Sample Questions for the Engineering Module

Subtest "Formalising Technical Interrelationships"

In the subtest "**Formalising Technical Interrelationships**," you are to transfer technical or scientific facts described verbally into a formulaic presentation and to interrelate the arising parameters to each other.

This test measures your ability to formalise, your deductive and combinatory powers and your ability to use basic mathematical tools of the trade. Deeper knowledge of mathematics and physics is not required to solve the problems – formulae and laws are given but must be used and interrelated correctly.

Instructions

Working time: **60 minutes**

In the following items, the relationships between various technical quantities will be described in a text or a sketch. Your task is to determine the formal relationship between the given quantities.

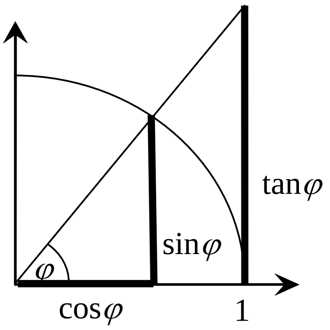
Aids:

- Circumference of a circle: $U = 2\pi r = \pi D$
- Area of a circle: $A = \pi r^2 = \pi \frac{D^2}{4}$
- Circle: degrees: 360° and arc: 2π
- Average speed: Distance divided by time
- Rotational frequency: Number of revolutions per time unit (e.g. 10 revolutions per second or $n = 10\ s^{-1}$)
- Pressure: Force divided by area
- Torque: Force multiplied by lever arm (only applies to right angles)
- A lever is balanced when the clockwise torque and the counter-clockwise torque are equal.
- Proportionality:
  - The quantities x and y (e.g. weight and volume) of a body are **proportional** to one another $(x \sim y)$ if their quotient is a constant.
  - The quantities u and w (e.g. volume and pressure of an ideal gas at a constant temperature) are **inversely proportional** $(u \sim \frac{1}{w})$ to one another when their product is a constant

Trigonometry

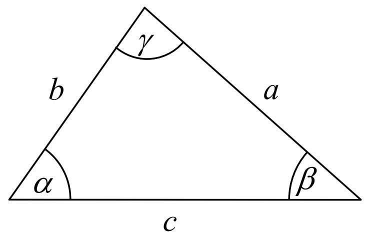
$$\sin^2\varphi + \cos^2\varphi = 1, \quad \tan\varphi = \frac{\sin\varphi}{\cos\varphi}, \quad \cot\varphi = \frac{1}{\tan\varphi}$$

φ	0°	30°	45°	60°	90°	120°	150°	180°
$\sin\varphi$ = cos (90°– φ)	0	$\frac{1}{2}$	$\frac{\sqrt{2}}{2}$	$\frac{\sqrt{3}}{2}$	1	$\frac{\sqrt{3}}{2}$	$\frac{1}{2}$	0



$$\frac{a}{\sin\alpha} = \frac{b}{\sin\beta} = \frac{C}{\sin\gamma}$$ (Sinussatz)

$$c^2 = a^2 + b^2 - 2ab\cos\gamma$$ (Kosinussatz)

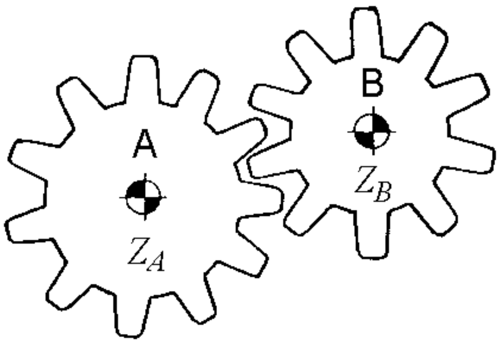


The illustrations are merely included as a visualization aid and are not true to scale.

Example 1
A gear mechanism consists of the gears A and B. Gear A has Z_A cogs; Gear B has Z_B cogs. In the time it takes Gear A to complete n_A number of rotations, Gear B completes n_B number of rotations.

Which of the following equations is correct?

