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Camp Algebra



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A puzzle from Fiddler on the Proof, in the style of the MIT Mystery Hunt rather than the usual brainteaser.

Problem

Camp Algebra held a competition in which campers were split into two teams: the Aces and the Ciphers. Members of the two teams competed in a triathlon of chess, basketball, and baseball. To commemorate the event, the counselors designed a cuboidal trophy whose dimensions related to the results of the three events. Then, being Camp Algebra after all, they computed the square of the shortest path along the trophy's surface from one corner to the opposite corner. After decoding that number, what camp mascot did they carve into the trophy?

Read the team names first

Everything in this puzzle is binary, and the puzzle says so in its first sentence. An ace is a one and a cipher is a zero. Both words carry that meaning in ordinary English, and the two teams are named for the two binary digits. Hold on to that, because it is the only instruction the puzzle gives about how to read anything.

The three events give three results, the three results give three dimensions, and the trophy does the rest.

Chess: Castor to play

Occupatus, playing as white for the Aces, had Castor, playing as black for the Ciphers, on the ropes. But the industrious Castor clearly gave a dam. With what next move did Castor turn the tables?

The game runs to 24. Rd1, reaching the position below with Black to move. White is a rook up for a knight and looks to be winning.

Black's queen already eyes d1 down the open file, but 24 ... Qxd1+ merely trades the queen for a rook after 25. Kxd1. The move that wins is quieter:

24 ... Bb4+

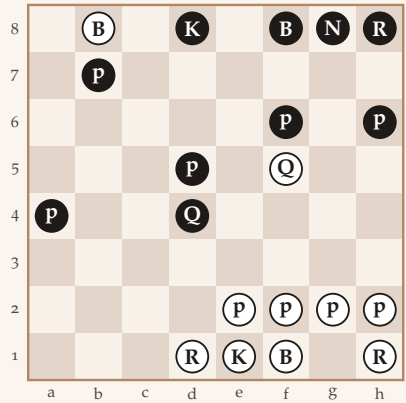


Figure 1: After 24. Rd1. Black plays and wins. White pieces are light, Black pieces dark; pawns are marked *p*.

The bishop, which has sat on f8 untouched all game, checks along the a5–e1 diagonal. Now count White’s replies. The king cannot move, because d2, e2 and f2 are all covered or occupied; nothing captures the bishop; and of the two squares that block the diagonal, c3 cannot be reached by any white piece. Exactly one legal move remains,

25. Rd2,

and the rook that interposes is pinned to its king by the very queen it is blocking, so

25 ... Q×d2#.

That is the dam: Castor forces White to build one across the diagonal, then takes it. The flavour is a fair warning as well as a joke, since *Castor* is the beaver’s genus.

For the trophy, only the result matters. The Ciphers win the chess, and a decisive chess game is scored 1–0, so the margin is 1.

Basketball: tally it yourself

The Aces crushed the Ciphers in the second competition. While the box score showed all the players’ names in order, it neglected to tally the two teams’ scores bit by bit.

The box score gives each player’s shooting but no team totals, so compute them. Total field goals include the three-pointers, so a player’s points are

$$2 \text{ (FG} - 3\text{FG)} + 3 \text{ (3FG)} + \text{FT}.$$

Aces				
Parker, Unity	8–14	2–4	2–2	20
Edwards, Solo	7–12	3–5	2–3	19
Roberts, Singleton	7–11	1–3	3–3	18
Foster, Primo	6–10	2–4	3–5	17
Ellis, Uno	6–9	2–3	4–4	18
Carter, Tally	6–10	3–5	3–4	18
Thompson, O’Neal	6–10	4–4	1–1	17
				127

Ciphers				
Smith, Zero	5–9	2–4	1–2	13
Taylor, Nil	4–8	2–3	2–3	12
Allen, Void	4–9	1–3	3–5	12
Harris, Off	4–7	1–2	2–2	11
Ingram, Null	4–6	1–2	2–4	11
Robinson, Nought	4–7	2–4	1–2	11
Davis, Nada	3–6	1–2	3–4	10
				80

Look at the first names. Every Ace is a word for one: Unity, Solo, Singleton, Primo, Uno, Tally, O'Neal. Every Cipher is a word for nothing: Zero, Nil, Void, Off, Null, Nought, Nada. Seven players a side, so each team's names spell a seven-bit string, and for the Aces that string is 1111111, which is 127 in binary. Their points also come to 127. The puzzle is confirming that you have read it correctly, which is what the phrase *bit by bit* is for.

