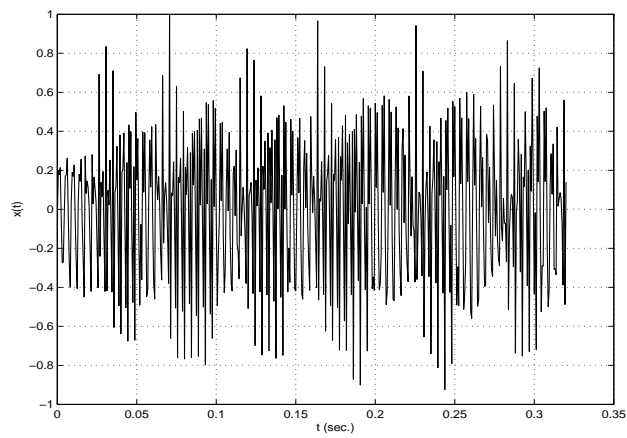
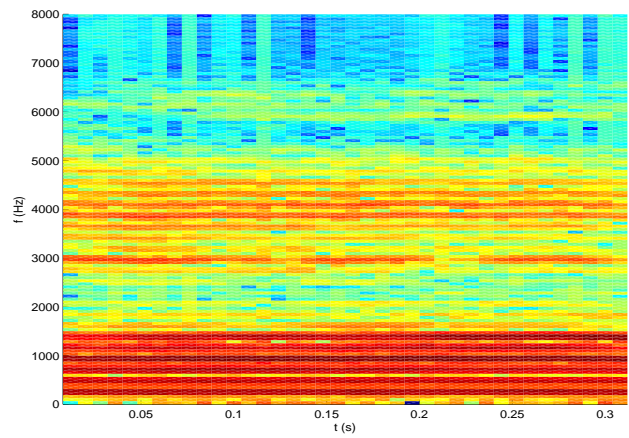


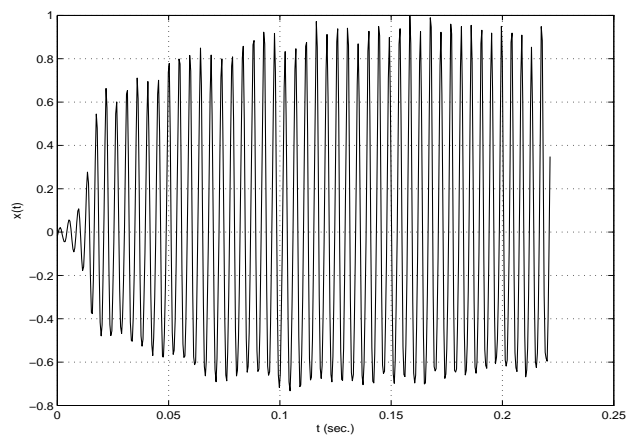
Figure 1.1: Plots of phoneme waveforms and periodograms for Prob. 1.



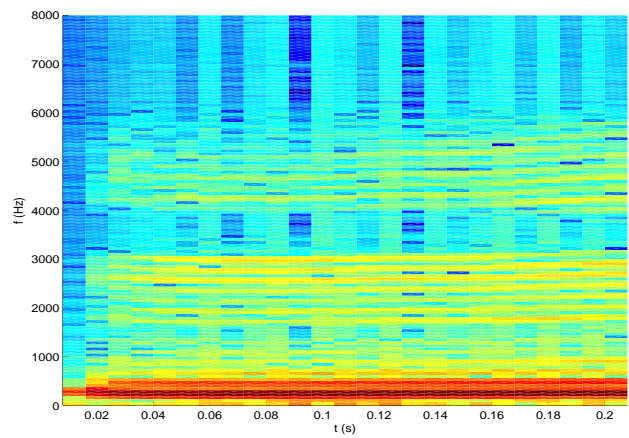
(a)



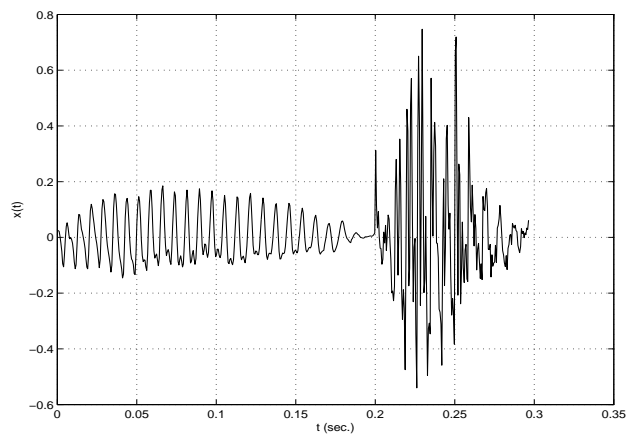
(b)



