

The Blitz-contest of IOM-2020

Nº 1

Inside a room with a black ceiling and walls there is a square table 1 m long. The only source of light in the room is a light bulb hanging 2 m above the table's center. If the light bulb is an isotropic point source of light, how many times is the illuminance of the table's center bigger than the illuminance of the table's corner?

The answer should be given in the SI units unless otherwise stated. If the numerical result turns out to be an integer, it should be given as the answer. Otherwise round the result to the first decimal.

Nº 2

Find the sum of all divisors k of $2^{253} - 1$ such that $1 \leq k \leq 100$.

Nº 3

Thorium-234 undergoes two β^- decays and two α decays. Name the mass number of the resulting isotope.

Nº 4

200 mL of a solution of $AgNO_3$ with a concentration of 0.2 M is subjected to electrolysis. What will be the pH at 25 °C, when 50% of Ag^+ ions discharge on the cathode?

0

0.7

1

1.7

7

Nº 5

A method returns a random number (like UUID) as a 4 bit value. If the method is called 4 times, what is the probability that at least two of the return values are equal?

approximately 10%

approximately 25%

approximately 33%

approximately 66%

Nº 6

A brick of the mass of 2 kg lies on a horizontal surface. The coefficient of static friction between the surface and the brick is $\mu = 0.6$. One side of the surface is being lifted. Determine the maximum angle before the brick starts to shift. The answer should be given in degree and rounded up to integer numbers.

Nº 7

At a certain temperature, the solubility of $BaSO_4$ in a 0.01 M Na_2SO_4 solution is $1 \cdot 10^{-8}$ M. Which of the statements about $BaSO_4$ are correct?

$K_{sp} = 1 \cdot 10^{-16}$

$K_{sp} = 1 \cdot 10^{-10}$

The solubility in water is $2.33 \cdot 10^{-3}$ g / L.

The solubility in water is $1 \cdot 10^{-8}$ M.

Nº 8

Find a 4-digit prime p that satisfies $p^2 = x^3 + y^3$ for some integers x and y .

Nº 9

A particle is projected with the speed 40 m/s from a point on horizontal ground, in the direction making an angle of α above the horizontal. The particle reaches the ground again after 4 s. Find the horizontal distance travelled by the particle.

$$g = 10 \text{ m/s}^2.$$

The answer should be given in the SI units unless otherwise stated. If the numerical result turns out to be an integer, it should be given as the answer. Otherwise round the result to the first decimal.

Nº 10

Let's consider the following function:

```
int f() {
    int i;
    int x = 0;
    for (i = 1; i <= 2020; i++) {
        if (i % 3 == 0) {
            continue;
        }
        x += (i % 5 == 0);
    }
    return x;
}
```

Find $f()$.

Nº 11

Which statement about the enantiomers of a chiral compound is correct?

- Their physical properties are different.
- All their chemical reactions are identical.
- A racemic mixture will rotate the plane of polarized light.
- They will rotate the plane of polarized light in opposite directions.

Nº 12

An excess of MgO is shaken with water. The resulting mixture is filtered, and the filtrate W is obtained. Two drops of dilute sulfuric acid are added to W and an observation is noted. An excess of BaO is shaken with water. The resulting mixture is filtered, and the filtrate X is obtained. Two drops of dilute sulfuric acid are added and an observation is noted. Choose the correct statement about these experiments.

	filtrate with higher pH	observation on addition of sulfuric acid to the filtrate with higher pH
1)	W	no change
2)	W	white precipitate
3)	X	no change
4)	X	white precipitate

1

2

3

4

Nº 13

A block of mass 8 kg is at rest on a plane inclined at 20° to the horizontal. The block is connected to a vertical wall at the top of the plane by a string. The string is taut and parallel to a line of greatest slope of the plane. Given that the tension in the string is 13 N, find the frictional force exerted on the block by the plane. $g = 10 \text{ m/s}^2$.

The answer should be given in the SI units unless otherwise stated. If the numerical result turns out to be an integer, it should be given as the answer. Otherwise round the result to the first decimal.

