

# **ELECTRONIC TESTS FOR SELF ASSESSMENT IN THE UNDERGRADUATE PHYSICS COURSE**

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## **ABSTRACT**

Traditionally the German system of higher education does not include midterms in the assessment; students are assessed only by one final examination. Consequently students receive no formal feedback during the study of their courses. This paper presents a computer based test program which was developed to address this lack of feedback on students' progress. These tests allow students to assess their individual progress in the undergraduate physics course by electronic tests for self-evaluation. The tests are intended to diagnose deficiencies and to foster self-directed learning. The pilot version of a 'physics entry test' for beginning students is available in German and English. A platform independent version is available on the internet. The tests are designed in multiple-choice-format; no time constraints apply.

In progress are follow-up tests covering the topics 'oscillations' and 'heat and thermodynamics'. These topics are part of the curriculum in any introductory physics course in engineering, covering about four to five weeks of instruction.

## **KEYWORDS**

Physics in engineering education, multimedia, self assessment and self-directed learning.

## **1. THE PRECEDING PAPER-AND-PENCIL TEST – HISTORY AND RESULTS**

### **1.1. Background**

The knowledge and skills of beginning students in mathematics and physics have been evaluated in Esslingen over the last 20 years with paper-and-pencil tests [1],[2]. These tests were designed in multiple-choice-format to ease the computer based analysis of the results. The tests were presented to the students in the first week of instruction. Each student received his/her personal test score and the mean of the cohort of the respective course of studies. The instructors received an analysis of the results according to the different certificates of entry to higher education. These are the general entry certificate to higher education ('Allgemeine Hochschulreife - AHR') and the specialized certificate for studies at Fachhochschulen ('Fachhochschulreife - FHR'). The 'Allgemeine Hochschulreife' is awarded by a gymnasium; at the gymnasium level a student can select a basic or an advanced course in physics or even withdraw from a course in the final two years of the gymnasium. In general the 'Fachhochschulreife' is awarded at specialized vocational schools.

## 1.2. Results - overview

The test results for the entry cohort in winter semester 1999/2000 are summarized in Fig. 1. The results are presented according to the fields of study [i.e. 'electrical engineering', 'mechanical engineering', 'chemical engineering' and 'business administration'] and according to the different certificates for admission [i.e. 'general certificates' and 'specialized certificates'].

The test results of the winter term 1999/2000 repeat the general pattern of the results over the last 20 years [1]. Year after year, we always observe the following:

- (1) students in the field of electrical engineering score significantly higher than students in the field of mechanical engineering (two sample t-test;  $p = 0.001$  level);
- (2) students holding a certificate of general admission score significantly higher than students holding a certificate of specialized admission (two sample t-test;  $p = 0.001$  level);
- (3) students who signed up for advanced courses in physics in the gymnasium score significantly higher than those who took only basic courses (two sample t-test;  $p = 0.001$  level).

Courses of study	N	M	SD
'Electrical Engineering'	226	53.5	14.4
'Mechanical Engineering'	231	43.7	12.6
'Chemical Engineering'	41	41.1	17.7
'Business Administration'	67	39.5	15.7
Admission certificates			
AHR - basic courses physics	115	48.1	15.3
AHR - advanced courses physics	113	57.1	12.3
AHR - physics 'withdrawn'	72	40.0	14.3
AHR - others	35	51.4	9.1
AHR - total	335	49.7	15.0
FHR- specialized vocational school	188	43.9	14.4
others	42	38.0	14.1
FHR- total	230	42.9	14.5
FHT- total	565	46.9	15.2

**Figure 1:** Results of the physics entry test (paper-and-pencil version) – University of Applied Sciences Esslingen- winter semester 99/00;  
top: arranged according to fields of study;  
bottom: arranged according to entry certificates to higher education.  
['AHR' = general certificate of admission; 'FHR' = specialized certificate of admission]  
Number of test items 60; maximum test score normalized to 100.  
N: number of participants; M: mean; SD: standard deviation.