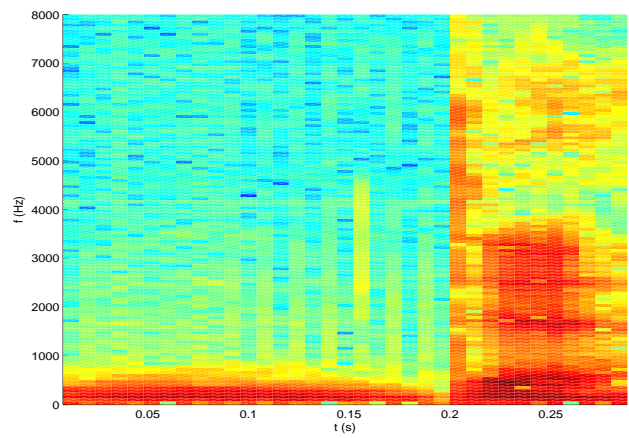
(c)



(d)



(e)



(f)

Figure 1.2: Plots of phoneme waveforms and periodograms for Prob. 1.

## Prob. 2

The following plots show the waveform for the utterance “The birch canoe slid on the smooth planks.” The signal was sampled at an 8 kHz rate.

- On the plots, mark the phoneme boundaries and label the phonemes (see Fig. 2.2 next page).
- Estimate the pitch period during the middle of the voiced parts.
- Is the talker most likely male or female?

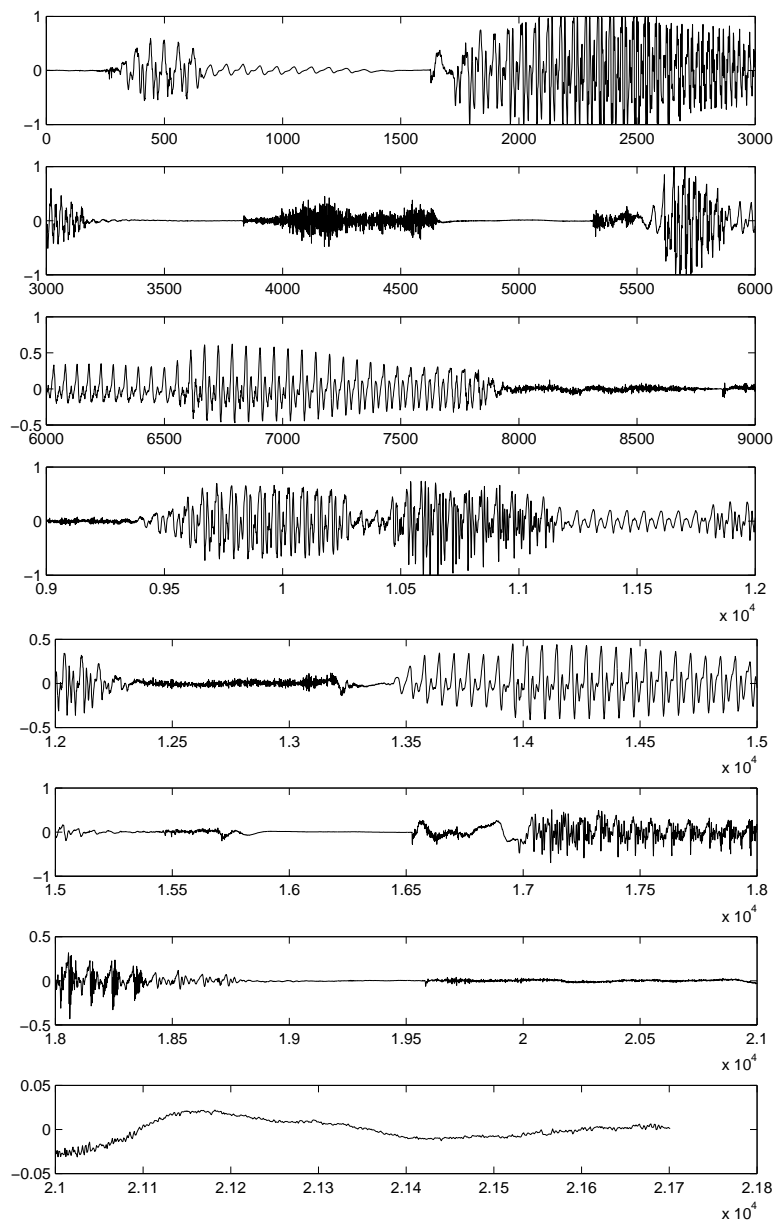


Figure 2.1: “The birch canoe slid on the smooth planks.”