Nº 14

Buckminsterfullerene C_{60} is the most commonly occurring fullerene molecule, found in small quantities in soot. Which statement about buckminsterfullerene is incorrect?

Its mass spectrum has a prominent peak at m/z value of 720.6

Each carbon atom in a molecule has four neighbors.

The molecule is composed of hexagons and pentagons of carbon atoms.

Van der Waals forces occur between C_{60} molecules in a solid.

Nº 15

For a positive integer n and nonzero digits a, b , and c , let A_n be the n -digit integer each of whose digits is equal to a ; let B_n be the n -digit integer each of whose digits is equal to b , and let C_n be the $2n$ -digit (not n -digit) integer each of whose digits is equal to c . Consider the triples (a, b, c) for which there are at least two values of n such that $C_n - B_n = A_n^2$. Find the maximal value of $a + b + c$ for such triples.

Nº 16

John is driving a car at 20 m/s when he notices a child on the road ahead of him. After 1 second (John's reaction time) he starts to brake. The total mass of car and John is 1500 kg. The braking force is 5000 N. What is the total distance in meters that car travels (from the moment John spots a child to the moment he stops)?

The answer should be given in the SI units unless otherwise stated. If the numerical result turns out to be an integer, it should be given as the answer. Otherwise round the result to the first decimal.

Nº 17

How many fewer bits would be required to represent the word ABRACADABRA using Huffman's compression, compared to 8-bit ASCII representation?

Nº 18

How many 10-digit positive integers have the sum of digits equal to 7?

Nº 19

Temperature of a body is 27°C . Absolute temperature of the body drops to one half of its initial value. What is the final temperature in $^\circ\text{C}$?

Nº 20

A 600 meter wide river flows directly south at 4 m/s. A small motor boat travels at 5 m/s in still water and points in such a direction so that it will travel directly east relative to the land. The time it takes to cross the river is closest to

 67 s 120 s 150 s 200 s 600 s**Nº 21**

A 50 kg woman stands up in a 75 kg boat 10 m long. She walks from one end of the boat to the other end. If you ignore resistance to motion of boat in the water and assume that the mass of the boat is uniformly distributed, how far does the boat move during this process?

The answer should be given in the SI units unless otherwise stated. If the numerical result turns out to be an integer, it should be given as the answer. Otherwise round the result to the first decimal.

Nº 22

All people of our world (assume there are about 8 billion) participate in a competition that consists of a sequence of rounds. After each round, half of the remaining participants have to leave. How many rounds do we need to determine the final winner?

 about 12 about 33 about 124 about 512

Nº 23

You are given the sequence $A = (1, 5, 10, 3, 15, x, y)$. For how many positive integer pairs (x, y) does the longest strictly increasing subsequence of A have a length of 4?

Nº 24

```
int binary_search(vector<int> vec, int value, int n){
    sort(vec.begin(),vec.end());
    int l = 0, r = n - 1
    while (l <= r){
        int mid = (l + r) / 2;
        if (vec[mid] <= value)
            l = mid;
        else
            r = mid;
    }
    return l;
}
```

Determine the time complexity of the function above

$O(N)$

$O(\log N)$

$O(N \log N)$

$O(N \log^2 N)$

$O(\infty)$

Nº 25

For a heating element of a certain device, the temperature dependence (in K) on the operating time was experimentally obtained:

$$T(t) = T_0 + bt + at^2$$

where t is the time (in minutes), $T_0 = 1380$ K, $a = -15$ K/min², $b = 165$ K/min. It is known that if the heating element's temperature rises above 1800 K, the device may break down, so it must be turned off.

Find the longest operation time after which the device must be turned off. Give your answer in minutes.

Fractional numbers can be entered either as a decimal fraction or as m/n .

Nº 26

How many connected components has a forest with 2020 nodes and 1000 edges?

Nº 27

A ball falls down vertically from the initial height of 5 m. After each hit with the ground it bounces back, losing 30% of its energy. What is the total duration of its motion? $g = 10 \text{ m/s}^2$.

The answer should be given in the SI units unless otherwise stated. If the numerical result turns out to be an integer, it should be given as the answer. Otherwise round the result to the first decimal.

