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Norwegian University of
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Department of Physics

Examination paper for TFY4185 Measurement Technique/ Måleteknikk

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Examination date: 11 August 2016

Examination time (from-to): 09:00 – 13:00

Permitted examination support material:

Single or Bi-lingual dictionary permitted
All calculators permitted
1 side of an A5 sheet with printed or handwritten formulas permitted

Other information:

Language: English

Number of pages:

Number of pages enclosed:

Checked by:

_____

Date Signature

The Norwegian University of Science and Technology Department of Physics
ENGLISH

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EXAM IN TFY 4185 Measurement Technique/Måleteknikk

August 2016
Time: 09:00-13:00

Number of pages: 11

Permitted aids: 1) Dictionary (ordinary or bi-lingual)
2) All calculators
3) 1 side of an A5 sheet with printed or handwritten formulas permitted

Last page contains a listing of parameters for BJT transistors

You can answer in either Norwegian or English. The weight for each multiple-choice question is 4%, the weight for each calculation problem is given in parenthesizes.

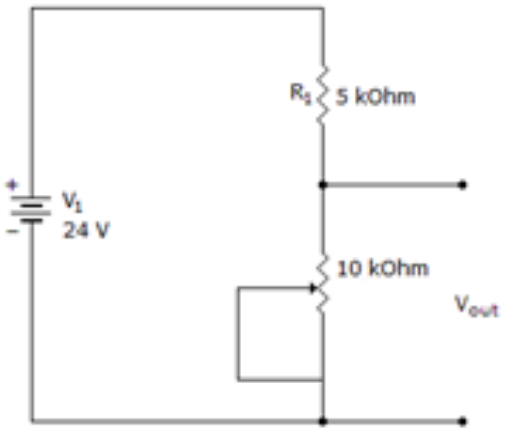
Multiple Choice Questions-1 (40% total).

There is only **one** correct answer so you must **CHOOSE THE BEST ANSWER**. Answer A, B, C… (Capital letters). Correct answers give +4; **incorrect or blank answers give 0**.

Write the answers for the multiple-choice questions **on the answer sheet you turn in** using a table similar to the following:

Question	1	2	3	4	5	6	7	8	9	10
Answer										

1. **Calculate the voltage at point B in the following circuit:**

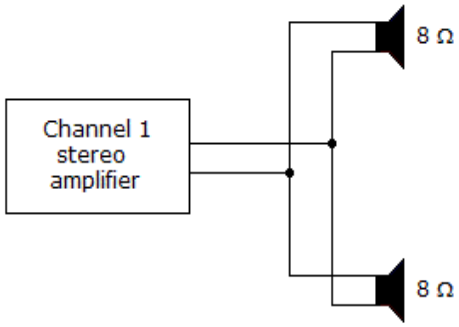


A) 0 V, 4 V B) 0 V, 8 V C) 0 V, 12 V D) 0 V, 16 V

2. **When parallel resistors are of three different values, which has the greatest power loss?**

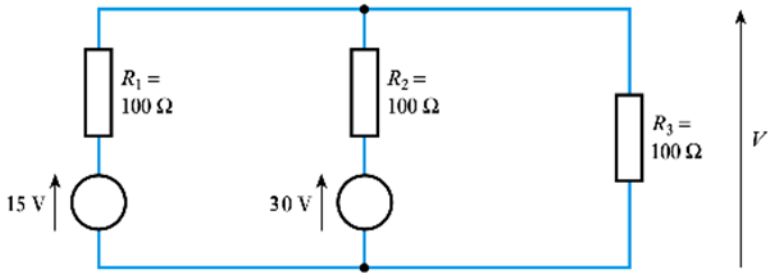
A) The smallest resistance
B) The largest resistance
C) They all have the same poser loss
D) It depends on the values of the resistances
E) Not enough information given

3. **In the following circuit, Channel 1 of the stereo amplifier outputs 12 V to the speakers. How much total power is the amplifier delivering to the speakers?**