(A) $n_B = \frac{Z_B}{Z_A\ n_A}$



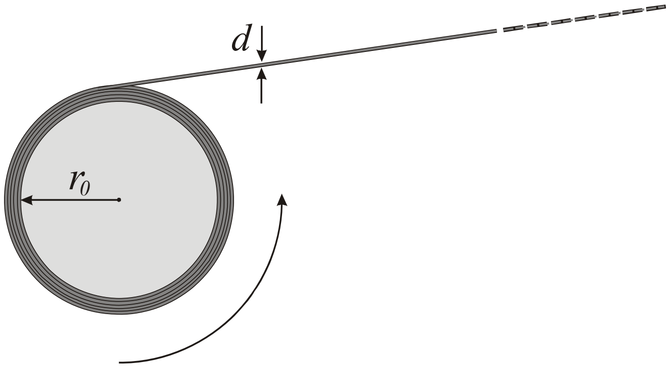
(B) $n_B = \frac{Z_A\ n_A}{Z_B}$

(C) $n_B = \frac{Z_A\ Z_B}{n_A}$

(D) $n_B = \frac{Z_B\ n_A}{Z_A}$

Degree of difficulty: low

Example 2
In a steel mill, sheet steel is rolled onto cylinders at the end of the production process. When empty, the radius of one of these cylinders is r_0 and the cylinder turns at a constant rotation speed *n* during the rolling process. The thickness of the sheet steel is expressed as *d*.
Which equation expresses the change in a cylinder's radius *r* in relation to the time *t* (in seconds)?



(A) $r = r_0 + dt$

(B) $r = \left(r_0 + nd\right)t$

(C) $r = r_0 + ndt$

(D) $r = r_0 + \dfrac{nd}{t}$

Degree of difficulty: medium

Example 3
The initial weight of a rocket is W_I. After the engines are started (t=0), fuel is expelled; the amount of fuel is proportional to time. When the fuel has been burned up, at the point in time T, the engines are turned off. The weight of the rocket has decreased to W_T.
Which of the following equations applies for the rocket weight W at the point in time t in the time interval 0<= t <= T ?

(A) $W = W_I - W_T \dfrac{t}{T}$

(B) $W = W_I - W_T\ t$

(C) $W = (W_I - W_T)\dfrac{t}{T}$

(D) $W = W_I - \dfrac{(W_I - W_T)}{T}\ t$

Degree of difficulty: high

Solutions

Subtest “Formalising Technical Interrelationships“

Example 1

To solve this problem, an equation is to be derived from the introductory text and then transformed. As described in the text, the time required by Gear A to rotate exactly n_A times is equal to the time it takes Gear B to rotate n_B number of times. The following products can therefore be equated: $Z_A n_A = Z_B n_B$.

To solve this equation for n_B, both sides must be divided by Z_B. Therefore the solution is the equation shown under (B).

Example 2

To solve this problem, it is necessary to find a formula with which the value of a constantly changing variable (the radius of the cylinder) can be determined at any given point in time.

Since the cylinder moves at a constant rotation speed n – this speed being defined as number of rotations per unit of time – n has to be multiplied by the time t. The result (nt) indicates how often the cylinder has turned at this point in time.

With every rotation of the cylinder, one layer of steel sheet is added. Therefore, if the product nt is multiplied by the sheet thickness d, the increase of the cylinder’s radius after t seconds can be determined.

In order to calculate the total radius, the radius r_0 of the empty cylinder at the beginning of the rolling process must be added to the result.

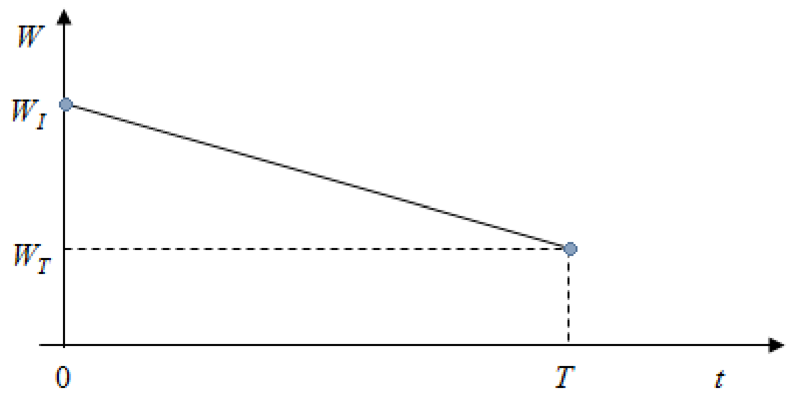
Alternative C is the only equation which reflects all of these aspects and is therefore the correct answer.

Example 3

The task presented by this test item is to find an equation which describes the change in the rocket's weight over the course of time. To this end, let us consider the following figure (see below). At the time of take-off (t = 0) the weight is W_I. After take-off, fuel is expelled, and the rocket's weight decreases. It can be deduced from the text that the amount of fuel expelled is proportional to time. In other words, in the time interval between 0 and T, the weight decreases linearly (W_I - W_T). The slope of the resulting straight line is thus (W_I - W_T)/T and is preceded by a minus sign because the weight is decreasing. This line intersects the vertical axis at the point W_I.