Nº 28

Magnetic neodymium disc (diameter 40 mm \times thickness 20 mm and mass 100 g) has a remnant magnetization of typically 1.3 teslas. Determine the magnetic flux through the sphere of radius 1 m surrounding the magnet.

Nº 29

An Unrooted tree has 1011 leaves, and every non-leaf node of the tree has degree 3. How many nodes has the tree have?

Nº 30

Evaluate and express the result in decimal: $2020_{16} - 2020_8 - 2020_4$

Nº 31

How many *cis-trans* isomers does nona-1,3,5,7-tetraene have?

Nº 32

Determine the number of secondary carbon atoms in 5-(sec-butyl)-2-methylnonane.

Nº 33

Let a and b be real numbers such that $\frac{ab}{a^2+b^2} = \frac{1}{6}$.

Find the value of $\left(\frac{a^2-b^2}{a^2+b^2}\right)^2$.

Fractional numbers can be entered either as a decimal fraction or as m/n .

Nº 34

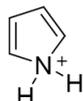
Which of the following molecules and ions are aromatic?



1



2



3



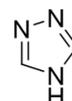
4



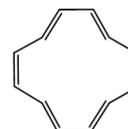
5



6



7



8

Nº 35

In the first order reaction $A \rightarrow P$, 50% of the initial amount of A reacts during 12 minutes. How long will it take for 25% of A to react?

4 min

5 min

6 min

8 min

10 min

24 min

Nº 36

The line $y = 8x - 1$ is tangent to the curve $y = 2x^2 + c$. Determine the constant c .

Fractional numbers can be entered either as a decimal fraction or as m/n .

Nº 37

Consider a circle with six pairwise different points fixed on it. Three of these points are randomly selected and joined to form a triangle. The remaining three points form a second triangle. Compute the probability that the two triangles do not overlap.

Express the probability as a number between 0 and 1. Fractional numbers can be entered either as a decimal fraction or as m/n .

Nº 38

Anhydrous salt X is a white powder, which gives a white precipitate when it gets into water, but easily dissolves in dilute nitric acid without gas evolution. On strong heating, X decomposes with the release of brown gas, leaving no solid residue. When solution X is exposed to a solution of potassium iodide, a red precipitate is formed, which dissolves in the excess of the reagent to form a pale yellow solution. Determine X . Write down its molar mass (in g/mol) rounded to the nearest integer.

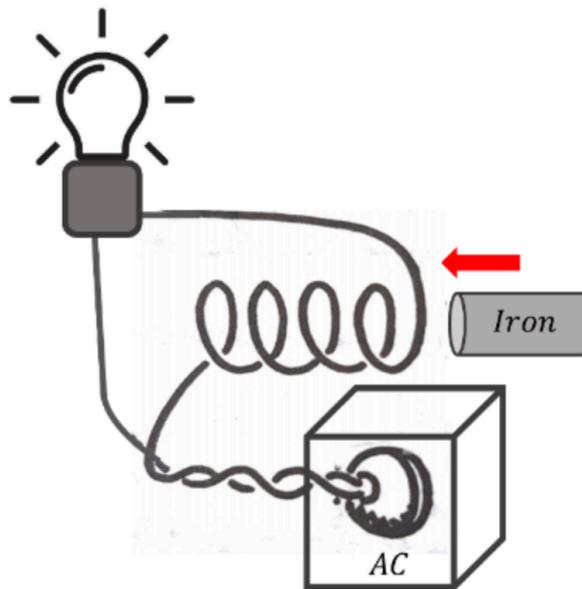
Nº 39

You drive a boat on the river upstream from point A to point B and back downstream from B to A and the trip takes t_1 seconds. When you drive the same boat the same straight distance ($A - B - A$) on a still lake the trip takes t_2 seconds. Calculate the ratio t_1/t_2 if the speed of the river is 2 km/h and the speed of the boat (regarding the still water and the river) is 5 km/h.

The answer should be given in the SI units unless otherwise stated. If the numerical result turns out to be an integer, it should be given as the answer. Otherwise round the result to the first decimal.

