

# Exemplar für Prüfer/innen

Supplementary Examination for the  
Standardised Competence-Oriented  
Written School-Leaving Examination

AHS

May/June 2023

## Mathematics

Supplementary Examination 1  
**Examiner's Version**

## Instructions for the standardized implementation of the supplementary examination

The following supplementary examination booklet contains four tasks that can be completed independently of one another as well as the corresponding solutions.

Each task comprises three competencies to be demonstrated.

The preparation time is to be at least 30 minutes; the examination time is at most 25 minutes.

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### Evaluation grid for the supplementary examination

The evaluation grid below may be used to assist in assessing the candidates' performances.

	Candidate 1			Candidate 2			Candidate 3			Candidate 4			Candidate 5		
Task 1															
Task 2															
Task 3															
Task 4															
Total															

## Explanatory notes on assessment

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12	Very good
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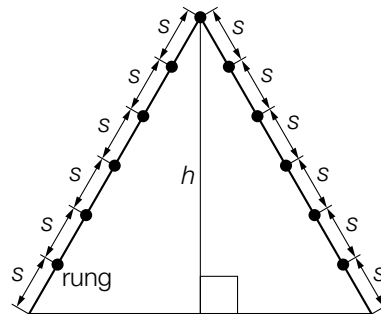
# Task 1

## Climbing Frame

- a) The diagrams below show a climbing frame. The side view shows an equilateral triangle. The rungs are represented as points.



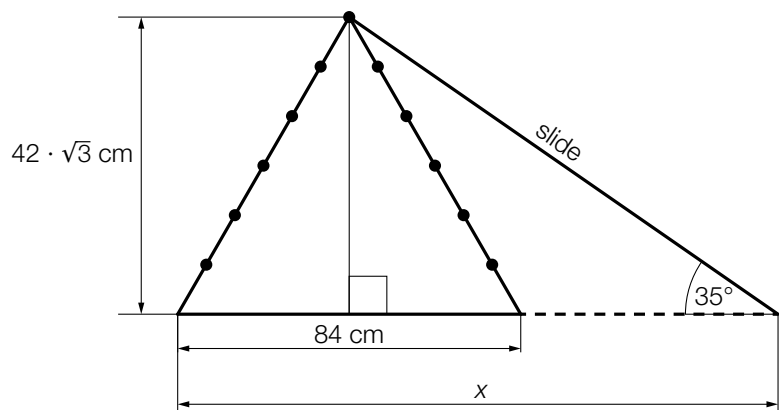
Source: BMBWF



- 1) Using the distance between the rungs  $s$ , write down a formula that can be used to calculate the height  $h$  of this climbing frame.

$$h = \underline{\hspace{10cm}}$$

In a toy shop, a climbing frame is also sold together with a straight slide (see the not-to-scale diagram on the right).



- 2) Determine  $x$ .

- b) A toy shop sells  $x$  climbing frames without slides and  $y$  climbing frames with slides in a particular month. In this month, the toy shop takes in a total of € 5 760 from the sale of climbing frames with and without slides.

This situation can be described by the system of linear equations shown below.

$$\text{I: } 100 \cdot x + 120 \cdot y = 5\,760$$

$$\text{II: } x + y = 50$$

- 1) Interpret the values 100, 120 and 50 in the given context.

# Solution to Task 1

## Climbing Frame

$$\text{a1) } h = \sqrt{(6 \cdot s)^2 - (3 \cdot s)^2} = \sqrt{27 \cdot s^2} = \sqrt{27} \cdot s \quad \text{or} \quad h = \frac{6 \cdot s}{2} \cdot \sqrt{3} = 3 \cdot s \cdot \sqrt{3}$$

$$\text{a2) } \tan(35^\circ) = \frac{42 \cdot \sqrt{3}}{x - 42}$$

$$x = 145.89... \text{ cm}$$

- b1) The price of one climbing frame without a slide is € 100.  
The price of one climbing frame with a slide is € 120.  
This toy shop sold a total of 50 climbing frames in this month.

## Task 2

### Play Equipment

A company produces and sells play equipment.  
In order to plan financially, the costs, revenue and profit are investigated.

- a) The costs can be approximated by the quadratic function  $K$ .

$$K(x) = a \cdot x^2 + b \cdot x + c$$

$x$  ... number of play equipment units produced in ME

$K(x)$  ... the cost of producing  $x$  play equipment units in monetary units, GE

The following statements hold:

The fixed costs are 22 GE.

The cost of producing 20 ME is 40 GE.

The instantaneous rate of change of the costs when 20 ME are produced is 1.5 GE/ME.

- 1) Write down a system of equations that can be used to calculate the coefficients of  $K$ .

- b) The profit can be approximated by the function  $G$ .

$$G(x) = -\frac{11}{300} \cdot (x^2 - 70 \cdot x + 600)$$

$x$  ... number of play equipment units sold in ME

$G(x)$  ... the profit from selling  $x$  play equipment units in units of currency, GE

- 1) Determine the zeros of the function  $G$ .

- c) For a particular  $x_0$ , the following statements hold:

$$E'(x_0) = 0$$

$$E''(x_0) < 0$$

$x$  ... number of play equipment units sold in ME

$E(x)$  ... the revenue from selling  $x$  play equipment units in units of currency, GE

- 1) Interpret the meaning of  $x_0$  in the given context.

## Solution to Task 2

### Play Equipment

a1)  $K'(x) = 2 \cdot a \cdot x + b$

I:  $K(0) = 22$

II:  $K(20) = 40$

III:  $K'(20) = 1.5$

or:

I:  $a \cdot 0^2 + b \cdot 0 + c = 22$

II:  $a \cdot 20^2 + b \cdot 20 + c = 40$

III:  $2 \cdot a \cdot 20 + b = 1.5$

b1)  $G(x) = 0$

calculation using technology:

$$x_1 = 10, x_2 = 60$$

c1) The maximum revenue is obtained for  $x_0$  play equipment units (in ME).

## Task 3

### Internet Platform

- a) The function  $N$  models the number of people who use an internet platform in terms of the time  $t$ .

$$N(t) = 3000 \cdot 1.22^t$$

$t$  ... time in years since the start of the observations

$N(t)$  ... number of people who use this internet platform at time  $t$

- 1) Determine the doubling time for the number of people who use this internet platform.
- 2) Write down the equation of the function  $N$  in the form  $N(t) = a \cdot e^{\lambda \cdot t}$ .

The expression below can be used to calculate the average rate of change of the number of people who use this internet platform in the first 6 years.

$$\frac{3000 \cdot 1.22^{\boxed{\phantom{000}}} - \boxed{\phantom{000}}}{\boxed{\phantom{000}} - 0}$$

- 3) Complete the expression by writing the missing numbers in the boxes provided.