The correct equation is therefore

$$W = W_I - \frac{(W_I - W_T)}{T}\ t$$



Accordingly, if:

$t = 0$, then $W = W_I - \frac{(W_I - W_T)}{T} 0 = W_I$ and if

$t = T$, then $W = W_I - \frac{(W_I - W_T)}{T} T = W_I - W_I + W_T = W_T$

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Subtest “Visualising Solids“

In the subtest "**Visualising Solids**"; you have to infer perspectives of a solid from one given view of the solid.
The test measures your spatial sense.

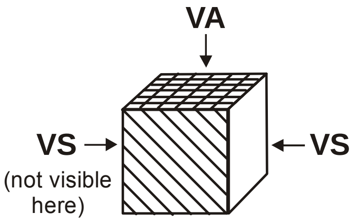
Instructions

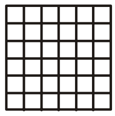
Two parts, Working time: **30 minutes**
Question type 1

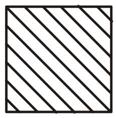
To solve the following items, you are to visualize the bodies three-dimensionally. In each exercise, the body is shown from two perspectives. You are to identify the view of the same body from a third perspective. Please mark the correct solution (A, B, C or D) on your answer sheet.

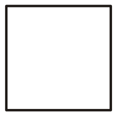
The views/perspectives are referred to as follows:

Parallel projection of a cube:



View from above **(VA)** 

View from the front **(VF)** 

View from the side **(VS)** 

Further pointers:

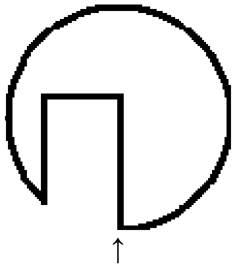
– In the illustrations, **all** visible edges are depicted as continuous (uninterrupted) lines.

– If the illustration of a view from the side is not accompanied by an arrow → indicating which of the two side views is intended, part of the task is to find that out.

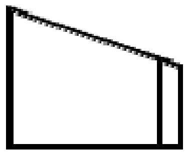
– If, for example, a side view is illustrated to the right of the view from the front or the view from above, it does not necessarily mean that it is a view from the right side.

Example 1
Given: The view of a solid from above and one side view of the same solid

View from above **(VA)**   View from one side **(VS)**

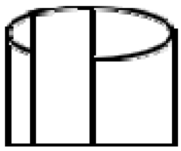


(VF)

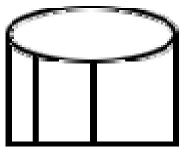


Wanted: View from the front **(VF)** of the solid

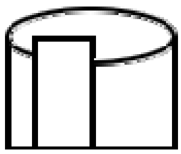
(A)



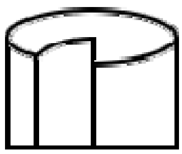
(B)



(C)



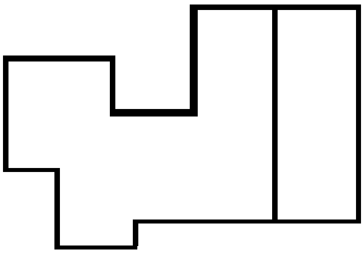
(D)



Degree of difficulty: low

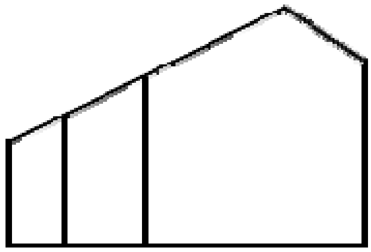
Example 2
Given: The view of a solid from above and the view from the front of the same solid

View from above **(VA)**



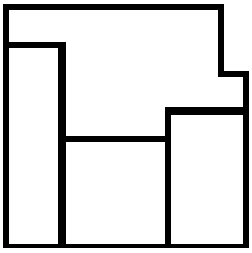
↑
(VS)

View from the front **(VF)**

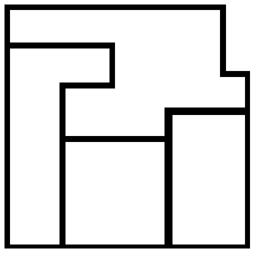


Wanted: View **(VS)** from the side of the solid indicated by the arrow

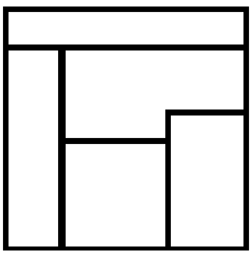
(A)