## 2. CHANGE OF FORMAT SUITED FOR SELF EVALUATION

As described in the preceding section, similar results are obtained year after year. It was decided to change the test to a format suited for self evaluation by the students. This included fully worked-out solutions with the aim of providing useful feedback to the students. They are intended to bridge the gap between the actual entry knowledge and the level for the introductory physics course requested by the instructors. They are also intended to foster self-directed learning which is a desirable life-long learning skill.

The revised 'Framework Act of Higher Education' (dated January 2000) clears the way for dramatic changes in the German system of higher education. In the future the traditional German degree of 'Diplom-Ingenieur' is intended to be replaced by degrees of 'Bachelor' and 'Masters' (and Ph.D.) awarded by consecutive courses of study. In addition courses of study might be offered in a foreign language (in general English). To address this new development, the entry test was translated to English as an offer for potential foreign students from different educational systems. All examples presented in this paper are taken from the English version of the entry test.

As a side product for organizing a 'virtual university' the German version of the entry test is also available in a platform independent version on the internet: The URL address is

<http://www.fht-esslingen.de/~kurz/physiktest>

The target groups for the German version of the entry test are:

- students at the transition from secondary to higher education interested in a course of study in a technically oriented field;
- beginning students in the system of higher education;

and for the English version:

- foreign students holding an entry certificate from an English/US based educational system applying for admission in a course of study 'engineering' in Germany;
- German students planning to study abroad for language preparation in science based fields of study.

## 3. STRUCTURE AND CONTENT OF THE ENTRY TEST PHYSICS

### 3.1. Content

The entry test is designed for self-evaluation and for independent study to remedy identified deficiencies in background knowledge in physics. The contents cover the basic requirements for a successful study in the general introductory general physics course for beginning students. It consists of four components i.e. 'mechanics' (23 items), 'structure of matter' (10 items), 'heat and thermodynamics' (11 items) and 'electricity and magnetism' (16 items).

The multiple-choice format of the preceding paper and pencil version was retained to keep the programming efforts at a reasonable level. Although open questions are desirable, they would require sophisticated programming to track and provide feedback to the different approaches students might take in providing a solution.

For each question five possible answers are presented, with only one answer being correct. For the entry test an additional answer 'don't know' is possible to prevent mere guessing by the

students. This holds whenever the content of an item was not covered on the individual track of a student through secondary education or the answer is ‘really’ unknown.

Reference to textbooks or printed material was omitted in the solution part to ease the use in different teaching environments. A combination of appropriate printed material and self assessment tests, however, could be useful for future courses in distance learning.

### **3.2. Structure of the test**

The overall structure of the test, i.e. the four components ‘introduction’, ‘test items’, ‘evaluation’ and ‘solution’ and their interdependencies are sketched in Fig. 2. The starting page allows for the selection of language, i.e. German or English (holds for the entry test only). The starting pages present information needed to undertake the test: introductory remarks, a short description ‘how to use the test’ (see Fig. 3), notation and navigation hints. The navigation buttons are standard ‘exit’, ‘next page’ and ‘previous page’. The last page of the introduction allows to select one of the test components mentioned above. The four test components can be worked on and assessed independently.

Individual items of a test component are earmarked in the left upper corner and they are presented in numbered order. They present the question, i.e. text, sketches and possible answers to chose. An additional navigation button allows for navigation from any page to the end or contents page.

The contents page presents a summary of the test items answered so far (framed in green) and those still to be worked on (framed in red). From the end page any given input can be altered by a back jump to any item, either to change the input for an item already solved or to solve an item which was not worked on yet. A student can loop from this page at his/her desire. If a student finally decides to ‘hand in’ his/her answers the evaluation is activated via the button ‘evaluate’. The individual results are presented and a paper printout is optional.