## Solution to Task 3

### Internet Platform

$$\text{a1) } 6000 = 3000 \cdot 1.22^t$$

calculation using technology:

$$t = 3.48\dots$$

The doubling time is around 3.5 years.

$$\text{a2) } \ln(1.22) = 0.1988\dots$$

$$N(t) = 3000 \cdot e^{0.199 \cdot t} \quad (\text{coefficient rounded})$$

$$\text{a3) } \frac{3000 \cdot 1.22^{\boxed{6}} - \boxed{3000}}{\boxed{6} - 0}$$

## Task 4

### Blood Groups

The table below shows the distribution of blood groups (in Austria).

blood group	0	A	B	AB
frequency	36 %	44 %	14 %	6 %

a) For a study,  $n$  people from Austria are selected at random and their blood group is determined.

1) Complete the formula below that can be used to calculate the probability that exactly 5 people have the blood group AB.

$$P(\text{"exactly 5 people have the blood group AB"}) = \binom{n}{5} \cdot \boxed{\phantom{0.06}}^5 \cdot \boxed{\phantom{0.36}} \boxed{\phantom{0.44}} \boxed{\phantom{0.14}}$$

b) For another study, 85 people from Austria are selected at random and their blood group is determined.

1) Determine the probability that the number of people with blood group A is at least 25 and at most 30.

c) In yet another study, 2 people from Austria are selected at random.

1) Write down a possible event  $E$  in the given context whose probability can be calculated using the expression below.

$$P(E) = 2 \cdot 0.36 \cdot 0.14 \approx 0.10$$

## Solution to Task 4

### Blood Groups

$$\text{a1) } P(\text{"exactly 5 people have the blood group AB"}) = \binom{n}{5} \cdot 0.06^5 \cdot 0.94^{n-5}$$

b1)  $X$  ... number of people with blood group A

binomial distribution with  $n = 85$  and  $p = 0.44$

calculation using technology:

$$P(25 \leq X \leq 30) = 0.0627\dots$$

The probability is around 6.3 %.

c1)  $E$  ... of these two people, exactly 1 person has the blood group 0 and 1 person has the blood group B

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AHS

October 2023

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# Task 1

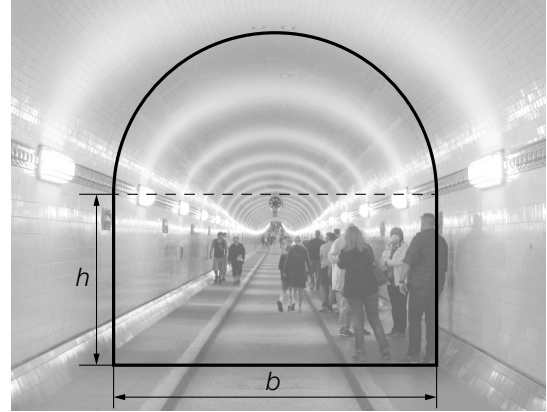
## Old Elbe Tunnel

The Old Elbe Tunnel in Hamburg is an underpass for the Elbe.

- a) The cross-section of the tunnel can be approximated by a rectangle with a semi-circle on top (see diagram on the right).

$b$  ... width in m  
 $h$  ... height in m

Daniel would like to calculate the volume of air  $V$  in the 426.5 m long Old Elbe Tunnel.

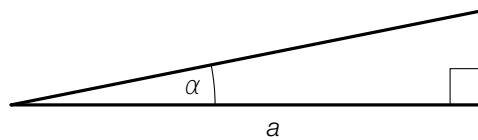


Source: BMBWF

- 1) Write down a formula that can be used to calculate  $V$  in terms of  $b$  and  $h$ .

$$V = \underline{\hspace{10cm}}$$

- b) The diagram below shows a model of the gradient of a section of the cycle path in the tunnel.



$a$  ... horizontal length of this section of the tunnel in m  
 $\alpha$  ... angle of elevation of this section of the tunnel

A cyclist cycles along this section of the tunnel with velocity  $v$  in m/s.

The following statement holds:  $\frac{a}{\cos(\alpha)} = 12.5$

- 1) Interpret the value 12.5 in the given context including the corresponding unit.
- c) In the first year after opening, 20 million people used the Old Elbe Tunnel. The number of people who used the Old Elbe Tunnel each year reduced by 97.5 % by 1985 and then increased again. In the year 2008, 40 % more people used the Old Elbe Tunnel than in the year 1985.
- 1) Determine the number of people who used the Old Elbe Tunnel in the year 2008.

# Solution to Task 1

## *Old Elbe Tunnel*

$$\text{a1) } V = 426.5 \cdot \left( b \cdot h + \frac{1}{2} \cdot \left( \frac{b}{2} \right)^2 \cdot \pi \right)$$

or:

$$V = 426.5 \cdot \left( b \cdot h + \frac{b^2}{8} \cdot \pi \right)$$

b1) The cyclist requires 12.5 s for this section of the tunnel.

$$\text{c1) } 20\,000\,000 \cdot 0.025 \cdot 1.4 = 700\,000$$

700 000 people used the Old Elbe Tunnel in the year 2008.

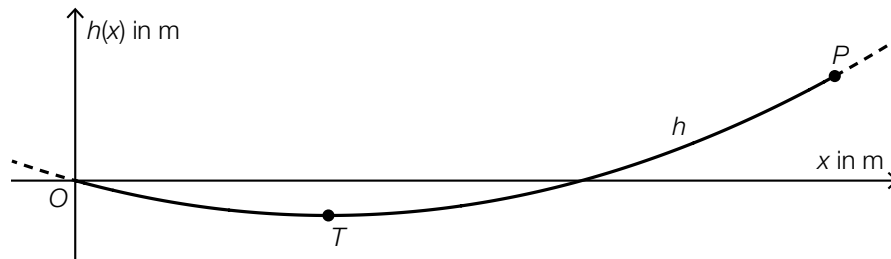


## Task 2

### Suspension Bridge

The shape of a particular suspension bridge for pedestrians can be modelled by quadratic functions.

- a) In one model, the shape of the suspension bridge is described by the function  $h$  with  $h(x) = a \cdot x^2 + b \cdot x$  (the side view is shown in the diagram below).



The graph of  $h$  goes through the point  $P = (120, 6)$ . The lowest point  $T$  of the bridge occurs when  $x = 40$ .

In order to determine the coefficients  $a$  and  $b$ , the system of equations shown below is created using the information about the points  $P$  and  $T$ .

- 1) Write down the missing numbers in the boxes provided.

I:  $a \cdot \boxed{\phantom{000}}^2 + b \cdot \boxed{\phantom{000}} = \boxed{\phantom{000}}$

II:  $a \cdot \boxed{\phantom{000}} + b = \boxed{\phantom{000}}$

The following statement about the function  $h$  holds:  $h(x) = 0.00125 \cdot x^2 - 0.1 \cdot x$

- 2) Determine the angle of elevation of the tangent to the graph of  $h$  at the point  $P$ .

In another coordinate system, the shape of the suspension bridge can be described by the function  $f$  with  $f(x) = a \cdot x^2$ .

- 3) In the diagram above, draw the coordinate axes for the graph of  $f$ .