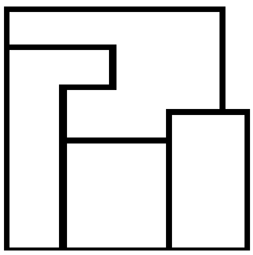
(B)



(C)



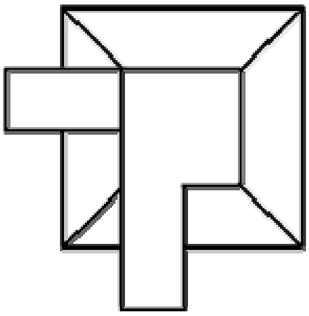
(D)



Degree of difficulty: medium

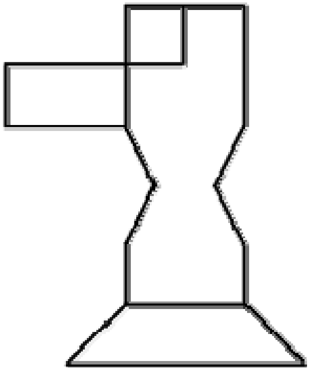
Example 3
Given: The View of a solid from above and the view from the front of the some solid

View from above **(VA)**



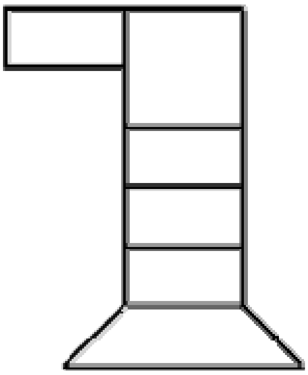
↑
(VF)

View from the front **(VF)**

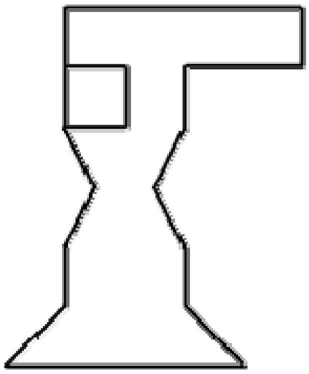


Wanted: View from the side **(VS)** of the solid

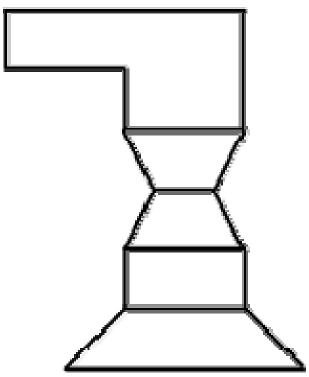
(A)



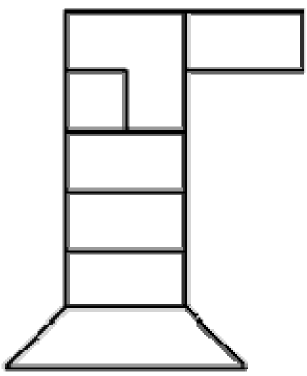
(B)



(C)



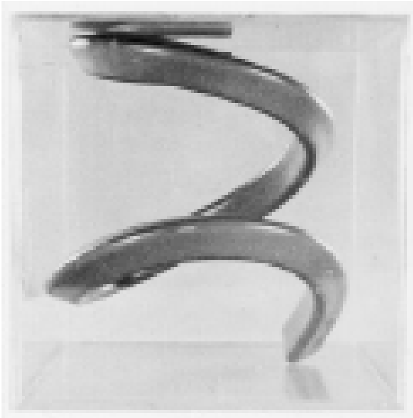
(D)



Degree of difficulty: high

Question type 2

The following items also test your ability to visualise three-dimensional figures. Each item consists of two illustrations showing a transparent cube with one or two cables in its interior. The first illustration (left) always shows the view from the front. In the picture on the right, the same cube is illustrated again. Your task is to determine whether the picture on the right shows that cube from the right (r), left (l), from below (w), above (a) or behind (d).



Here you see the cube from the front!

(A): r
(B): l
(C): w
(D): a
(E): d

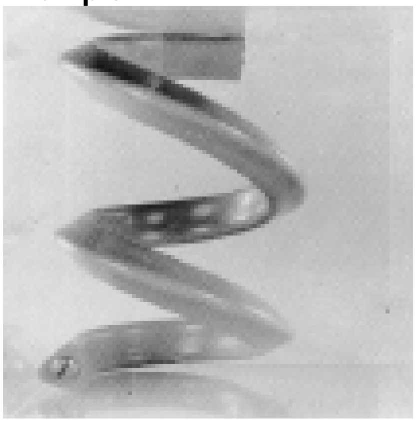
Here you see the cube from ?