Nº 40

A light bulb is connected to an AC power source with thick wires, as shown in the picture. What effect can you see after a piece of iron has been put into the wire coil?



- The light bulb shines brighter
- The light bulb shines darker
- Nothing changes

Nº 41

Hydrogen gas can dissolve in some transition metals such as palladium at room temperature. Palladium has the face-centered cubic crystal structure with the lattice parameter 389 pm. The radius of hydrogen atom is 54 pm. What is the maximum number of hydrogen atoms that can fit in a unit cell of metal palladium?

Nº 42

A girl shoots a ball in horizontal direction from a height of 5 m above the ground. In a distance of 12.5 m (horizontal) the ball reaches the ground. What is the (horizontal) velocity of the ball? $g = 10 \text{ m/s}^2$.

The answer should be given in the SI units unless otherwise stated. If the numerical result turns out to be an integer, it should be given as the answer. Otherwise round the result to the first decimal.

Nº 43

A neutral sub-atomic particle at rest in a magnetic field of flux density $B = 10^{-5}$ T. It spontaneously decays into two particles of mass m each. One of the particles has a negative charge $q = -1\mu\text{C}$. The particles move with velocities perpendicular to the magnetic field. After what time will the particles collide if $m = 2 \cdot 10^{-11}$ kg?

The answer should be given in the SI units unless otherwise stated. If the numerical result turns out to be an integer, it should be given as the answer. Otherwise round the result to the first decimal.

Nº 44

A circle with center I , inscribed in a right triangle ABC , is tangent to side BC at point X . Line XI intersects the hypotenuse AB at point Y . It turns out that $AY = BX$. Given $BC = 6$, calculate the area of the triangle BCY .

Fractional numbers can be entered either as a decimal fraction or as m/n .

Nº 45

A sphere is inscribed in a right circular cone. The angle between the generating line of the lateral surface of the cone and its base is 60° . Denote the volume of the cone by V_1 . Let B be the convex body spanned by the tangency points of the sphere with the cone, including the tangency point with the base (i.e., B is the convex hull of these points).

Denote the volume of the body B by V_2 . Determine V_1/V_2 .

Fractional numbers can be entered either as a decimal fraction or as m/n .

Nº 46

An adult absorbs about 8000 kJ of energy per 1 day from food. Half of it is used for ATP production. Given that the Gibbs energy of ATP hydrolysis is -52 kJ/mol and the molar mass of ATP is 503 g/mol, calculate the mass of ATP (in kg) produced in the human body every day. Round the answer to the nearest integer.

Nº 47

Choose one correct statement about natural amino acids.

- All natural L-amino acids are levorotatory.
- Natural L-amino acids can be levorotatory or dextrorotatory.
- All natural L-amino acids are (S).
- All natural L-amino acids are (R).

Nº 48

A penguin is jumping into the water from the uniform springboard, which rotates freely around the joint on the left and is firmly connected to the spring on the right. The length of the bridge plate is 2.0 m, the weight is 12 kg, the spring stiffness is 1300 N/m. The weight of the spring is negligible. When the penguin jumps, the bridge begins to oscillate with a small amplitude. What is the period of this oscillation? The board is solid, does not bend.

The answer should be given in the SI units unless otherwise stated. If the numerical result turns out to be an integer, it should be given as the answer. Otherwise round the result to the first decimal.

Nº 49

The stability constant of CdL^{4-} at 298 K is $a \cdot 10^b$ (a and b are integers, $1 \leq a < 10$). Given the standard potentials $E^\circ(Cd^{2+}/Cd) = -0,403$ V, $E^\circ(CdL^{4-}/Cd) = -0,958$ V, determine a and b .

Write a in the first field, and b in the second.

Nº 50

Let ABC be an obtuse triangle, such that $\angle BAC > 90^\circ$. M is the midpoint of BC , the internal bisectors of $\angle AMB$ and $\angle AMC$ intersect the circumcircles of ABM and ACM at points X and Y , respectively ($X, Y \neq M$). Line XY intersects line AM at P . Given $PX = 1188$, $PY = 2112$, and $AP = 334$, find the length of BC .