## Solution to Task 2

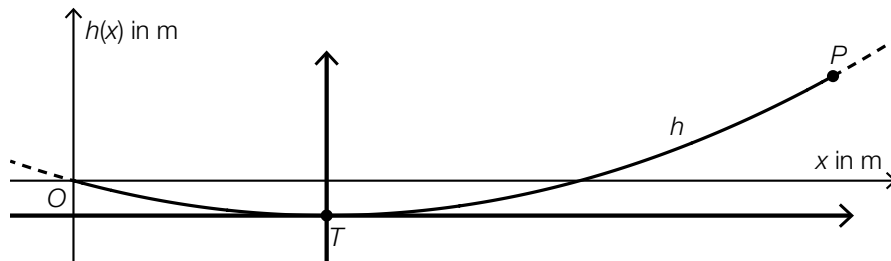
### Suspension Bridge

a1) I:  $a \cdot \boxed{120}^2 + b \cdot \boxed{120} = \boxed{6}$

II:  $a \cdot \boxed{80} + b = \boxed{0}$

a2)  $\alpha = \arctan(h'(120)) = \arctan(0.2)$   
 $\alpha = 11.30\dots^\circ$

a3)



## Task 3

### Sporting Goods

- a) For a particular item of sporting goods, the derivative  $K'$  of the cost function  $K$  is given.

$$K'(x) = 3 \cdot x^2 - 8 \cdot x + 20$$

$x$  ... number of produced units of quantity in ME

$K'(x)$  ... 1<sup>st</sup> derivative of the cost function  $K$  for  $x$  ME in GE/ME, where GE are units of currency

The fixed costs are 4 200 GE.

- 1) Write down an equation of the cost function  $K$ .

- b) For another item of sporting goods, the cost function  $K_1$  and the revenue function  $E_1$  are given.

$$K_1(x) = 0.01 \cdot x^2 + 10 \cdot x + 200$$

$$E_1(x) = -0.25 \cdot x^2 + 50 \cdot x$$

$x$  ... number of produced and sold units of quantity in ME

$K_1(x)$  ... total costs for  $x$  ME in units of currency, GE

$E_1(x)$  ... revenue for  $x$  ME in units of currency, GE

- 1) Determine the profit when  $x = 70$  ME.

- c) In a study it has been investigated how many units of a particular item of sporting goods can be sold long-term.

The number of units sold can be modelled by the function  $A$  in terms of time.

$$A(t) = a - 30 \cdot b^t \quad \text{with} \quad 0 < b < 1$$

$t$  ... time in months with  $t = 0$  for the start of sales

$A(t)$  ... number of units sold at time  $t$

$a, b$  ... parameters

- 1) Using the equation of the function of  $A$ , justify why no more than  $a$  units can ever be sold according to this model.

## Solution to Task 3

### Sporting Goods

$$\text{a1) } K(x) = \int K'(x) dx = 3 \cdot \frac{x^3}{3} - 8 \cdot \frac{x^2}{2} + 20 \cdot x + C = x^3 - 4 \cdot x^2 + 20 \cdot x + C$$

$$K(0) = 4\,200$$

$$C = 4\,200$$

$$K(x) = x^3 - 4 \cdot x^2 + 20 \cdot x + 4\,200$$

$$\text{b1) } G_1(x) = E_1(x) - K_1(x) = -0.26 \cdot x^2 + 40 \cdot x - 200$$

$$G_1(70) = 1\,326$$

The profit for 70 ME is 1 326 GE.

c1) The expression  $30 \cdot b^t$  is positive for all values of  $t$  and therefore the expression  $a - 30 \cdot b^t$  can never take a greater value than  $a$ .

## Task 4

### Dice

In a particular game, players roll fair six-sided dice. The faces of these dice are labelled with the digits 1, 2, 3, ..., 6.

a) Andrea rolls a dice multiple times.

1) Write down a formula that can be used to calculate the probability  $P$  shown below.

$$P(\text{"Andrea does not roll a single 6 in } n \text{ rolls"}) = \underline{\hspace{10cm}}$$

b) Ferdinand rolls 2 dice once.

He claims: "The probability that the sum of the faces is 5 is greater than the probability that the sum of the faces is 4."

1) Justify by calculation that Ferdinand's claim is correct.

c) Sabrina rolls 5 dice once.

1) Determine the probability that exactly 4 of the 5 dice show the same digit.

## Solution to Task 4

### Dice

a1)  $P(E) = \left(\frac{5}{6}\right)^n$

b1) sum of the faces is 5: 1 + 4 or 2 + 3 or 3 + 2 or 4 + 1  
sum of the faces is 4: 1 + 3 or 2 + 2 or 3 + 1

Therefore:

$$P(X = 5) = \frac{4}{36}$$

$$P(X = 4) = \frac{3}{36}$$

$$\frac{4}{36} > \frac{3}{36}$$

c1)  $6 \cdot \binom{5}{4} \cdot \left(\frac{1}{6}\right)^4 \cdot \left(\frac{5}{6}\right) = 0.0192\dots$

The probability is around 1.9 %.

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AHS

June 2022

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# Task 1

## Playground

At a playground, there is an assortment of play equipment.

a) Diagram 1 shows a seesaw. In diagram 2, a model of this seesaw is shown from the side.



Diagram 1

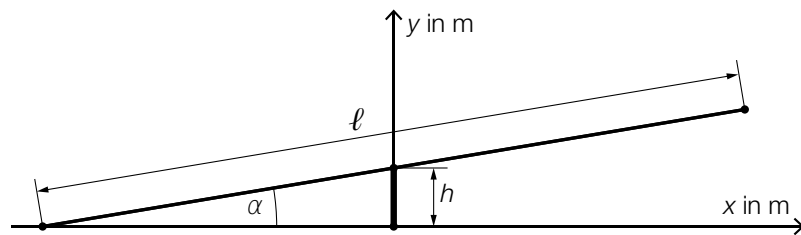


Diagram 2

Image source: Chabe01 – own work, CC BY-SA 4.0, [https://commons.wikimedia.org/wiki/File:Aire\\_Jeux\\_Rives\\_Menthon\\_St\\_Cyr\\_Menthon\\_16.jpg](https://commons.wikimedia.org/wiki/File:Aire_Jeux_Rives_Menthon_St_Cyr_Menthon_16.jpg) [23.12.2021] (adapted).

The beam has length  $\ell$  and its midpoint has a height  $h$ .

1) Using  $h$  and  $\ell$ , write down a formula that can be used to calculate the angle  $\alpha$ .

$$\alpha = \underline{\hspace{10em}}$$

b) The circular bounce mat of a trampoline has an area of  $5 \text{ m}^2$ .

1) Determine the diameter of the bounce mat of this trampoline.

c) An old sandpit with a square base with side length  $a$  and height  $h$  is to be replaced by a new sandpit.

This new sandpit with a square base should have the same height as the old sandpit but the side lengths should be 50 % longer.

1) Show that the volume of the new sandpit is not twice the size of that of the old sandpit.