In the picture on the right, you see the cube from above. On your answer sheet, you would mark the (D).

These items can be solved in one of the following two ways:

- Imagine that the cube had been placed on a glass table and that you could walk all the way around it. Standing to the right or left of the table, you look at the cube from the right or from the left. If you go behind the table, you look at the cube from behind. If you come back to the front of the table and bend over it, to look at the cube from above, and if you imagine yourself lying down underneath the table, feet first, you see the view from below.
- Or you imagine that you could pick up the cube and turn it around in your hands. If you looked at the cube from the front, i.e. from the position shown in the left-hand illustration, and then tipped it towards you by 90 degrees, not changing your own position at all, then you would see the view from above. If you looked at the cube from the front and then turned it 90 degrees to the right you would see the view from the left. If you turned it from the starting position 90 degrees to the left, you would see it from the right. And if you turned it 180 degrees to the right or left from the starting position you would see it from behind. Finally, if you tipped it backward, you would see it from below

Example 1



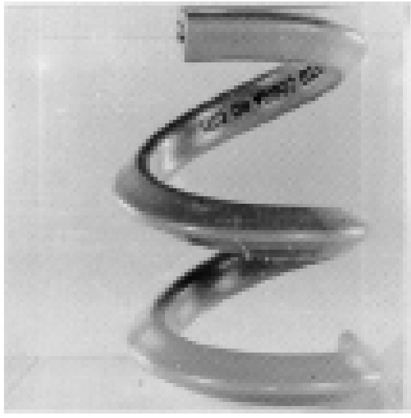
(A): r

(B): l

(C): w

(D): a

(E): d



Here you see the cube from the front!

Here you see the cube from ?

Degree of difficulty: low

Example 2

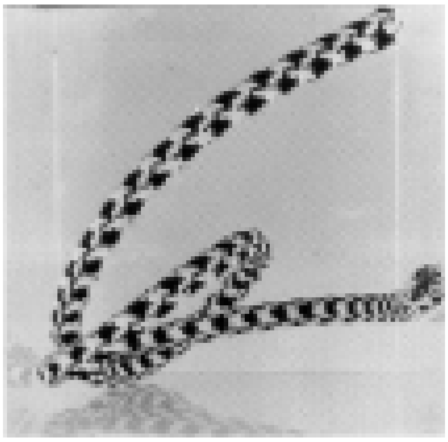
(A): r

(B): l

(C): w

(D): a

(E): d

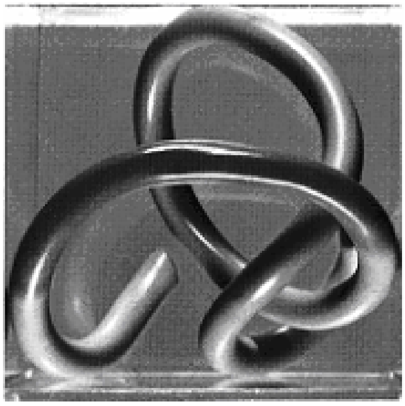


Here you see the cube from the front!

Here you see the cube from ?

Degree of difficulty: medium

Example 3



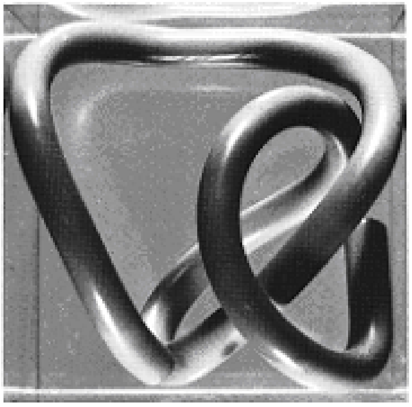
(A): r

(B): l

(C): w

(D): a

(E): d



Here you see the cube from the front!

Here you see the cube from __?__

Degree of difficulty: high

Solutions

Subtest "Visualising Solids"

Question type 1

Example 1
Visualise this solid as a tree stump which has been cut off diagonally. When you look at it from above (view from above), you see that a fairly large piece has been cut out of its left half. Behind the cut-out section, however, a relatively large section of the stump has remained standing.
You can therefore rule out Option (A) immediately, because this option shows nothing remaining behind the cut-out section except for the outer bark. Option (B) can likewise not be the correct solution, since here only a section of bark has been removed from the front. The piece cut out of Option (D) has only one straight side. According to the view from above, however, the cut-out section has to have three straight sides. This is the case only with the section cut out of Option (C). Therefore, (C) is the correct answer.