Fractional numbers can be entered either as a decimal fraction or as m/n .

Nº 51

In a factorial positional system, the maximum 4-digit number is 4321. What's its decimal value?

Nº 52

Crystal hydrate $K_3PO_4 \cdot nH_2O$ was slightly heated in vacuum. As a result, the mass of a solid decreased by 28,9%. Determine n .

Nº 53

Consider the list of numbers 2, 3, ..., N . All these numbers are written on a whiteboard; further, each product of two or more different numbers from this list is also written there (some numbers may appear several times). For example, for $N = 3$ we would have 2, 3, and 6 on the board.

Given $N = 2021$, determine the sum of reciprocal values of all numbers written on the board (i.e., the sum of $1/x$ for all x on the board).

Fractional numbers can be entered either as a decimal fraction or as m/n .

Nº 54

The binary substance has the ionic structure. The total number of electrons in all positive ions is 4 times less than the total number of electrons in all negative ions. Determine the substance. Write down its relative molecular mass (give the integer value).

Nº 55

According to Mr. Boole the most minimal way of saying A and B , or, not B and A is saying _____.

A

B

not A

not B

A xor B

A or B

Nº 56

Two mols of iron were dissolved in hot 40% HNO_3 and the mixture of NO and NO_2 with a density equal to that of fluorine was released. How many mols of HNO_3 were consumed? Give the integer value.

Nº 57

In a movie theater there are 4 VIP chairs labelled from 1 to 4. We call a few consecutive vacant chairs a block. In the online VIP seat reservation process the guest can choose in which block she wants to sit, and that if she wants to choose the first, last or middle seat (in case of a block of size even this means the middle chair with the smaller number). At some screening all VIP seats were reserved. In how many ways the reservation order could have happened?

For instance, if the seat 2 is reserved, then there are two blocks, one of them consists of the seat 1, the other one consists of the seats 3 and 4. Two reservation orders are different if there is a seat that was reserved in a different moment in the two orders.

Nº 58

Santa Claus plays a guessing game with Marvin before giving him his present. He hides the present behind one of 100 doors, numbered from 1 to 100. Marvin can point at a door, and then Santa Claus will reply with one of the following words:

- "hot" if the present lies behind the guessed door,
- "warm" if the guess is not correct but the number of the guessed door differs from that of the present's door by at most 5,
- "cold" if the numbers of the two doors differ by more than 5.

How many such guesses does Marvin need at least, so that he can be certain about where his present is? *Marvin does not necessarily need to make a "hot" guess. He just wants to know the correct door with 100% certainty.*

Nº 59

Given the following binary search algorithm:

```
int X, L, R, c;
L = 0; R = N;
while ( L < R-1 )
{
    c = (L+R) / 2;
    if ( X < A[c] )
        R = c;
    else L = c;
}
if ( A[L] == X )
    cout << "A[" << L << "]=" << X << endl;
else cout << -1 << endl;
```

How many comparisons will be made if we are looking for an element that is not in the array. Sorted array length N is 10.

Nº 60

Long travelators are installed at Moscow Airport to move passengers through the corridor more quickly. Peter did not walk on the travelator and crossed the corridor in 150 s. Thomas stood on the travelator and did the same distance in 70 seconds. Jane walked along the travelator at the same speed as Peter. How long did it take Jane to walk through the corridor?

The answer should be given in the SI units unless otherwise stated. If the numerical result turns out to be an integer, it should be given as the answer. Otherwise round the result to the first decimal.

Nº 61

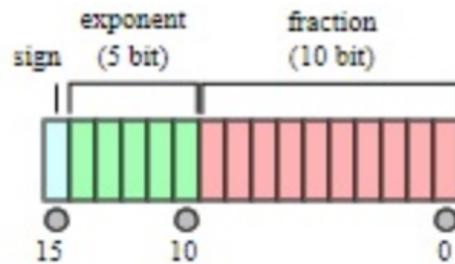
Consider 10 squares lined up in a row. Each square is colored in either red, blue or green so that each square has at least 1 adjacent square of the same color. How many ways are there to color the squares?