# Solution to Task 1

## Playground

$$\text{a1) } \alpha = \arcsin\left(\frac{h}{\frac{\ell}{2}}\right)$$

or:

$$\alpha = \arcsin\left(\frac{2 \cdot h}{\ell}\right)$$

$$\text{b1) } d = 2 \cdot \sqrt{\frac{5}{\pi}} = 2.52\dots$$

The bounce mat has a diameter of around 2.5 m.

$$\text{c1) } V_{\text{old}} = a^2 \cdot h$$

$$V_{\text{new}} = (1.5 \cdot a)^2 \cdot h = 2.25 \cdot a^2 \cdot h = 2.25 \cdot V_{\text{old}}$$

The volume of the new sandpit is therefore not twice the size of that of the old sandpit.

*A justification that uses concrete values is also correct.*

## Task 2

### Beer Foam

After a beer has been poured into a glass, the resulting beer foam slowly collapses in upon itself.

- a) Thomas measures the height of the beer foam after beer has been poured into a particular glass. The table below shows the results of his measurements.

Time after pouring in s	0	20	60
Height of the beer foam in cm	4	2.5	2

- 1) Determine the average rate of change of the height of the beer foam for the first 60 seconds after it has been poured. Write down the result with the corresponding unit.

The height of the beer foam is to be described by an exponential function  $h$  of the form

$$h(t) = a \cdot b^t.$$

$t$  ... time after pouring in s

$h(t)$  ... height of the beer foam at time  $t$  in cm

- 2) Show that no exponential function  $h$  of this form exists whose graph goes through all 3 measurement points.

b) Martin describes the height of the beer foam after pouring beer into a different glass with the function  $f$  (see diagrams below).

1) In diagram 2 below, sketch the graph of  $f'$ .

Diagram 1

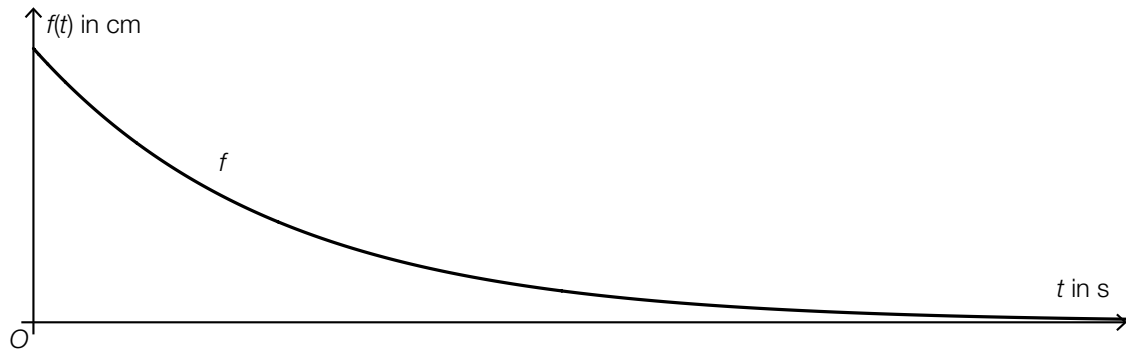


Diagram 2



## Solution to Task 2

### Beer Foam

a1)  $\frac{2-4}{60-0} = -0.03$

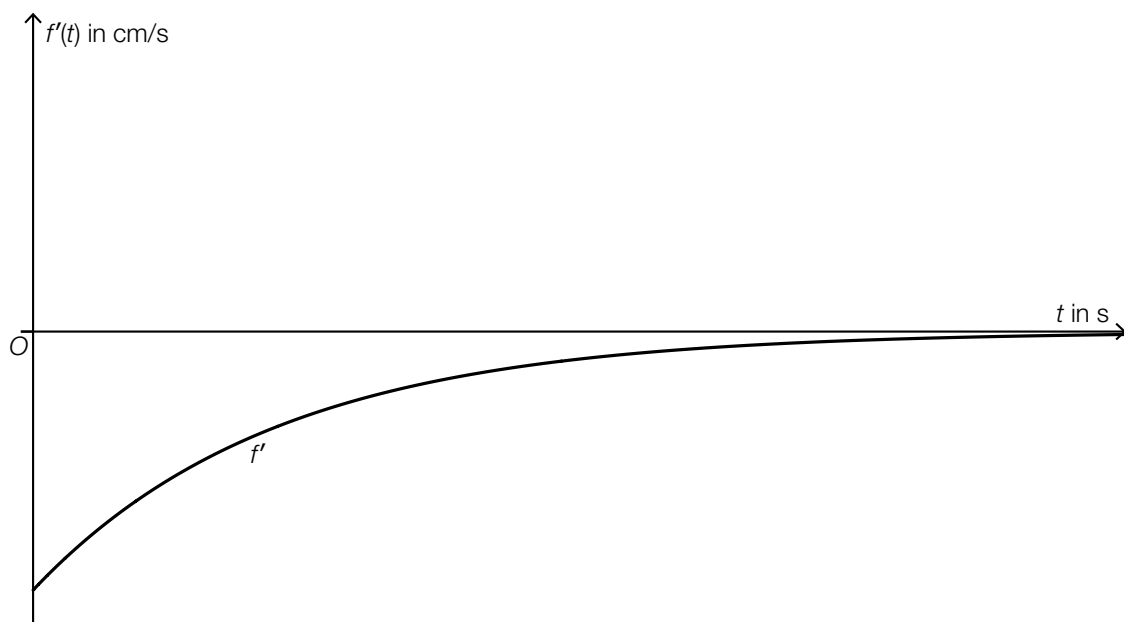
The average rate of change is around  $-0.03$  cm/s.

a2)  $4 \cdot b^{20} = 2.5 \Rightarrow b = \sqrt[20]{\frac{2.5}{4}} = 0.976\dots$

$4 \cdot b^{60} = 2 \Rightarrow b = \sqrt[60]{\frac{2}{4}} = 0.988\dots$

As the change factors are not the same, there is no exponential function of this form whose graph goes through all 3 measurement points.

b1)



*The graph must be monotonically increasing and concave down; it must also approach the horizontal axis asymptotically.*

## Task 3

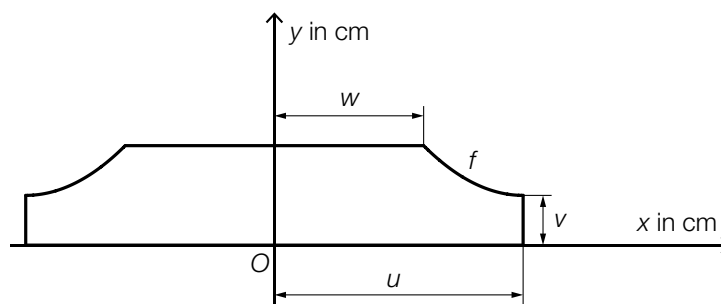
### Pipe Covering

- a) The diagram on the right shows an image of a pipe covering for two heating pipes.



Image source: BMBWF

The diagram below shows a model of the cross-section of this pipe covering from the side.



A part of the boundary line of this cross-section can be modelled by the graph of the quadratic function  $f$  with  $f(x) = a \cdot x^2 + b \cdot x + c$ .

The vertex of the function  $f$  has coordinates  $(u, v)$ .

The angle of the slope when  $x = w$  is  $-45^\circ$ .

