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--- Day 16: Packet Decoder ---

As you leave the cave and reach open waters, you receive a transmission from the Elves back on the ship.

The transmission was sent using the Buoyancy Interchange Transmission System (BITS), a method of packing numeric expressions into a binary sequence. Your submarine's computer has saved the transmission in `hexadecimal` (your puzzle input).

The first step of decoding the message is to convert the hexadecimal representation into binary. Each character of hexadecimal corresponds to four bits of binary data:

0	=	0000
1	=	0001
2	=	0010
3	=	0011
4	=	0100
5	=	0101
6	=	0110
7	=	0111
8	=	1000
9	=	1001
A	=	1010
B	=	1011
C	=	1100
D	=	1101
E	=	1110
F	=	1111

The BITS transmission contains a single packet at its outermost layer which itself contains many other packets. The hexadecimal representation of this packet might encode a few extra `0` bits at the end; these are not part of the transmission and should be ignored.

Every packet begins with a standard header: the first three bits encode the packet version, and the next three bits encode the packet type ID. These two values are numbers; all numbers encoded in any packet are represented as binary with the most significant bit first. For example, a version encoded as the binary sequence `100` represents the number `4`.

Packets with type ID `4` represent a literal value. Literal value packets encode a single binary number. To do this, the binary number is padded with leading zeroes until its length is a multiple of four bits, and then it is broken into groups of four bits. Each group is prefixed by a `1` bit except the last group, which is prefixed by a `0` bit. These groups of five bits immediately follow the packet header. For example, the hexadecimal string `D2FE28` becomes:

```
1101001011111111000101000
VVVTTTAAAAABBBBBCCCCC
```

Below each bit is a label indicating its purpose:

- The three bits labeled `V` (`110`) are the packet version, `6`.
- The three bits labeled `T` (`100`) are the packet type ID, `4`, which means the packet is a literal value.
- The five bits labeled `A` (`10111`) start with a `1` (not the last group, keep reading) and contain the first four bits of the number, `0111`.
- The five bits labeled `B` (`11110`) start with a `1` (not the last group,

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- keep reading) and contain four more bits of the number, `1110`.
- The five bits labeled `C` (`00101`) start with a `0` (last group, end of packet) and contain the last four bits of the number, `0101`.
- The three unlabeled `0` bits at the end are extra due to the hexadecimal representation and should be ignored.

So, this packet represents a literal value with binary representation `011111100101`, which is `2021` in decimal.

Every other type of packet (any packet with a type ID other than `4`) represent an operator that performs some calculation on one or more sub-packets contained within. Right now, the specific operations aren't important; focus on parsing the hierarchy of sub-packets.

An operator packet contains one or more packets. To indicate which subsequent binary data represents its sub-packets, an operator packet can use one of two modes indicated by the bit immediately after the packet header; this is called the length type ID:

- If the length type ID is `0`, then the next 15 bits are a number that represents the total length in bits of the sub-packets contained by this packet.
- If the length type ID is `1`, then the next 11 bits are a number that represents the number of sub-packets immediately contained by this packet.

Finally, after the length type ID bit and the 15-bit or 11-bit field, the sub-packets appear.

For example, here is an operator packet (hexadecimal string `38006F45291200`) with length type ID `0` that contains two sub-packets:

```
0011110000000000000011011110100010100101001000100100000000
VVVTTTILLLLLLLLLLLLLLLLLLAAAAAAAAAABBBBBBBBBBBBBBBBBB
```

- The three bits labeled `V` (`001`) are the packet version, `1`.
- The three bits labeled `T` (`110`) are the packet type ID, `6`, which means the packet is an operator.
- The bit labeled `I` (`0`) is the length type ID, which indicates that the length is a 15-bit number representing the number of bits in the sub-packets.
- The 15 bits labeled `L` (`000000000011011`) contain the length of the sub-packets in bits, `27`.
- The 11 bits labeled `A` contain the first sub-packet, a literal value representing the number `10`.
- The 16 bits labeled `B` contain the second sub-packet, a literal value representing the number `20`.

After reading 11 and 16 bits of sub-packet data, the total length indicated in `L` (27) is reached, and so parsing of this packet stops.

As another example, here is an operator packet (hexadecimal string `EE00D40C823060`) with length type ID `1` that contains three sub-packets:

```
1110111000000000001101010000001100100000100011000001100000
VVVTTTILLLLLLLLLLLLLLLLLLAAAAAAAAAABBBBBBBBBBBCCCCCCCCCCC
```

- The three bits labeled `V` (`111`) are the packet version, `7`.
- The three bits labeled `T` (`011`) are the packet type ID, `3`, which means the packet is an operator.
- The bit labeled `I` (`1`) is the length type ID, which indicates that the length is a 11-bit number representing the number of sub-packets.
- The 11 bits labeled `L` (`00000000011`) contain the number of sub-packets, `3`.
- The 11 bits labeled `A` contain the first sub-packet, a literal value

- representing the number `1`.
- The 11 bits labeled `B` contain the second sub-packet, a literal value representing the number `2`.
- The 11 bits labeled `C` contain the third sub-packet, a literal value representing the number `3`.

After reading 3 complete sub-packets, the number of sub-packets indicated in `L` (3) is reached, and so parsing of this packet stops.

For now, parse the hierarchy of the packets throughout the transmission and add up all of the version numbers.

Here are a few more examples of hexadecimal-encoded transmissions:

- `8A004A801A8002F478` represents an operator packet (version 4) which contains an operator packet (version 1) which contains an operator packet (version 5) which contains a literal value (version 6); this packet has a version sum of `16`.
- `620080001611562C8802118E34` represents an operator packet (version 3) which contains two sub-packets; each sub-packet is an operator packet that contains two literal values. This packet has a version sum of `12`.
- `C0015000016115A2E0802F182340` has the same structure as the previous example, but the outermost packet uses a different length type ID. This packet has a version sum of `23`.
- `A0016C880162017C3686B18A3D4780` is an operator packet that contains an operator packet that contains an operator packet that contains five literal values; it has a version sum of `31`.

Decode the structure of your hexadecimal-encoded BITS transmission; what do you get if you add up the version numbers in all packets?

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