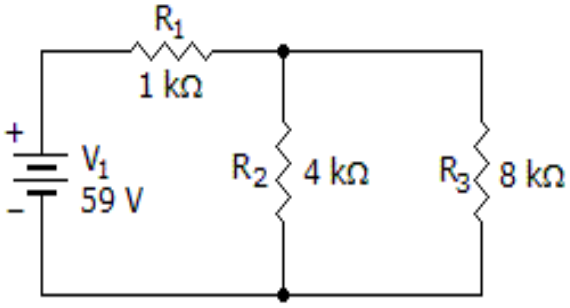
A) 55 W B) 25 W C) 35 W D) Not enough information given

4. **Determine the output voltage V of the following circuit:**



A) 5 V B) 7.5 V C) 12 V D) 15 V

5. **What is the power dissipated by R1, R2, and R3?**

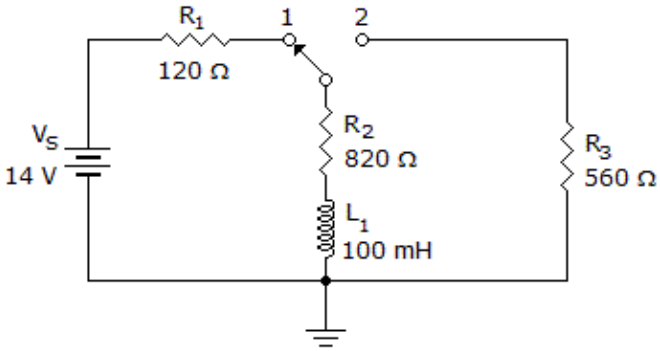


A) P1 = 0.1 W, P2 = 0.3 W, P3 = 0.1 W
B) P1 = 0.3 W, P2 = 0.5 W, P3 = 0.2 W
C) P1 = 0.5 W, P2 = 0.9 W, P3 = 0.5 W
D) P1 = 1.0 W, P2 = 1.8 W, P3 = 0.9 W

6. **With a 500 kHz signal source, what would be the value of a capacitor yielding a capacitive reactance of 1 kΩ?**

A) 320 pF B) 3.8 nF C) 318 nF D) 2 μF E) 2 F

7. **In the following circuit that has stabilized, what will the voltage be across R_3 at a time t = 25 ms after the switch is moved to position 2?**

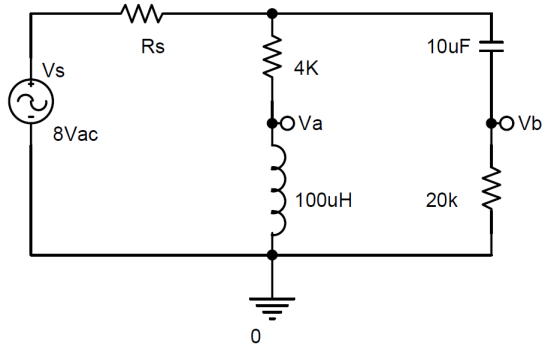


A) 4 V B) 5.9 V C) 8.6 V D) 9.9 V E) 14.0 V

8. **If a sinusoidal voltage $v = V_p \sin \omega t$ is applied across a capacitor, C, what is the average value of the power dissipated in the capacitor?**

A) 0 W B) CV_p^2 C) V_p^2 / C D) $2CV_p^2$

9. **For R_s= 10 kΩ, estimate the voltage V_b at very high frequencies.**



A) 0 V B) 5 V C) 8 V D) One cannot estimate V_b.

10. **At any resonant frequency in an RLC series circuit, what characteristics will the voltage across the two series reactive components have?**

A) The applied voltage
B) A reactive voltage
C) There will be zero voltage
D) The same as the resistive voltage

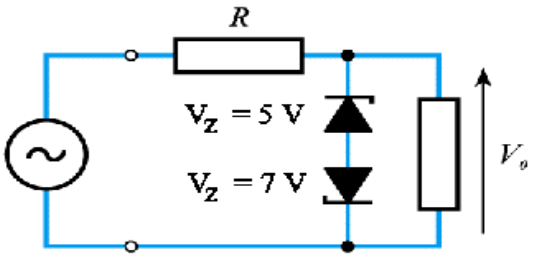
Multiple Choice Questions-2 (40% total).

There is only **one** correct answer so you must **choose the best answer**. Answer A, B, C, … (Capital letters). Correct answers give +4; incorrect or blank answers give 0.