## Prob. 2 (cont.)

A condensed list of phonetic symbols for American English.

Phoneme	ARPABET	Example	Phoneme	ARPABET	Example
/ɪ/	IY	b <u>ea</u> t	/ɪŋ/	NX	si <u>ng</u>
/ʊ/	IH	b <u>i</u> t	/p/	P	p <u>e</u> t
/e/ (eʹ)	EY	b <u>ai</u> t	/t/	T	t <u>e</u> n
/ɛ/	EH	b <u>e</u> t	/k/	K	k <u>i</u> t
/æ/	AE	b <u>a</u> t	/b/	B	b <u>e</u> t
/ɑ/	AA	B <u>o</u> b	/d/	D	d <u>e</u> bt
/ʌ/	AH	b <u>u</u> t	/g/	H	g <u>e</u> t
/ɔ/	AO	b <u>ou</u> ght	/h/	HH	h <u>a</u> t
/o/ (oʷ)	OW	b <u>o</u> at	/f/	F	f <u>a</u> t
/ʊ/	UH	b <u>oo</u> k	/θ/	TH	t <u>h</u> ing
/u/	UW	b <u>oo</u> t	/s/	S	s <u>a</u> t
/ə/	AX	ab <u>o</u> ut	/ʃ/ (sh)	SH	sh <u>u</u> t
/ɪ/	IX	ros <u>e</u> s	/v/	V	v <u>a</u> t
/ɜ/	ER	bir <u>d</u>	/ð/	DH	th <u>a</u> t
/ə/	AXR	b <u>u</u> tt <u>e</u> r	/z/	Z	z <u>oo</u>
/ɑʷ/	AW	down	/z/ (zh)	ZH	az <u>u</u> re
/ɑʹ/	AY	b <u>u</u> y	/tʃ/ (tsh)	CH	ch <u>u</u> r <u>ch</u>
/ɔʹ/	OY	b <u>o</u> y	/dʒ/ (dzh, j)	JH	ju <u>d</u> ge
/y/	Y	y <u>ou</u>	/w/	WH	w <u>h</u> ich
/w/	W	w <u>i</u> t	/l/	EL	batt <u>l</u> e
/r/	R	r <u>e</u> nt	/m/	EM	bot <u>to</u> m
/l/	L	l <u>e</u> t	/n/	EN	butt <u>o</u> n
/m/	M	m <u>e</u> t	/ŋ/	DX	batt <u>er</u>
/n/	N	n <u>e</u> t	/ʔ/	Q	(glottal stop)

Figure 2.2: American English phonemes.

**Prob. 3**

In the concatenated tube model, the reflection coefficient at the  $k$ th junction can be written in terms of the tube areas  $A_k$  and  $A_{k+1}$  as

$$r_k = \frac{A_{k+1} - A_k}{A_{k+1} + A_k} = \frac{\frac{A_{k+1}}{A_k} - 1}{\frac{A_{k+1}}{A_k} + 1}. \quad (3.1)$$

Show that since  $A_k$  and  $A_{k+1}$  are both positive,  $-1 \leq r_k \leq 1$ .

Hint: consider (3.1) when  $A_{k+1}/A_k \geq 1$  and  $A_{k+1}/A_k < 1$ .

**Prob. 4**

Consider the following systems with conjugate reciprocal zero locations

$$H(z) = 1 - \alpha z^{-1}$$

and

$$G(z) = 1 - \frac{1}{\alpha^*} z^{-1}.$$

Show that replacing a zero by its conjugate reciprocal at most alters the magnitude response by a constant factor but does not change its shape, i.e.

$$|H(\omega)| = C|G(\omega)|$$

where  $C$  is a constant.

Note: the Quatieri text p. 51 Prob. 2.11 incorrectly ignores the constant factor.