The summary of the evaluation (Fig. 4) presents the percentage of correctly and wrongly answered items as well as for any individual item ‘correct’ (a smiling face in green) or ‘wrong’ (a sad face in red). The answer ‘don’t know’ is of course not the correct one and therefore treated as ‘wrong’. The philosophy of the test – to provide help and to foster self-directed learning – is revealed by the question asked to the individual student after presentation of his/her results: “Are you satisfied with your result? If yes: please remind there is no course of complacency. If not: it is time to bridge the gap; use your textbooks from the gymnasium or the library”. If desired a student can branch back to each item and via a button ‘S’ (for ‘solution’) a fully worked-out solution is available.

At first the respective item is presented again for refreshment and the smiling or sad face on the bottom indicates whether the item was answered correctly or wrongly (an example is given in Fig. 5). Fully worked-out solutions are available (an example is given in Fig. 6). Whenever possible, background information is supplied and appropriate comments on ‘impossible or obviously silly answers’ are given. Wherever appropriate, animations to visualize the underlying physics and the solution are included (an example is given in Fig. 7). Also, branching to general overviews – as for instance to the SI system of units – is offered to reinforce learning (an example is given in Fig. 8). For general scientific literacy some information is given about great scientists who are remembered and honored by physics units named after them: their life dates and the most noticeable inventions or contributions are

mentioned. Reinforcement is the main objective; redundancies, repetition of expressions and symbols are intentional. Thus the multiple use of pages like 'SI units' throughout the test or in the respective test component the page 'structure of matter' presents hints on the structure of atoms and the physical quantities of nucleons and electrons.

After finishing with the solution part the program can be exited via the 'exit' button (see Fig. 2). Either another test component can be activated or the test session can be left for good.

### **3.3. Technical details and requirements**

The tests are developed under ToolBook – Instructor II. A runtime version is part of the program. To run the program the user's PC should meet the following minimum requirements: Pentium processor, 32 MB RAM and at least 10 MB empty hard disk space, Microsoft Windows 9x or Windows NT, a CD-ROM drive, SVGA graphic card, high color 16 Bit and a MS compatible mouse.

## **4. OUTLOOK**

### **4.1. Developments in progress**

At present the pattern of test, evaluation and feedback, and fully worked out solutions is being extended to other topics of the traditional introductory physics course 'oscillations and waves' and 'heat and thermodynamics'. The learner may evaluate his/her individual progress during the term. It should be mentioned again that the German system of higher education does not offer midterms at all, so this is the only opportunity students have to obtain timely feedback.

In the test under construction 'oscillations' a new strategy will be implemented. The program will be split into a 'learning' and an 'evaluation' division. In the 'learning part' the worked-out solution will be presented immediately after the student confirms his/her answer to an individual item. With this immediate feedback the ideas and arguments behind a given answer are still freshly present in the student's mind. A separate 'evaluation part' is offered in the manner described above for the entry test to determine the learning progress during the term.

### **4.2. Evaluation**

As the use of the entry test is left to the discretion of an individual student, a desirable and comprehensive evaluation of the value and effect of the test is not possible. As the test is performed anonymously no data at all are recorded, neither to register the number of students participating nor the duration of individual sessions in front of the monitor. One possibility in future releases could be to establish an electronic mail box for general comments and/or revealing specific difficulties of an individual learner.