The Ciphers score 80, so the margin is $127 - 80 = 47$.

Baseball: the line score is already binary

In the final event, the Aces narrowly defeated the Ciphers, 5–4. But whatever did the scoreboard look like? Surely both line-ups had something to say about that.

The play-by-play is given inning by inning, so replay it. Singles, doubles, triples, home runs and walks advance the runners in the ordinary way, and strikeouts, fly outs and ground outs are outs. Every half-inning comes to exactly three outs, which is the check that the replay is being done right.

	1	2	3	4	5	6	7	8	9	R
Aces	0	0	1	0	1	1	1	0	1	5
Ciphers	0	1	0	1	0	0	1	1	0	4

The totals come to 5–4 as promised. The detail worth noticing is that no inning ever scores two: every entry is a 0 or a 1, so the scoreboard is itself a pair of binary numbers, nine bits each. That is the third appearance of the same idea, and it is why the line-ups have something to say.

The margin is $5 - 4 = 1$.

The trophy

Three events, three margins, three dimensions:

$$1 \times 47 \times 1.$$

A long thin bar, which is an odd trophy but a good one for this question, because the shortest path across its surface is exactly where the interest lies.

To find that path, unfold the box flat. A path between opposite corners crosses two faces, and each choice of two faces unfolds to a straight line whose length is the hypotenuse of a right triangle. For a box $a \times b \times c$ the three candidates are

$$(a + b)^2 + c^2, \quad (a + c)^2 + b^2, \quad (b + c)^2 + a^2,$$

and the shortest path squared is the smallest. With $\{a, b, c\} = \{1, 1, 47\}$,

$$(1 + 1)^2 + 47^2 = 2213, \quad (1 + 47)^2 + 1^2 = 2305, \quad (1 + 47)^2 + 1^2 = 2305.$$

Crossing the two small square ends is worse than it looks, and the winner is the route that keeps the two unit steps together:

$\text{shortest path}^2 = 2^2 + 47^2 = 2213.$

Decoding 2213

The puzzle has said *binary* three times, so write 2213 in binary:

$$2213 = 100010100101_2.$$

Twelve bits, which is not a multiple of five, so pad to fifteen and cut into three:

00010	00101	00101
↓	↓	↓
2	5	5
B	E	E

With A = 1 through Z = 26, five bits is exactly the width a letter needs, and the padding is forced: pad to twenty bits instead and the leading group is 00000, which is not a letter.

The mascot is a **BEE**.

Why the answer is safe

A puzzle of this kind can be talked into almost any answer, so it is worth saying what pins this one down. Searching every cuboid with sides up to 400, computing the shortest surface path squared, and decoding it five bits to a letter, the word BEE appears for exactly one set of dimensions, namely $1 \times 1 \times 47$. The three margins were derived independently of that search, from three events that have nothing to do with one another, and they land on the only triple that works.

```
def path2(a, b, c):
    return min((a+b)**2 + c**2, (a+c)**2 + b**2, (b+c)**2 + a**2)

def decode(n):
    # five bits to a letter, A = 1
    s = bin(n)[2:]
    s = s.rjust(((len(s) + 4) // 5) * 5, "0")
    v = [int(s[i:i+5], 2) for i in range(0, len(s), 5)]
    return "".join(chr(64 + x) for x in v) if all(1 <= x <= 26 for x in v) else None

hits = [(a, b, c) for a in range(1, 401) for b in range(a, 401)
        for c in range(b, 401) if decode(path2(a, b, c)) == "BEE"]
print(hits, path2(1, 1, 47))
# [(1, 1, 47)] 2213
```