- 1) Write down a system of equations in terms of  $u$ ,  $v$  and  $w$  that can be used to calculate the coefficients  $a$ ,  $b$  and  $c$ .
- 2) On the diagram above, mark the area whose size can be calculated with the expression shown below.

$$\int_w^u f(x) dx$$

For a particular pipe covering with  $u = 5$ , the following equation holds:

$$f(x) = 0.25 \cdot x^2 - 2.5 \cdot x + 8.75 \quad \text{with} \quad w \leq x \leq u$$

- 3) Determine the length  $v$  for this pipe covering.

## Solution to Task 3

### Pipe Covering

a1)  $f(x) = a \cdot x^2 + b \cdot x + c$   
 $f'(x) = 2 \cdot a \cdot x + b$

I:  $f(u) = v$

II:  $f'(u) = 0$

III:  $f'(w) = -1$

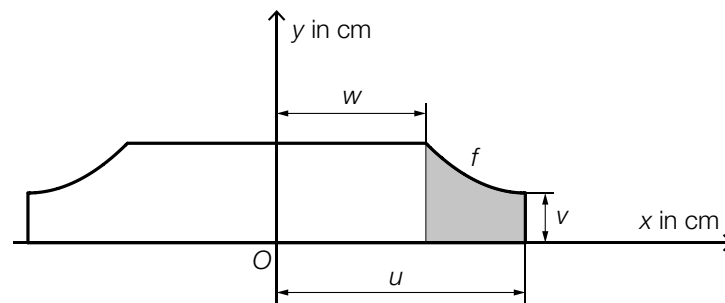
or:

I:  $a \cdot u^2 + b \cdot u + c = v$

II:  $2 \cdot a \cdot u + b = 0$

III:  $2 \cdot a \cdot w + b = -1$

a2)



a3)  $f(5) = 2.5$

The length  $v$  is 2.5 cm.



## Task 4

### Parcel Services

Due to the sharp increase in online trade, more and more people are using parcel services.

- a) There are complaints offices for registering problems with parcel services. From long-term observations it is known that 11 % of all complaints at one particular complaints office are due to delivery times that are too long.

On a particular day, a total of 42 independent complaints are received.

- 1) Determine the probability that exactly 8 of these 42 complaints are received due to delivery times that are too long.

- b) For every parcel service, the *first attempt success ratio* is an important metric. The first attempt success ratio is the probability that a packet selected at random can be delivered on the first attempt. At a particular parcel service, the first attempt success ratio is 90 %.

A delivery driver is to deliver  $n$  parcels.

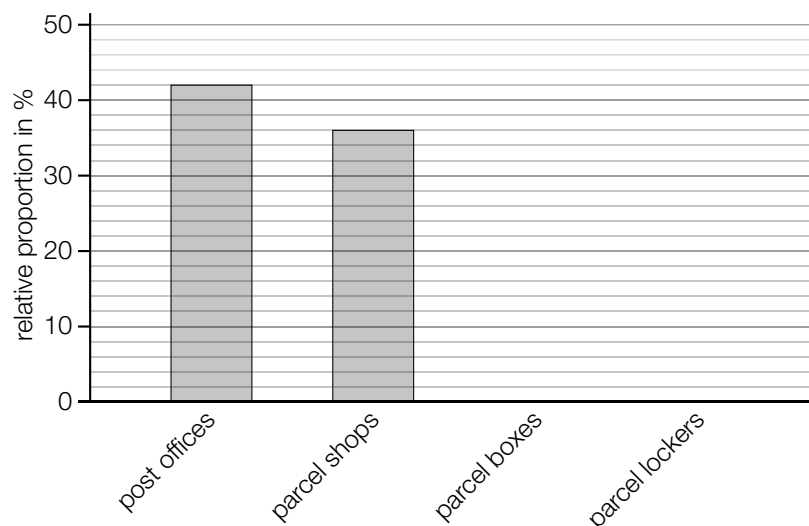
- 1) Describe the event  $E$  whose probability can be calculated with the expression shown below in the given context.

$$P(E) = 1 - 0.9^n$$

- c) In the year 2020, parcels could be sent through a particular parcel service from a total of 31 200 drop-off points.

These 31 200 drop-off points comprised 13 104 post offices, 11 232 parcel shops, 624 parcel boxes and a particular number of parcel lockers.

- 1) Complete the two missing columns in the bar chart shown below.



## Solution to Task 4

### Parcel Services

a1)  $X$  ... number of complaints due to delivery times that are too long

binomial distribution with  $n = 42$ ,  $p = 0.11$

calculation using technology:

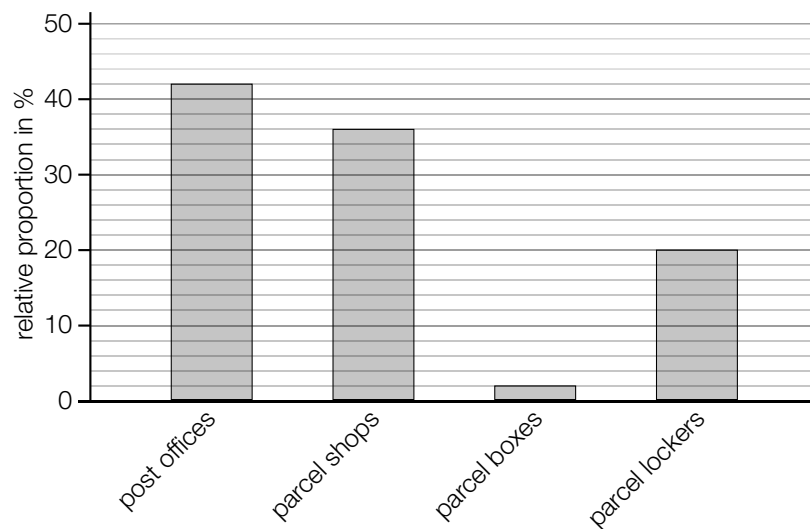
$$P(X = 8) = 0.0481\dots$$

The probability is around 4.8 %.

b1)  $E$  ... "the delivery driver cannot deliver at least 1 parcel of these  $n$  parcels on the first attempt"

$$\text{c1) } \frac{624}{31200} = 0.02$$

$$\frac{31200 - 13104 - 11232 - 624}{31200} = 0.2$$



# Exemplar für Prüfer/innen

Supplementary Examination for the  
Standardised Competence-Oriented  
Written School-Leaving Examination

AHS

October 2022

## Mathematics

Supplementary Examination 1  
**Examiner's** Version

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Task 1															
Task 2															
Task 3															
Task 4															
Total															