Again, **on the answer sheet you turn in** use a table similar to the following:

Question	11	12	13	14	15	16	17	18	19	20
Answer										

11. Estimate the maximum positive voltage produced by the following arrangement:

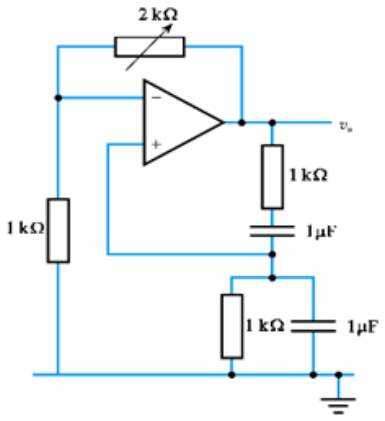


A) 7.7 V B) 6.3 V C) 5.7 V D) 4.3 V

12. An amplifier has a voltage gain of 20, an input resistance of 500 ohms and an output resistance of 50 ohms. The amplifier is connected to a voltage source that produces an output voltage of 1 V and has an output resistance of 75 ohms, and to a load resistance of 800 ohms. What is the voltage gain of this amplifier system?

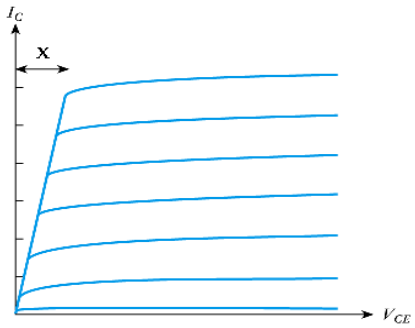
A) 18.9 V
B) 20 mV
C) 17.4 V
D) 16.4 V
E) 20 V
F) 0 V

13. Calculate the frequency of oscillation of the Wien-bridge oscillator shown here.



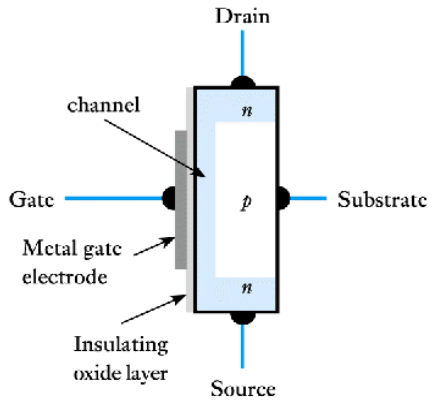
A) 159 Hz. B) 238 Hz. C) 327 Hz. D) 424 Hz. E) 522 Hz.

14. In the bipolar transistor output characteristics shown below, what region is represented by the symbol 'X'?



A) The active region
B) The space-charge region
C) The saturation region
D) The ohmic region

15. What form of FET is shown here?



A) An *n*-channel JFET.
B) An *n*-channel MOSFET.
C) A *p*-channel JFET.
D) A *p*-channel MOSFET.

16. What form of noise is produced as a result of the random, thermally induced motion of the atoms in a material?

A) Johnson noise.
B) Shot noise.
C) Flicker noise.
D) Interference.
E) Pink noise.

17. Which logic gate has the following truth table?

A	B	C
0	0	0
0	1	1
1	0	1
1	1	1

A) A two-input AND gate
B) A two-input EXCLUSIVE OR gate
C) A two-input NOR gate
D) A two-input EXCLUSIVE NOR gate
E) A two-input OR gate

18. Simplify the expression $Y = (\overline{A + B}) \cdot (\overline{C + D + E}) + (\overline{A + B})$:

A) $Y = A + B$
B) $Y = C + D + E$
C) $Y = \bar{C} \cdot \bar{D} \cdot \bar{E}$
D) $Y = \bar{A} \cdot \bar{B}$
E) $Y = \bar{A} \cdot \bar{B} \cdot \bar{C} \cdot \bar{D} \cdot \bar{E}$
F) None of the above

