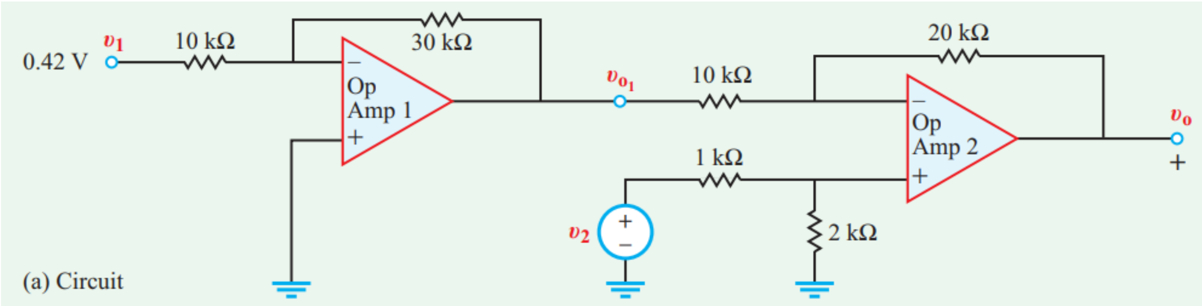
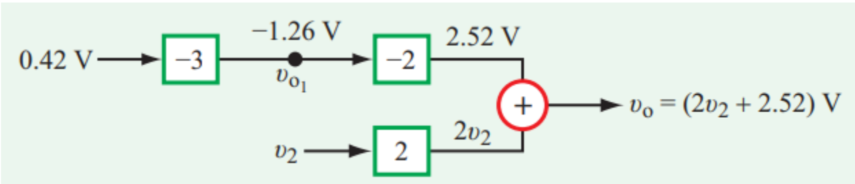
ECEN203 Tutorial 4: Operational Amplifiers (with answers)

Answer all 9 questions. Answers are provided for your self-checking.

Q1. Generate a block-diagram representation for the circuit shown below. See Pg 211 Example 4-4.

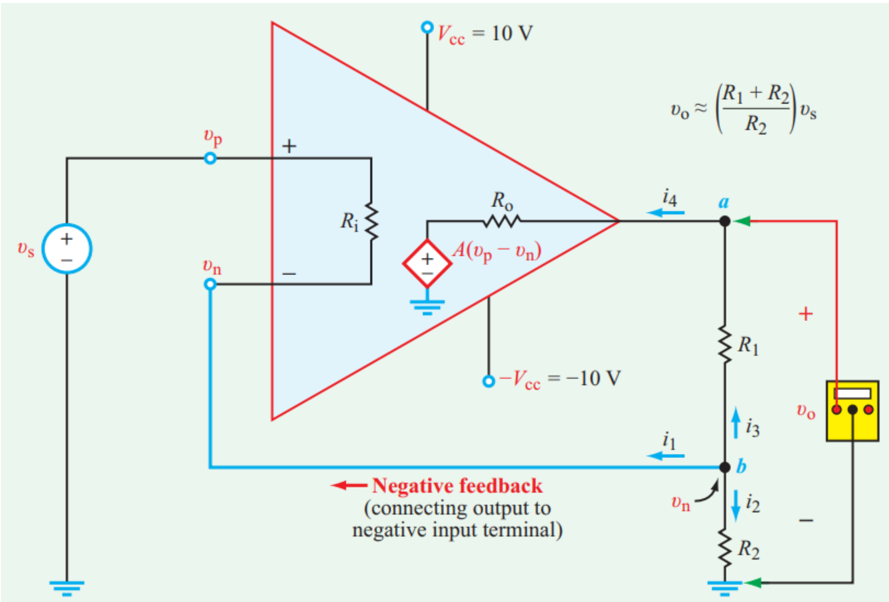


(a) Circuit

(Answer: 

)

Q2. In the circuit shown below, insert a series resistance R_s between υ_s and υ_p and then repeat the solution to obtain an expression for G. Evaluate G for R_s = 10. What impact does the insertion of Rs have on the magnitude of G?
For $V_{cc} = 10$ V, $A = 10^6$, $R_i = 10^7$ Ω, $R_o = 10$ Ω, $R_1 = 80$ kΩ, and $R_2 = 20$ kΩ,



(Answer:
$$G = \frac{[A(R_i + R_s)(R_1 + R_2) + R_2 R_o]}{[AR_2(R_i + R_s) + R_o(R_2 + R_i + R_s) + R_1 R_2 + (R_i + R_s)(R_1 + R_2)]}$$
$$= 4.999977 \quad \text{(negligible impact).}$$
)

Q3. To evaluate the trade-off between the circuit gain G and the linear dynamic range of υ_s, apply this equation $G = \frac{\upsilon_o}{\upsilon_s} = \frac{[AR_i(R_1 + R_2) + R_2R_o]}{AR_2R_i + R_o(R_2 + R_i) + R_1R_2 + R_i(R_1 + R_2)}$, to find the magnitude of G and then determine the corresponding dynamic range of υ_s for each of the following values of R_2: 0 (no feedback), 800 , 8.8 k, 40 k, 80 k, and 1 M. Except for R_2, all other quantities remain unchanged.