Example 2
One means of solving this item is to begin by looking at a detail which does not occur in all four answer options. Look, for example, at the figure which looks like an upside-down "L" on the left edge of Option (B) and (D). Does this figure result from the view from above and the view from the front? Yes, it does, because the "upside-down L" is the unobstructed view of the high surface at the figure's centre. Accordingly, you can already rule out Options (A) and (C). Options (B) und (D) differ in that, in Figure (B), a step has been indicated over the rectangular figure to the right, whereas (D) shows a straight edge all the way to the top. In the view from above, however, you can see the protruding section which forms the step: Therefore (B) is the correct answer here.

Example 3
In the process of solving this item, it is initially unclear whether the side view we are looking for is a view from the left or one from the right. On the basis of the view from above, it can be deduced that in the view from the left side (VSL), one of the two protruding beams at the upper end of the figure points towards the viewer, the other towards the right. In the view from the right side (VSR), only one of the two protruding beams can be seen; it points towards the left.
The answers (B) and (D) are therefore options for the VSL, and the answers (A) and (C) are options for the VSR. Answer (B) is out of the question because there is no line indicating an edge at the transition from the figure's base to the vertical element, or "pillar", on top of it. – On the basis of the view from above it can be deduced that the base of the figure is square. Therefore any view from the side would have to indicate the upper edge of the base, just as the view from the front does.
In the case of answer (D) there is a vertical line at the transition between the upper end of the "pillar" and the protruding beam. In the view from above, however, this line cannot be accounted for.
In the case of answer (A), on the other hand, there is likewise a vertical line at the transition between the upper end of the "pillar" and the protruding beam. Here that line is correct, because this is one of the two options for a VSR. The left, vertical edge of the pillar must therefore be visible in front of the protruding beam. The other elements of answer (A) also correspond with the view of the three-dimensional figure from above and the view of it from the side, and (A) is accordingly the correct solution to this task.
Answer (C) cannot be the correct solution because the transition between the upper end of the pillar and the upper protruding beam is shown as a single plane. According to the view from above, however, the vertical edge of the uppermost end of the pillar would have to be visible here.

Question type 2

Example 1
In the case of this simple example, you can immediately rule out the perspective from "below" and "above." From below as well as from above, you would be looking through a kind of "tube.". Therefore the perspective illustrated on the right can only be the view from the "right.", the "left" or "behind.". Now look at the bottom end of the cable: In the left-hand picture it "faces" you. In the right-hand picture it faces away from you, i.e. points in exactly the opposite direction. Therefore it is clear that the right-hand picture shows the view from "behind."

Example 2
Here the only view you can rule out immediately is the one from "behind" (Option E): If the view from the front shows one end of the cable leading toward the back of the cube at the top right, the view from behind would show this cable end "coming at you" at the top left. This is not the case in the right-hand picture. If you tip the cube forward in your imagination, you immediately see that the correct answer cannot be the view from "above;" and turning the cube 180 degrees or 90 degrees to the right also does not lead to the desired perspective. But if you imagine yourself standing on the right side of the cube, you see that the end of the cable which is concealed in the left-hand illustration comes toward you on the right side of the cube in the right-hand illustration: Therefore "right" (A) is the correct answer.

Example 3
Here the figure on the right cannot be showing the view of the cable from the left (B): In the view from the left, the section of the cable running horizontally in the view from the front would have to be visible in the middle of the right-hand edge. Answer (E) is incorrect for the same reason: In the view from behind, the horizontal section of cable would have to be

visible in the background, likewise running horizontally about halfway between bottom and top.

In the view from above (D), this same section of cable would have to be seen leading from one side to the other along the bottom surface of the cube.
The figure on the right cannot be showing the view from the right (A), because the part of the cable touching the upper left-hand wall in that figure would have to be touching the upper right-hand wall in the view from the front, which is not the case.
The only remaining option is the view from below (C), which only reveals itself to be correct, however, upon closer examination. We might easily find ourselves looking for the end of the cable clearly seen at the bottom left in the view from the front. – In the view from below it runs right into a curve in the cable and thus appears not to be an end at all. On the other hand, the end of the cable visible on the right-hand edge in the view from below is not visible in the view from the front because it is hidden behind a curving section of cable.