Nº 62

The numbers 2, 3, 4, 5, 6, 7 are assigned to the six faces of a cube, one number to each face. At each vertex of the cube, the product of the numbers assigned to the three faces meeting at this vertex is calculated. What is the greatest possible value of the sum of these eight products?

Nº 63

Binary-16 floating-point format is assumed to have an implicit lead bit with value 1 unless the exponent field is stored with all zeros. Thus only 10 bits of the significand appear in the memory format but the total precision is 11 bits. The format is laid out as follows:



Floating-point value is $(-1)^{\text{signbit}} \times 2^{\text{exponent}-15} \times 1.\text{significantbits}_2$.

Calculate the binary-16 floating-point representation of -192.5 . Answer must contain 16 bits without blanks.

Nº 64

A body moves in a circular orbit with a radius of 0,6 m at a constant speed of 3 m/s. What speed would it achieve in 3 secundum if it started from a standing position on a straight track with the same acceleration?

The answer should be given in the SI units unless otherwise stated. If the numerical result turns out to be an integer, it should be given as the answer. Otherwise round the result to the first decimal.

Nº 65

Quicksort algorithm that sorts elements at lo through hi (inclusive) of an array A can be expressed as

```
algorithm quicksort(A, lo, hi) is
  if lo < hi then
    p := partition(A, lo, hi)
    quicksort(A, lo, p - 1)
    quicksort(A, p + 1, hi)

algorithm partition(A, lo, hi) is
  pivot := A[hi]
  i := lo
  for j := lo to hi - 1 do
    if A[j] < pivot then
      swap A[i] with A[j]
      i := i + 1
  swap A[i] with A[hi]
  return i
```

The letters of the word OLYMPIAD are placed in a random order. How many comparisons in the partition algorithm does the quicksort algorithm need in the worst case to bring the letters back into the correct order?

Nº 66

For storing an arbitrary 128×320 bitmap pixels allocated 50 kibibytes (KiB) of memory without taking into account the size of the file header. For colour encoding each pixel uses the same amount bits, pixel codes are written to the file one by one without gaps. What is the maximum number of colours that can be used in an image?

Nº 67

Let f be a function that maps every positive integer n to the number of decimal digits of n . Find $f(f(2020^{2021}))$.

Nº 68

We are given a set S which contains only elements 0 and 95 at the beginning. At each step we add elements to S according to the following rule: We choose a non-constant polynomial whose all coefficients are in S , and add all its integer roots to S . What is the maximal number of elements that S can have after finitely many such steps?

Nº 69

The result of the decimal expression $81^{17} + 3^{24} - 45$ was written in the base 9 notation. How many digits "8" does it contain?

Nº 70

A 100 W light source converts 5% of the absorbed power into light with a wavelength of 700 nm. How many photons does it emit in each second? Multiply the answer by 10^{-19} .

Nº 71

Which of the following statements about "Domain Name System" are true?

The Domain Name System (DNS) is a centralized naming system.

DNS is a decentralized naming system.

DNS database contains IP-addresses.

DNS database contains SMTP mail exchangers.

DNS database is a general purpose database.

Nº 72

The number of d -electrons in a triply charged ion of a $3d$ -metal is half of the number of d -electrons in an atom of the same metal (both particles are in their ground state). Determine the metal and write down its atomic number.

Nº 73

Consider a triangle with side lengths a , b , and c and area P such that

$$\sqrt{3}(b^2 + a^2 - c^2) = 2ab - 4P.$$

Calculate the measure of the angle opposite to the side c . Give the answer in degrees.

Nº 74

Consider all pairs (r, s) of integers such that $0 < s < 200$ satisfying:

$$\frac{45}{61} > \frac{r}{s} > \frac{59}{80}.$$

Find the sum of all integers in such pairs.

Nº 75

Calculate the volume of 0.02M potassium hydroxide solution that should be added to 63 mL of 0.01M sulfuric acid solution so that pH of the obtained solution is 3.00. Assume that sulfuric acid is a strong diprotic acid. Give the integer answer, expressed in mL.