19. What is the resolution of a 5-bit analogue (0-10V) to digital data converter?

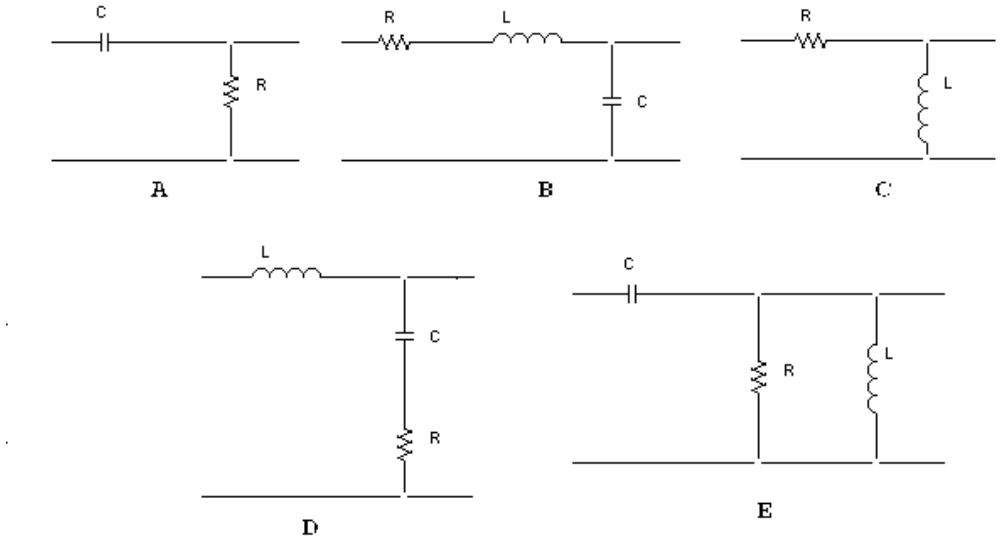
A) 3% B) 6% C) 1.56% D) 10% E) 16%

20. How many storage locations are available when a memory device has nine address lines?

A) 144 B) 256 C) 512 D) 2048 E) 4096

Calculations (20% total)

21. Shown below are 5 circuits. Assume that the input voltage (V_{in}) is applied across the leftmost terminals, and the output voltage, V_{out}, is measured across the rightmost terminals.



Given below are several possible expressions for generic transfer functions for such circuits. Write down which function goes with which circuit. (2 points each)