Subtest “Analysing Technical Interrelationships“

In the subtest "**Analysing Technical Interrelationships**," you have to analyse and interpret diagrams, charts or tables depicting technical laws or formulae.

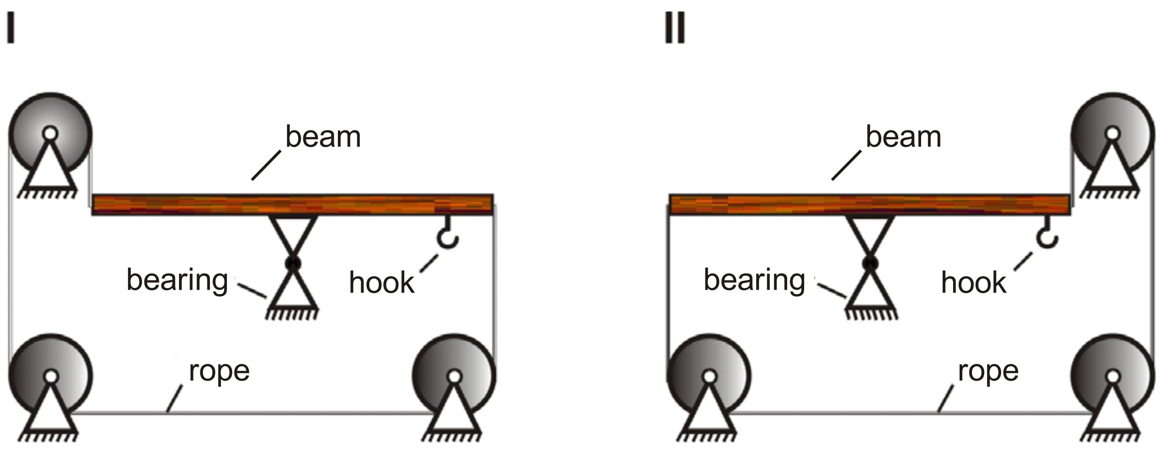
The test measures the ability to abstract from scientific and technical facts and to put abstract facts in concrete terms. Knowledge of mathematics, physics or technology is not needed, background information will be provided if necessary.

Instructions

Working time: **60 minutes**

These items contain questions from various technical areas. Your task is to visualize simple technical procedures and recognize technical interrelationships. Unless otherwise indicated, the axes (scales) of all diagrams are linearly subdivided. In some of the items, you must identify the “qualitatively” correct diagram. In other words, your task is to decide which graph best represents the relationship between the variables shown. Even the correct diagram will not necessarily drawn to scale.

Example 1
Arrangements I and II each include a beam which is pivot-mounted (like a swing or see-saw). A hook has been mounted on the right end of the beam. The ends of the beam are connected by a rope which is threaded through rolls.



A weight is hung on the hook.

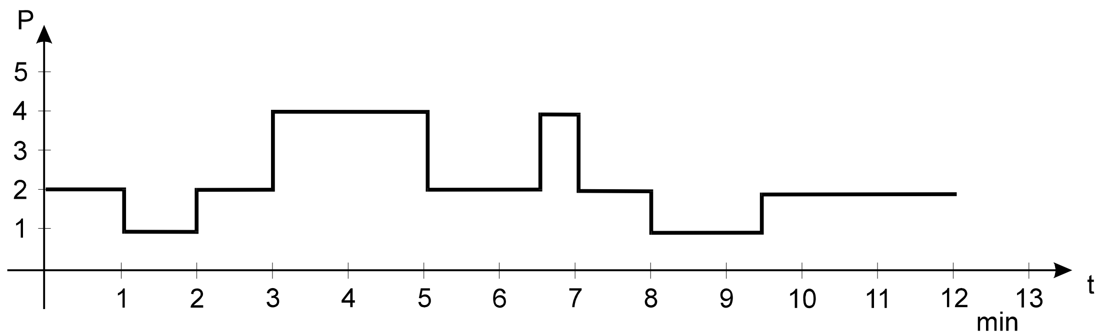
Which of the following statements is/are then correct? (The masses of the beam, rope and hook can be neglected.)

I. In the case of Arrangement I, the right end of the beam moves downward.
II. In the case of Arrangement II, the right end of the beam moves downward.