## Explanatory notes on assessment

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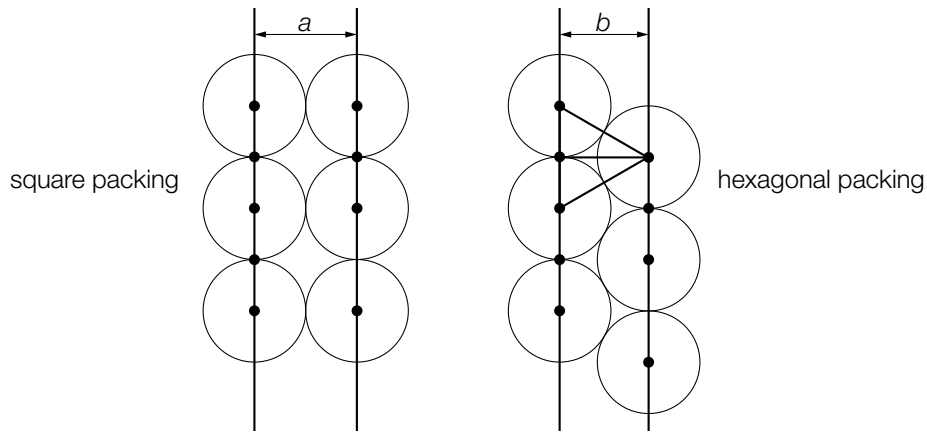
### Assessment scale for the supplementary examination

Total number of competencies demonstrated	Assessment of the oral supplementary examination
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0–5	Fail

# Task 1

## Plant Pots

Cylindrical plant pots can be arranged in so-called *square packing* or *hexagonal packing* (see the model bird's-eye view diagrams shown below).



a) The distance  $b$  in hexagonal packing is smaller than the distance  $a$  in square packing.

1) Determine the difference  $a - b$  for the case when the diameter of the plant pots is 40 cm.

b) Two cylindrical plant pots with a circular base are compared to each other.

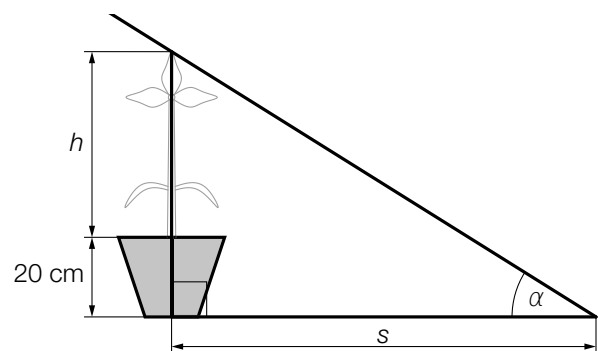
Plant pot  $A$  has radius  $r$  and height  $h$ .

The volume of the plant pot is  $V_A$ .

Plant pot  $B$  has the same height  $h$  but a radius that is 10 % larger than plant pot  $A$ .

1) Show that the volume  $V_B$  of plant pot  $B$  is 21 % greater than  $V_A$ .

c) In a plant pot with a height of 20 cm, there is a plant with height  $h$  (in cm). The rays of sunlight that fall on the plant make an angle of  $\alpha$  with the horizontal (see diagram on the right).



1) Write down a formula in terms of  $h$  and  $\alpha$  that can be used to determine the length  $s$  (in cm) of the shadow.

$s =$  \_\_\_\_\_

# Solution to Task 1

## Plant Pots

a1)  $a = 40$

$b$  is the height of an equilateral triangle with side length 40.

$$b = \frac{a}{2} \cdot \sqrt{3} = 34.64\dots$$

or:

$$b = \sqrt{40^2 - 20^2} = 34.64\dots$$

$$a - b = 40 - 34.64\dots$$

$$a - b = 5.35\dots \text{ cm}$$

b1)  $V_A = r^2 \cdot \pi \cdot h$

$$V_B = (1.1 \cdot r)^2 \cdot \pi \cdot h = 1.21 \cdot V_A$$

c1)  $s = \frac{h + 20}{\tan(\alpha)}$

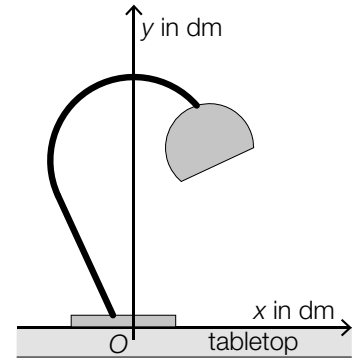
## Task 2

### Desk Lamps

Various models of desk lamp are available. The light source is suspended in different ways depending on design of the model. The suspension methods are modelled by a thick black line in the diagrams below.

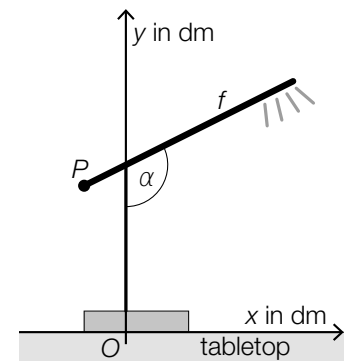
- a) The suspension of the light source in model A is shown in the diagram on the right.

- 1) Justify why this method of suspension cannot be described by the graph of a single function ( $y$  in terms of  $x$ ).



- b) The suspension of the light source in model B can be described by the graph of the linear function  $f$  (see diagram on the right).

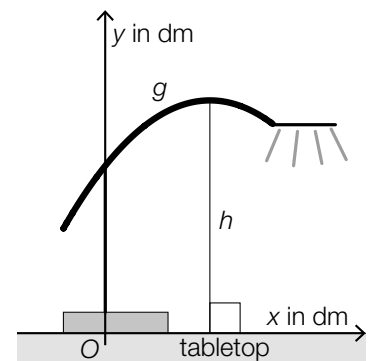
- 1) Using  $P = (-1, 3.5)$  and  $\alpha = 116.56^\circ$ , write down an equation of the function  $f$ .



- c) The suspension of the light source in model C can be described by the graph of the quadratic function  $g$  (see diagram on the right).

The following statement holds:  $g(x) = -0.25 \cdot x^2 + 1.25 \cdot x + 4$

- 1) Determine the maximum height  $h$  of the lamp above the tabletop.





## Solution to Task 2

### Desk Lamps

a1) A function assigns each  $x$ -value to exactly one  $y$ -value. As there is a region for which 2 points of the desk lamp are directly above each other, this method of suspension cannot be described by the graph of a single function.

b1)  $f(x) = k \cdot x + d$

$$k = \tan(116,56^\circ - 90^\circ) = 0.499\dots$$

$$-1 \cdot 0.499\dots + d = 3.5$$

$$d = 3.99\dots$$

$$f(x) = 0.5 \cdot x + 4 \quad (\text{coefficients rounded})$$

c1)  $g'(x) = 0$  or  $-0.5 \cdot x + 1.25 = 0$

Calculation using technology:

$$x = 2.5$$

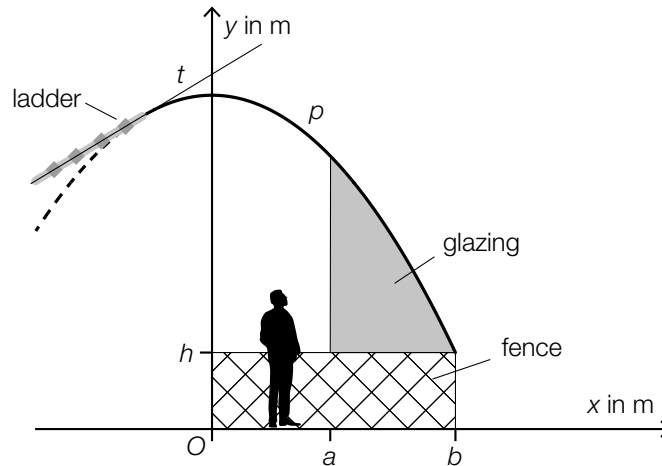
$$g(2.5) = 5.56\dots$$

The maximum height  $h$  of the desk lamp above the tabletop is around 5.6 dm.

