

- 1] Given triangle  $ABC$  the point  $J$  is the centre of the excircle opposite the vertex  $A$ . This excircle is tangent to the side  $BC$  at  $M$ , and to the lines  $AB$  and  $AC$  at  $K$  and  $L$ , respectively. The lines  $LM$  and  $BJ$  meet at  $F$ , and the lines  $KM$  and  $CJ$  meet at  $G$ . Let  $S$  be the point of intersection of the lines  $AF$  and  $BC$ , and let  $T$  be the point of intersection of the lines  $AG$  and  $BC$ . Prove that  $M$  is the midpoint of  $ST$ .

(The *excircle* of  $ABC$  opposite the vertex  $A$  is the circle that is tangent to the line segment  $BC$ , to the ray  $AB$  beyond  $B$ , and to the ray  $AC$  beyond  $C$ .)

- 2] If positive reals  $a_2, a_3, \dots, a_n$  satisfy  $a_2 \cdot a_3 \cdot \dots \cdot a_n = 1$  prove that

$$(a_2 + 1)^2 (a_3 + 1)^3 \dots (a_n + 1)^n > n^n$$

- 3] The *liar's guessing game* is a game played between two players  $A$  and  $B$ . The rules of the game depend on two positive integers  $k$  and  $n$  which are known to both players.

At the start of the game  $A$  chooses integers  $x$  and  $N$  with  $1 \leq x \leq N$ . Player  $A$  keeps  $x$  secret, and truthfully tells  $N$  to player  $B$ . Player  $B$  now tries to obtain information about  $x$  by asking player  $A$  questions as follows: each question consists of  $B$  specifying an arbitrary set  $S$  of positive integers (possibly one specified in some previous question), and asking  $A$  whether  $x$  belongs to  $S$ . Player  $B$  may ask as many questions as he wishes. After each question, player  $A$  must immediately answer it with *yes* or *no*, but is allowed to lie as many times as she wants; the only restriction is that, among any  $k + 1$  consecutive answers, at least one answer must be truthful.

After  $B$  has asked as many questions as he wants, he must specify a set  $X$  of at most  $n$  positive integers. If  $x$  belongs to  $X$ , then  $B$  wins; otherwise, he loses. Prove that:

1. If  $n \geq 2^k$ , then  $B$  can guarantee a win.
2. For all sufficiently large  $k$ , there exists an integer  $n \geq (1.99)^k$  such that  $B$  cannot guarantee a win.