(A) Only statement I is correct.
(B) Only statement II is correct.
(C) Both statements are correct.
(D) Neither of the two statements is correct

Degree of difficulty: low

Example 2
This diagram shows the wattage required by a lift motor in a period of 12 minutes (min).
When the lift travels upward, four times as much wattage (per minute) is required as when the lift travels downward.
When the lift stops at a floor, twice as much wattage (per minute) is required as when the lift travels downward.
The running time between two consecutive floors is 30 seconds. At the point in time $t = 0$, the lift is on the third floor.



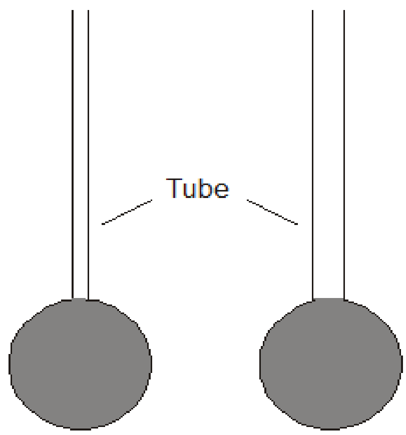
Which of the following statements is/are correct?

I. Within the 12 minutes shown, the lift travels up to the 6th floor.
II. At the point in time t = 10 min, the lift is on the 3rd floor.

(A) Only statement I is correct.
(B) Only statement II is correct.
(C) Both statements are correct.
(D) Neither of the two statements is correct.

Degree of difficulty: medium

Example 3
The diagram shows two thermometers on which no temperature scales have yet been indicated. They are both filled with the same liquid, and the amount of liquid is also the same. Their tubes are of the same length. However, the tube of the left-hand thermometer has a narrower diameter than that of the right-hand thermometer.



We will assume that the markings for the two temperature scales are added correctly: they begin at the same height on each tube and end at the same height. Both thermometers are used only at temperatures for which they are suitable.

Which of the two statements is (or are) therefore correct?

> I. Rises in temperature can be measured less accurately with the left-hand thermometer than with the right-hand one.
> II. The right-hand thermometer covers a greater temperature range than the left-hand one.

(A) Only statement I is correct.
(B) Only statement II is correct.
(C) Both statements are correct.
(D) Neither of the two statements is correct.

Degree of difficulty: high

Solutions

Subtest "Analysing Technical Interrelationships"

Example 1
If there is no rope, the right end of the beam moves downward in both cases when a weight is suspended from the hook. So the question is whether this movement is prevented by the rope. When a weight is suspended from the hook in Arrangement I, the rope slackens at the right end and at the left end. The right end of the beam moves downward, and **Statement I** is accordingly correct. When a weight is suspended from the hook in Arrangement II, traction (pulling power) is applied to the right end of the rope. By way of the rope, this traction is transferred to the left end of the beam. Since both ends of the beam are pulled downward with the same force, the beam does not move. **Statement II** is false.

The solution to this item is therefore **A**.

Example 2

Three different values for the wattage P are shown in the diagram: 1, 2 and 4. According to the text, P is the lowest when the lift travels downward. In this case, therefore, P = 1. When the lift stops at a floor, P = 2. When the lift travels upward, P = 4.

On the basis of this information, it is possible to interpret the movement of the lift. At the point in time t = 0, the lift is on the 3rd floor and stops there for 1 minute. Then it travels downward for 1 minute. Since it takes 30 seconds to travel one floor, it is then on the 1st floor. Following a stop of 1 minute, it travels upward 2 minutes (corresponding to 4 floors). At the point in time t = 5 it is therefore on the 5th floor. There it stops for 1.5 minutes, then travelling upward to the 6th floor – **Statement I** is therefore correct. One minute later, it travels 1.5 minutes (corresponding to 3 floors) downward and, at the point in time t = 9.5, is therefore on the 3rd floor – **Statement II** is accordingly also correct.

The solution to this item is therefore **C**.

Example 3
If the temperature is increased by x degrees, the liquid inside each thermometer expands by the same volume. However, this increase in liquid volume makes the liquid rise to a higher level in the tube of the thermometer on the left. Since the cross-section of the tube in the left-hand thermometer is smaller than that of the right-hand one, a defined temperature change generally leads here to a greater change in the liquid level than with the right-hand

thermometer. Consequently, temperature changes can be measured more accurately with the left-hand thermometer than with the right-hand one. **Statement I** is therefore false.

Since a rise in temperature has a lesser effect on the liquid level in the tube of the right-hand thermometer than on that in the left-hand one, greater changes in temperature can be measured with the right-hand thermometer. The right-hand thermometer thus covers a larger temperature range. **Statement II** is therefore correct.

The solution to this item is therefore **B**.