## Task 3

### Viewing Platform

The diagram below shows a covered viewing platform shown from the side.



- a) The roof is modelled by the graph of the quadratic function  $p$ .

$$p(x) = -0.302 \cdot x^2 + 4.8$$

$x, p(x)$  ... coordinates in m

For cleaning purposes, a ladder is mounted on the roof. The ladder runs along the tangent  $t$  to the graph  $p$  when  $x = -1$ .

- 1) Determine the angle of elevation of the tangent  $t$ .
- b) The platform is to be glazed at the side. The glazing will cover the space between the top of the fence and the roof (see diagram above).

- 1) Write down a formula that can be used to calculate the size  $A$  of the area shaded grey.

$$A = \underline{\hspace{10cm}}$$

- c) For safety reasons, the roof requires a supporting beam of length  $\ell = p(a) - h$ .

- 1) Draw the length  $\ell$  in the diagram above.

## Solution to Task 3

### Viewing Platform

a1)  $p'(x) = -0.604 \cdot x$

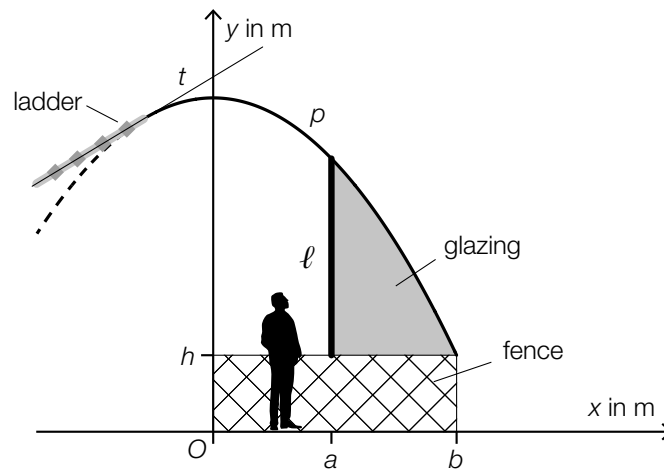
$$p'(-1) = 0.604$$

$$\alpha = \arctan(0.604) = 31.13\dots^\circ$$

The angle of elevation of the tangent  $t$  is around  $31.1^\circ$ .

b1)  $A = \int_a^b (p(x) - h) dx$  or  $A = \int_a^b p(x) dx - (b - a) \cdot h$

c1)



## Task 4

### Cigarettes

Many of the substances contained in cigarette smoke are hazardous to health.

- a) The amount in mg of substances contained in cigarette smoke in the cigarettes of 100 smokers is investigated. These have been sorted into 3 categories (see table below).

class	amount in mg of substances per cigarette	class midpoint	absolute frequency
1	[0, 10[	5	55
2	[10, 30[	20	40
3	[30, 50[	40	5

An estimate of the mean of the amount of substances is to be calculated. The respective class midpoints are determined for this purpose.

- 1) Determine the mean of the amount of substances.
  - 2) Explain why the median of the amount of substances is in class 1.
- b) The probability that a randomly chosen smoker smokes more than one cigarette per day is  $p$ .

The probability that exactly 5 out of 100 smokers smoke more than one cigarette per day is to be calculated.

- 1) Write down a formula that can be used to determine this probability.

## Solution to Task 4

### Cigarettes

$$\text{a1) } \frac{5 \cdot 55 + 20 \cdot 40 + 40 \cdot 5}{100} = 12.75$$

The mean of the amount of substances is 12.75 mg.

a2) The median of an ordered list always lies in the middle of all values. Of the given 100 values, 55, so more than half, are in class 1. Therefore, the median must also lie in this class.

b1)  $X$  ... The number of smokers that smoke more than one cigarette per day

Binomial distribution with  $n = 100$  and  $p$

$$P(X = 5) = \binom{100}{5} \cdot p^5 \cdot (1 - p)^{95}$$

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# Task 1

## The Number $\pi$

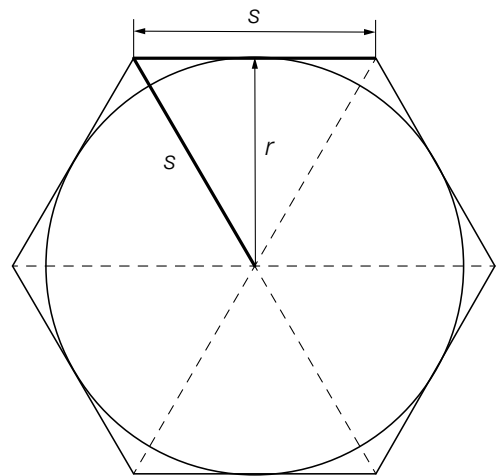
Over the course of history, various methods have been used to determine the value of the number  $\pi = 3.141\dots$  as accurately as possible.

- a) In the oldest known book of calculations (*Rhind Mathematical Papyrus*), the following approximation  $\pi_N$  is given:

$$\pi_N = \left(\frac{16}{9}\right)^2$$

- 1) Determine in how far the approximation  $\pi_N$  differs from  $\pi$  as a percentage.

- b) In another method, the circumference of a circle with radius  $r$  is approximated by the perimeter of a circumscribed hexagon (see diagram on the right).

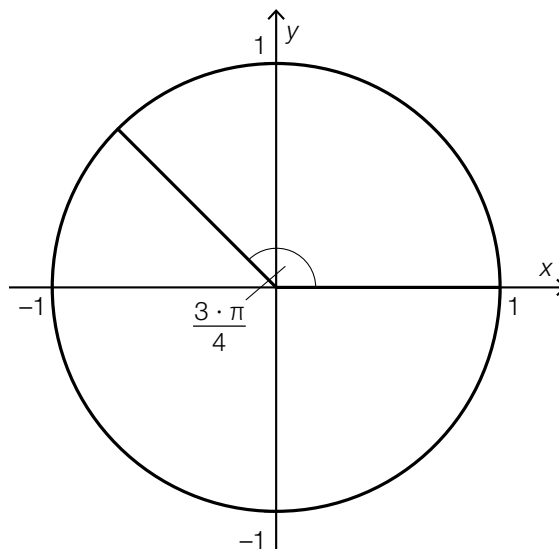


- 1) Write down a formula in terms of  $r$  that can be used to determine the perimeter  $u$  of the circumscribed hexagon.

