1. A commonly used circuit for sensitive resistance measurements is Wheatstone bridge. An amplification circuit (Fig. 1) is needed to amplify the voltage difference generated in Wheatstone bridge. Assume all operational amplifiers are ideal, and answer the following questions:

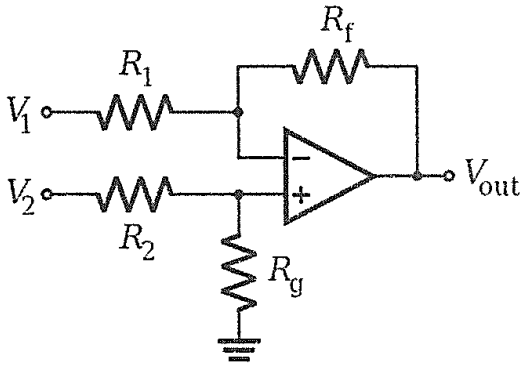

Fig. 1

(a) (5%) Derive the voltage gain, V_{out}/V_2, if V_1=0. What kind of amplifier is it?

(b) (5%) Derive the voltage gain, V_{out}/V_1, if V_2=0. What kind of amplifier is it?

(c) (5%) Using superposition, derive the relation of V_{out} and V_2-V_1 as a function of R_1, R_2, R_f and R_g.

(d) (5%) The instrumentation amplifier (Fig. 2) is an advanced version. Please describe the top-1 benefit, comparing to the circuit in Fig. 1.

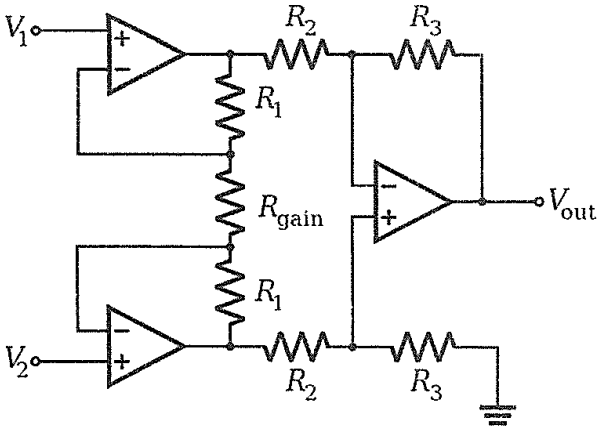

Fig. 2

(e) (10%) Determine the gain, $V_{out}/(V_2-V_1)$, of the advanced version.

2. (10%) Design the current limiting resistance for a circuit (Fig. 3) with a LED (Forward Voltage, V_f= 3.5V, Current $I_{f,max}$= 320 mA), a lithium-ion battery (Supply Voltage = 4.1V), and the Resistance. Specify the required resistance value and power rating of the resistance.

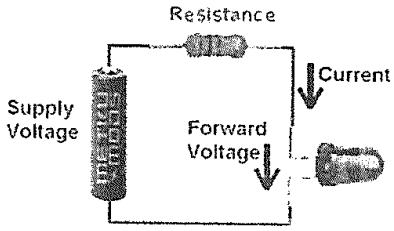

Fig. 3

見背面

3. (20%) For the circuit in Fig. 4, find the range of v_I over which Q_1 is operating in saturation. Under such condition, find the output voltage. Assume the threshold voltage $V_{t1} = V_{t2} = V_t$.
4. (20%) Evaluate the voltages at all nodes and the currents through all branches in the circuit of Fig. 5. Assume $\beta = 100$. Please first mark all the nodes and the branch currents of Fig. 5 on the answer sheet.
5. (20%) A common-source amplifier using an NMOS transistor biased in the manner of Fig. 6 for which g_m = 2 mA/V is found to have an overall voltage gain G_v of −16 V/V. What value should a resistance R_S inserted in the source lead have to reduce the voltage gain by a factor of 4?

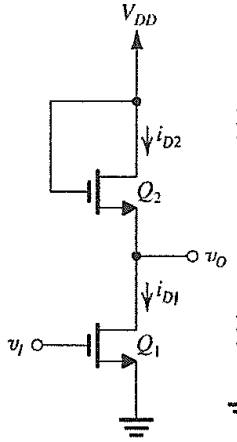

Fig. 4

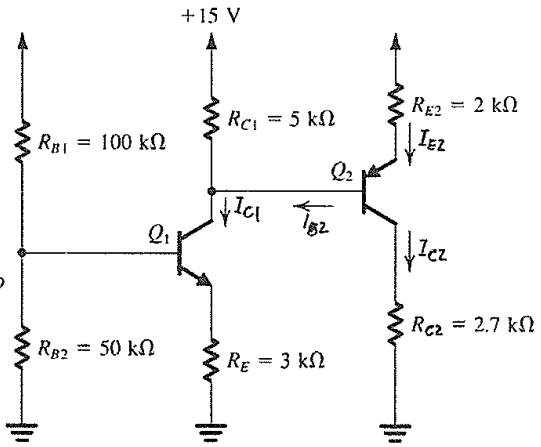

Fig. 5

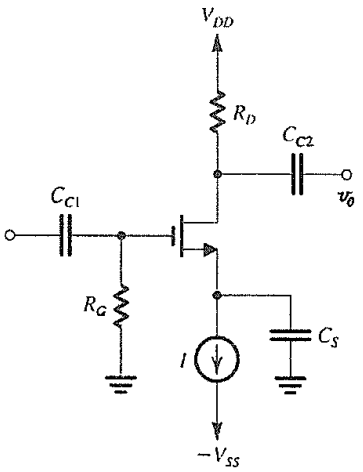

Fig. 6