Learning Objective 3.1: I can describe DSB-AM, DSB-SC, and SSB and identify each on a spectrum.
Learning Objective 3.2: I can implement an AM modulator and demodulator in GNU Radio and verify demodulated audio against the source.

Show your work. Write a **Documentation** line at the end (**None** if you did not collaborate).

1. **Reading a spectrum.** A 1 kHz tone modulates a 100 kHz carrier.

   (a) List the frequencies of the spectral lines for DSB-AM, DSB-SC, USB, and LSB.

Signal	Lines (kHz)	Bandwidth (kHz)
DSB-AM		
DSB-SC		
USB		
LSB		

   (b) A spectrum display shows two lines of equal height at 14.997 and 15.003 MHz and nothing between them. Name the modulation, the carrier frequency, and the message tone.

   (c) A waterfall shows a voice signal from 7.1970 to 7.1997 MHz that comes and goes with speech, with no steady line beside it. Voice runs from 300 Hz to 3 kHz. Name the modulation and the frequency a receiver must tune to.

2. **DSB-AM.** A transmitter sends $s(t) = [1 + m\cos(2\pi f_m t)]\cos(2\pi f_c t)$, with m set by a slider.

   (a) On the flowgraph's frequency sink you drag m from 0.5 up to 1. Say which lines change and which do not.

   (b) The carrier is the tallest line on the display. Explain why it carries no information, and why AM broadcasting keeps it anyway.

   (c) A station carries audio up to 5 kHz. Find its bandwidth.

   (d) The operator raises m to 1.2. Explain in words what an envelope detector now outputs, and why it no longer matches the message.

3. **The envelope detector flowgraph.** The receiver in `L06-dsb-am.grc` is Abs, then a low-pass filter, then Multiply Const. The flowgraph runs at 48 kHz with a 10 kHz carrier and a message up to 2.5 kHz.

   (a) The low-pass filter has a 3 kHz cutoff and a 1 kHz transition. Explain why that works: what must it pass, and what must it stop?

   (b) Explain the Multiply Const of $\pi/2$ after the filter.

   (c) The time sink shows the detector output lagging the envelope by 57 samples. Find the lag in milliseconds, and name the block that causes it.

   (d) The flowgraph has an Audio Sink and no Throttle. Explain why.

4. **Coherent and product detectors.**

(a) In `L06-dsb-sc.grc` you drag the LO phase slider from 0° to 90° with the audio on. Describe what the coherent receiver's trace on the time sink and the audio do.

(b) Explain why a DSB-SC receiver on the air needs carrier recovery, and how FM stereo provides it for its DSB-SC subcarrier.

(c) A USB signal carries a 1 kHz tone. The product detector's LO sits 150 Hz above the carrier. Find the output tone. Repeat for LSB.

USB:

LSB:

(d) The SSB flowgraph's Delay block holds the message back $(129 - 1)/2 + 57$ samples before comparing it with the receiver's output. Find the delay and explain each term.

Documentation: _____