$$u = \underline{\hspace{10cm}}$$

- c) 1) On the unit circle shown below, sketch the angle  $\alpha$  with  $\alpha \neq \frac{3 \cdot \pi}{4}$  for which the following statement holds:

$$\sin\left(\frac{3 \cdot \pi}{4}\right) = \sin(\alpha)$$



# Solution to Task 1

## The Number $\pi$

$$\text{a1) } \frac{\pi_N - \pi}{\pi} = \frac{0.0189\dots}{3.1415\dots} = 0.0060\dots$$

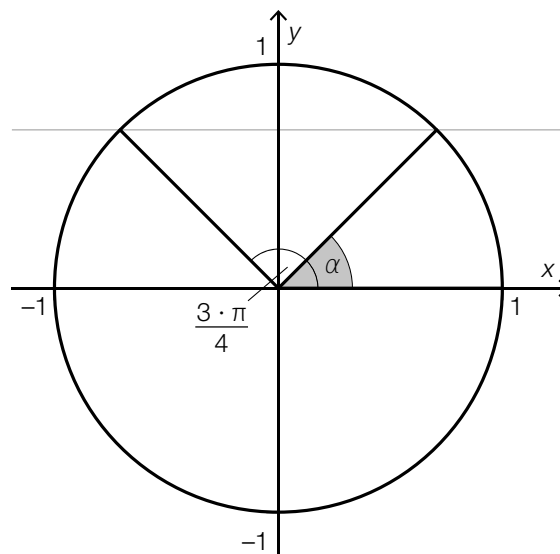
The approximation differs from the number  $\pi$  by around 0.6 %.

$$\text{b1) } s^2 = \left(\frac{s}{2}\right)^2 + r^2$$

$$s = \frac{2 \cdot r}{\sqrt{3}}$$

$$u = 6 \cdot s = \frac{12 \cdot r}{\sqrt{3}}$$

c1)



## Task 2

### Car Journey

- a) The diagram below shows the velocity in terms of time for a particular car journey for a time period of 15 s.



The distance covered in the first 5 s is the same as the distance covered in the following 10 s.

- 1) Write down an equation in terms of  $v_0$  and  $v_1$  that describes this situation correctly.
- b) For another car journey, the velocity can be approximated by the function  $v_A$ .

$$v_A(t) = 70 \cdot t^3 - 260 \cdot t^2 + 230 \cdot t + 80 \quad \text{with} \quad 0 \leq t \leq 1.5$$

$t$  ... time in h

$v_A(t)$  ... velocity at time  $t$  in km/h

- 1) Determine the maximum velocity for this car journey.
- 2) Interpret the result of the calculation shown below in the given context.

$$v_A'(0) = 230$$

## Solution to Task 2

### Car Journey

$$\text{a1) } \frac{(v_0 + v_1) \cdot 5}{2} = 10 \cdot v_1$$

$$\text{b1) } v_A'(t) = 210 \cdot t^2 - 520 \cdot t + 230$$
$$v_A'(t) = 0 \quad \text{or} \quad 210 \cdot t^2 - 520 \cdot t + 230 = 0$$

Calculation using technology:

$$t_1 = 0.57... \quad (t_2 = 1.89...)$$

$$v_A(t_1) = 139.59...$$

The maximum velocity is around 140 km/h.

b2) The instantaneous rate of change of the velocity (acceleration) at time  $t = 0$  is 230 km/h<sup>2</sup>.

## Task 3

### Bacteria

A sample of bacteria is investigated in a laboratory.

The number of bacteria is 1 200 when the observations begin.

After 6 days, the number of bacteria is 1 800.

a) The development of the number of bacteria over time can be modelled by the linear function  $f$ .

$t$  ... time in days with  $t = 0$  corresponding to the beginning of the observations

$f(t)$  ... number of bacteria at time  $t$

1) Write down an equation of the linear function  $f$ .

b) In a different model, the development of the number of these bacteria over time is described by the exponential function  $g$ .

$t$  ... time in days with  $t = 0$  corresponding to the beginning of the observations

$g(t)$  ... number of bacteria at time  $t$

1) Complete the boxes below with the missing symbol ( $<$ ,  $>$  or  $=$ ).

$$g'(t) \square g'(t + 1)$$

$$g''(t) \square 0$$

2) Determine the time at which the number of bacteria reaches 6 000 according to this model.

## Solution to Task 3

### Bacteria

a1)  $f(t) = 100 \cdot t + 1\,200$

or:

$$f(t) = \frac{600}{6} \cdot t + 1\,200$$

b1)  $g'(t) < g'(t + 1)$

$$g''(t) > 0$$

b2)  $g(t) = a \cdot b^t$

$$g(0) = 1\,200$$

$$g(6) = 1\,800$$

Calculation using technology:

$$g(t) = 1\,200 \cdot 1.0699^t \quad (\text{coefficient rounded})$$

$$g(t) = 6\,000$$

Calculation using technology:

$$t = 23.8\dots$$

The number of bacteria reaches 6 000 around 24 days after the beginning of the observations.

## Task 4

### Dice

- a) Two fair six-sided dice with faces showing the values 1, 2, 3, 4, 5 and 6 are rolled simultaneously. The sum of the values shown is determined.

The random variable  $X$  describes the sum of the values shown on the pair of dice.

- 1) Justify why the following statement holds:  $P(X = 11) = 2 \cdot P(X = 12)$ .

- b) Alex participates in a competition. In this competition, a fair six-sided dice with faces showing the values 1, 2, 2, 3, 3 and 3 is rolled once.

Before Alex rolls the dice, the game master collects an amount of  $e$  euros.

If the dice shows the value 1, the game master will pay Alex  $x$  euros.

If the dice shows the value 2, the game master will pay Alex 2 euros.

If the dice shows the value 3, the game master will not pay Alex any money.

From experience, the game master knows that he can expect a profit of 0.50 euros per roll of the dice.

- 1) Write down an equation in terms of  $e$  that can be used to calculate  $x$ .

- c) In the production of a particular six-sided dice with faces showing the values 1, 2, 3, 4, 5 and 6, inaccuracies have occurred. This has resulted in one particular face being rolled with a different probability from the others.

The dice is rolled 500 times. The results are shown in the table below.

value shown on the face	1	2	3	4	5	6
absolute frequency of the value shown on the face	75	98	65	110	80	72

- 1) Based on these results, determine an estimate for the probability shown below.

$P(\text{"the value shown on the face is greater than 3 when the dice has been rolled once"}) = \underline{\hspace{2cm}}$

## Solution to Task 4

### Dice

a1) The sum 12 is possible in one outcome of the experiment:  $\{(6, 6)\}$

The sum 11 is possible in two outcomes of the experiment:  $\{(5, 6), (6, 5)\}$

All of the possible outcomes of the experiment have the same probability, therefore:

$$P(X = 11) = 2 \cdot P(X = 12)$$

$$\text{b1) } e - \left( x \cdot \frac{1}{6} + 2 \cdot \frac{1}{3} + 0 \cdot \frac{1}{2} \right) = 0.5$$

$$\text{c1) } P(\text{"the value shown on the face is greater than 3 when the dice has been rolled once"}) = \frac{110 + 80 + 72}{500} = 0.524$$