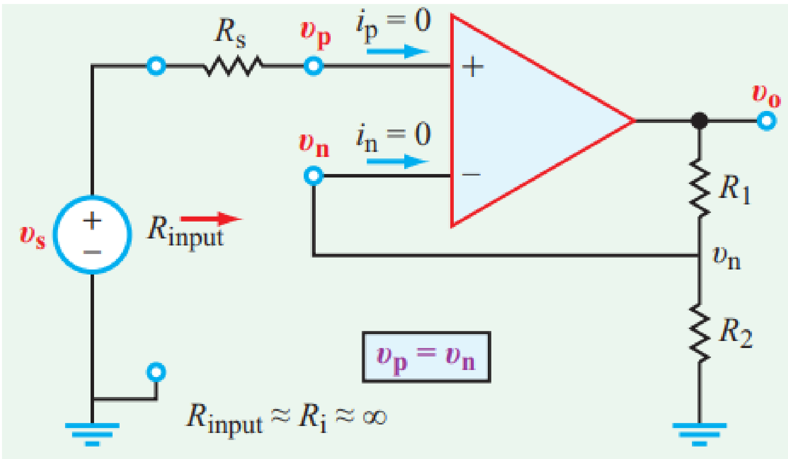
For $V_{cc} = 10$ V, $A = 10^6$, $R_i = 10^7$ Ω, $R_o = 10$ Ω, $R_1 = 80$ kΩ, and $R_2 = 20$ kΩ,

(Answer:

R_2	G	υ_s Range
0	10^6	$-10\ \mu$V to $+10\ \mu$V
800 Ω	101	-99 mV to $+99$ mV
8.8 kΩ	10.1	-0.99 V to $+0.99$ V
40 kΩ	3	-3.3 V to $+3.3$ V
80 kΩ	2	-5 V to $+5$ V
1 MΩ	1.08	-9.26 V to $+9.26$ V

)

Q4. Consider the noninverting amplifier circuit as shown below under the conditions of the ideal op-amp model. Assume V_{cc} = 10 V. Determine the value of G and the corresponding dynamic range of υ_s for each of the following values of R_1/R_2: 0, 1, 9, 99, 10^3, 10^6.



Answer:

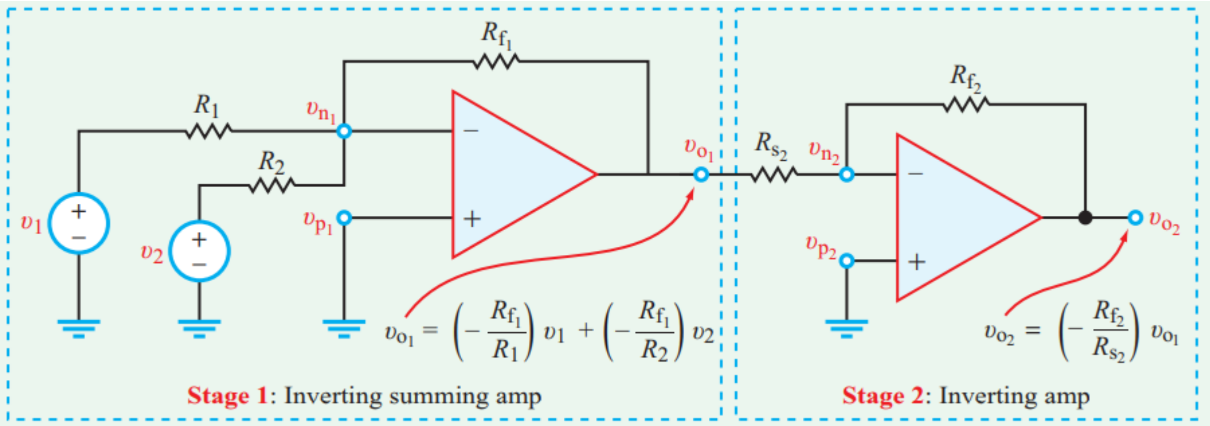
R_1/R_2	G	υ_s Range
0	1	-10 V to $+10$ V
1	2	-5 V to $+5$ V
9	10	-1 V to $+1$ V
99	100	-0.1 V to $+0.1$ V
1000	~ 1000	-10 mV to $+10$ mV (approx.)
10^6	$\sim 10^6$	$-10\ \mu$V to $+10\ \mu$V (approx.)

)

Q5. The input to an inverting-amplifier circuit consists of υ_s = 0.2 V and R_s = 10 . If V_{cc} = 12 V, what is the maximum value that R_f can assume before saturating the op amp?