Nº 76

What is the result of the following program?

```
s = '1'*99
while s.find('111') >= 0:
    s = s.replace('111', '22')
    s = s.replace('222', '11')
print(s)
```

Nº 77

Calculate $f^{2020}(2020)$, where function $f: \mathbb{R} \rightarrow \mathbb{R}$ satisfies

$$(x - 1) \cdot f(x) + f\left(\frac{1}{x}\right) = \frac{1}{x-1}$$

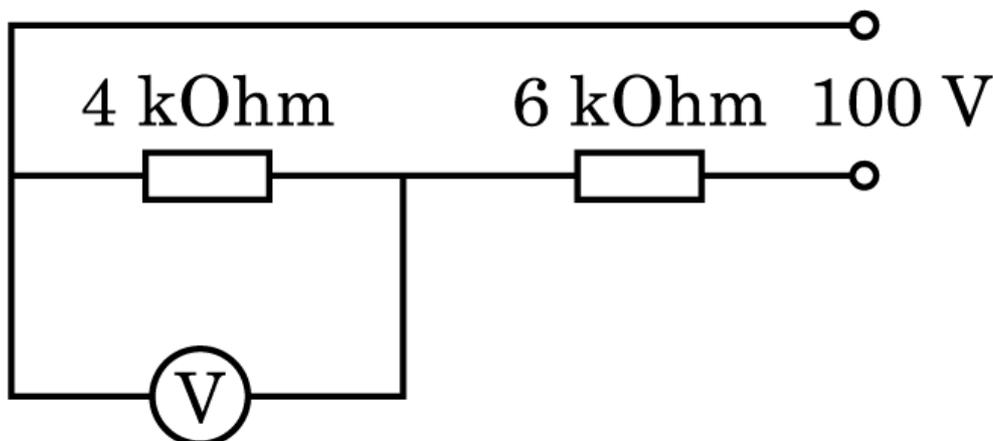
for all real $x \neq 0, 1$.

(Here f^{2020} denotes the 2020th application of f , i.e., $\underbrace{f(f(\dots(f(x))\dots))}_{2020}$, not numerical power.)

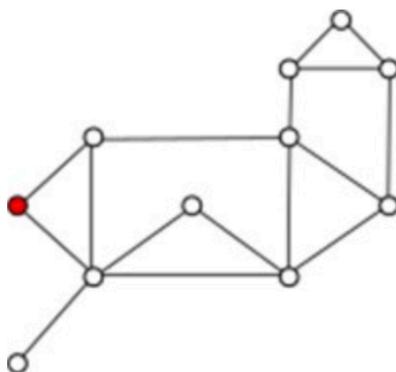
Fractional numbers can be entered either as a decimal fraction or as m/n .

Nº 78

The voltmeter connected in parallel to resistor $R_1 = 4 \text{ k}\Omega$ show a reading of $U_v = 36 \text{ V}$. A source with terminals of constant potential difference of $U = 100 \text{ V}$ is connected to the circuit. Find the ratio of the currents flowing through voltmeter and resistor $R_2 = 6 \text{ k}\Omega$.



Nº 79



The picture describes the computer network with 11 computers which names are A, B, C, \dots, K . In the network you can find these four sequences of the adjacent computers:

1. IDCJG
2. BDFGHK
3. JKAH
4. GCBDEF

What is the name of the red computer?

Nº 80

Currently the largest passenger aircraft is A380 and the longest scheduled non-stop route this plane flew was from Dallas International Airport in the USA to Sydney Airport in Australia. This route is 13800 km in length.

Given that each of these flights typically has a fuel consumption rate of 21.7 L/km of jet A-1 fuel at full passenger capacity of 525 people, use the jet A-1 fuel composition below to estimate the carbon footprint (in kg of CO_2) of each passenger. (All the CO_2 produced is only to be attributed to the passengers for this calculation, assume complete combustion conditions).

Jet A-1 fuel typical chemical composition

Chemical species	Averaged molecular formula	Percentages (by mass)
Alkanes	$C_{12}H_{25}$	80 %
Aromatics	$C_{11}H_{16}$	20 %
Density of jet A-1 fuel	0.800 g/mL	