$$\frac{j\omega L}{R + j\omega L + \frac{1}{j\omega C}}$$

$$\frac{R}{R + \frac{1}{j\omega C}}$$

$$\frac{R + \frac{1}{j\omega C}}{R + j\omega L + \frac{1}{j\omega C}}$$

$$\frac{j\omega C + \frac{1}{j\omega L}}{R + j\omega C + \frac{1}{j\omega L}}$$

$$\frac{\frac{1}{j\omega C}}{R + j\omega L + \frac{1}{j\omega C}}$$

$$\frac{R}{R + j\omega L}$$

$$\frac{R + j\omega L}{R + j\omega L + \frac{1}{j\omega C}}$$

$$\frac{\frac{R}{j\omega RC + 1}}{j\omega L + \frac{R}{j\omega RC + 1}}$$

$$\frac{j\omega L}{R + j\omega L}$$

$$\frac{R}{R + j\omega L + \frac{1}{j\omega C}}$$

$$\frac{\frac{1}{j\omega C}}{R + \frac{1}{j\omega C}}$$

$$\frac{j\omega L + \frac{1}{j\omega C}}{R + j\omega L + \frac{1}{j\omega C}}$$

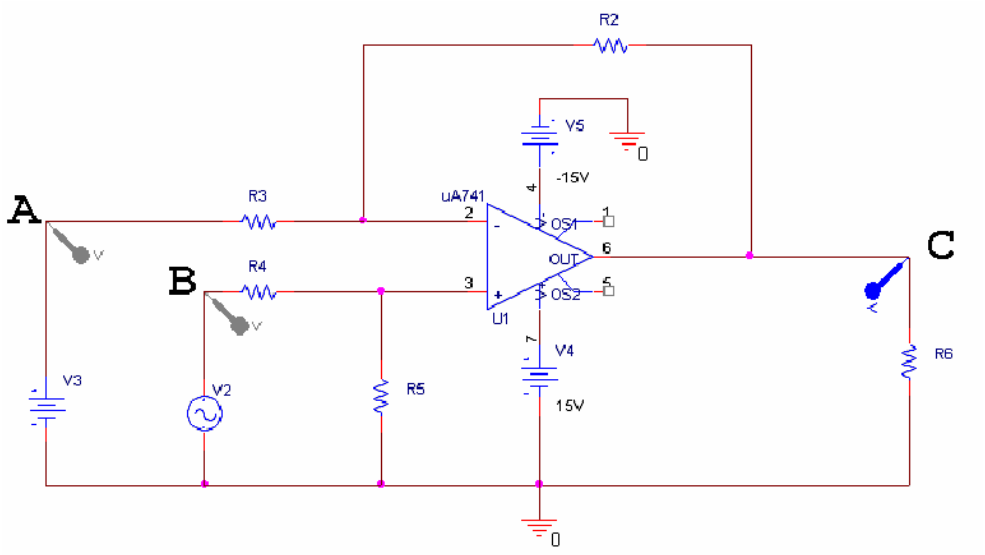
$$\frac{\frac{j\omega LR}{R + j\omega L}}{\frac{1}{j\omega C} + \frac{j\omega LR}{R + j\omega L}}$$

22. For the circuit below, assume the following about the components:

V2: has a DC offset of 500mV, and an AC amplitude 100 mV at a frequency of 1 KHz

V3: is a DC voltage of 300mV

R2=18 kΩ, R3=3 kΩ, R4=3 kΩ, R5=18 kΩ, R6=10 kΩ



a. **What kind of amplifier is this (1%)**

b. **Write an expression for the input signal at B in the form $v(t)=A\sin(\omega t) + V_{DC}$, using the values above (3%)**

c. **Write an equation for the output at C (V_C) in terms of the input voltages V2 and V3. Simplify, but do not substitute for V2 and V3. (2%)**

d. **Write an expression for the output signal at C in the form $v(t)=A\sin(\omega t) + V_{DC}$ substituting in values. (4%)**

BJT parameters for common emitter configuration (subscript $_e$)

other subscripts: Input$_i$ Output$_o$ Forward$_f$ Reverse$_r$

h_{FE}	DC gain	I_C / I_B	
h_{fe}	AC gain	i_c / i_b	$h_{FE} \approx h_{fe}$ (mostly)
g_m	Transconductance	$\Delta I_C / \Delta V_{BE} = i_c / v_{be}$	$\sim 40 \cdot I_C \approx 40 \cdot I_E$
h_{ie}	Small signal input resistance	$\Delta V_{BE} / \Delta I_B = v_{be} / i_b$	$\sim 1 / (40 \cdot I_B)\ \Omega \approx h_{fe} / (40 \cdot I_C)$
h_{oe}	Output admittance ($1/r_o$) where r_o = Slope in the active region	$\Delta I_C / \Delta V_{CE} = i_c / v_{ce}$	
r_e	Emitter resistance	$\Delta V_{BE} / \Delta I_C = v_{be} / i_c = 1/g_m$	$\approx v_{be} / i_e$ that is, $h_{ie} = h_{fe} \cdot r_e$
h_{re}	Early effect (V_{CE} affects bias V_{BE})	$\Delta V_{CE} / \Delta V_{BE}$	

$$h_{FE} = \frac{I_C}{I_B}$$

$$I_E = I_C + I_B = (h_{FE} + 1) \cdot I_B$$

$$\text{but because } h_{FE} >> 1,$$

$$I_E \approx h_{FE} \cdot I_B = I_C$$

$$I_B = I_{BS} \cdot e^{40 \cdot V_{BE}} \quad \text{where } I_{BS} \text{ is constant}$$

$$I_C = h_{FE} \cdot I_B = h_{FE} \cdot I_{BS} \cdot e^{40 \cdot V_{BE}}$$

$$g_m = \frac{\Delta I_C}{\Delta V_{BE}} = \frac{dI_C}{dV_{BE}} = 40 \cdot h_{FE} \cdot I_{BS} \cdot e^{40 \cdot V_{BE}}$$

$$g_m = \qquad = 40 \cdot I_C \approx 40 \cdot I_E$$