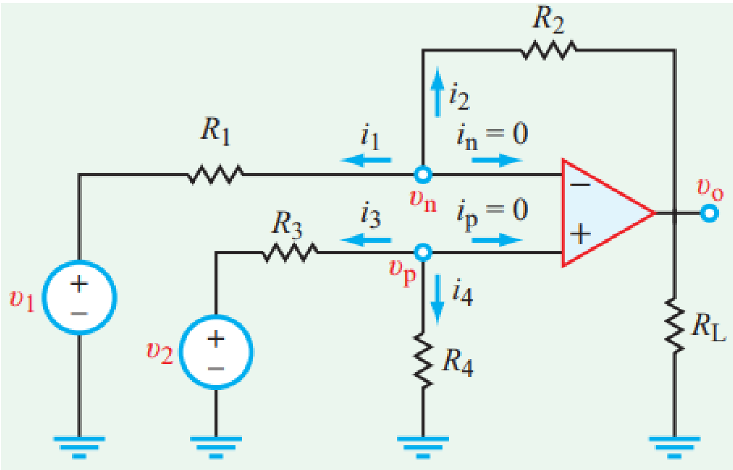
(Answer: $G_{max} = -60$, R_f = 600.)

Q6. The circuit shown in Fig. 4-14(a) is to be used to perform the operation $\upsilon_o = 3\upsilon_1 + 6\upsilon_2$. If R_1 = 1.2 k, R_{s2} = 2 k, and R_{f2} = 4 k, select values for R_2 and R_{f1} so as to realize the desired result.



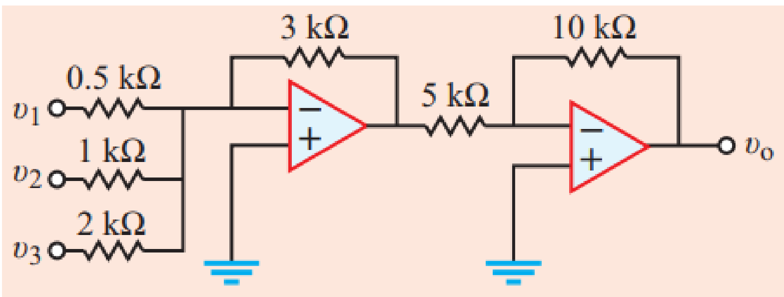
(Answer: R_{f1}= 1.8 k, R_2 = 600.)

Q7. The difference-amplifier circuit below is used to realize the operation $\upsilon_o = (6\upsilon_2 - 2)$ V. Given that R_3 = 5 k, R_4 = 6 k, and R_2 = 20 k, specify values for υ_1 and R_1.



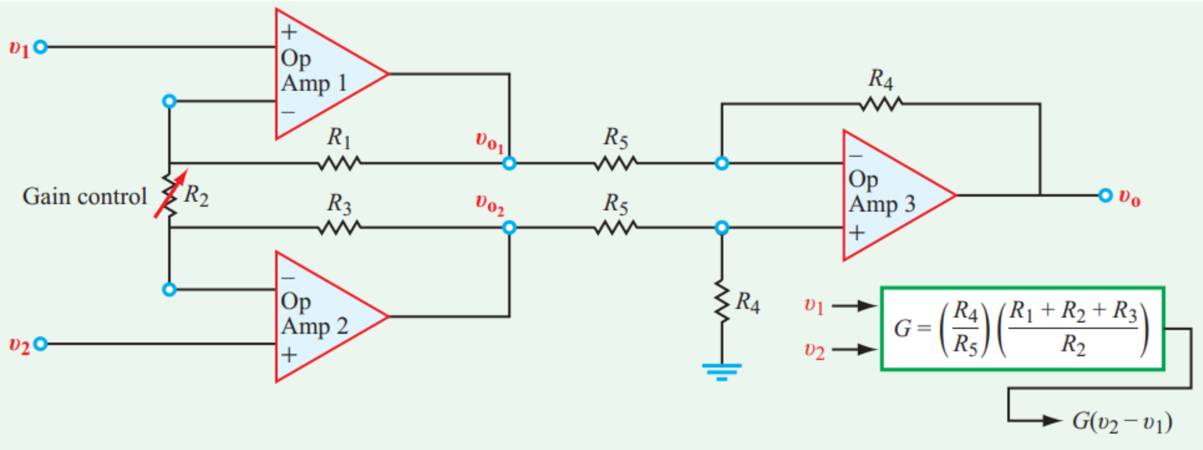
(Answer: υ_1 = 0.2 V, R_1 = 2 k.)

Q8. Express υ_o in terms of υ_1, υ_2, and υ_3 for the circuit below.



(Answer: $\upsilon_o = 12\upsilon_1 + 6\upsilon_2 + 3\upsilon_3$.)

Q9. To monitor brain activity, an instrumentation-amplifier sensor uses a pair of needle-like probes inserted at different locations in the brain to measure the voltage difference between them. If the circuit is of the type shown below with $R_1 = R_3 = R_4 = R_5 = R = 50$ k, $V_{cc} = 12$ V, and the maximum magnitude of the voltage difference that the brain is likely to exhibit is 3 mV, what should R_2 be to maximize the sensitivity of the brain sensor?



(Answer: $R_2 = 25$.)