## **5. ACKNOWLEDGMENT**

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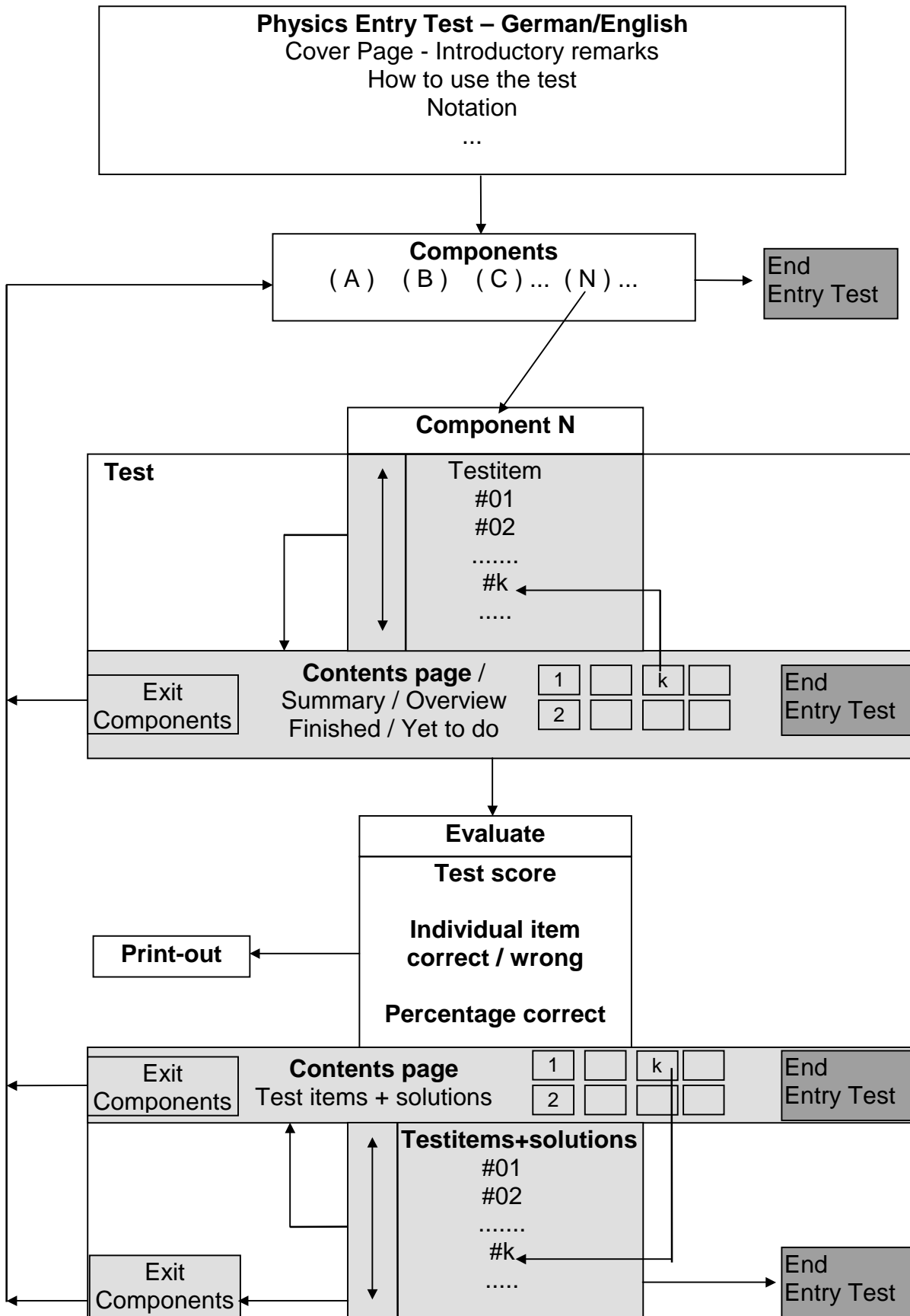
## 6. REFERENCES

- [1] Kurz, G.: Das Eingangswissen von Studienanfängern in Mathematik und Physik. Wiederholte Querschnittsuntersuchungen an der FHT Esslingen. In: *Empirische Pädagogik*, 2(1); S. 5-32 (1988)
- [2] Kurz, G.: *Die Schnittstelle Schule-Hochschule: das Eingangswissen in Mathematik und Physik von Studienanfängern*. LARS Projektbericht; FHT Esslingen (1994).

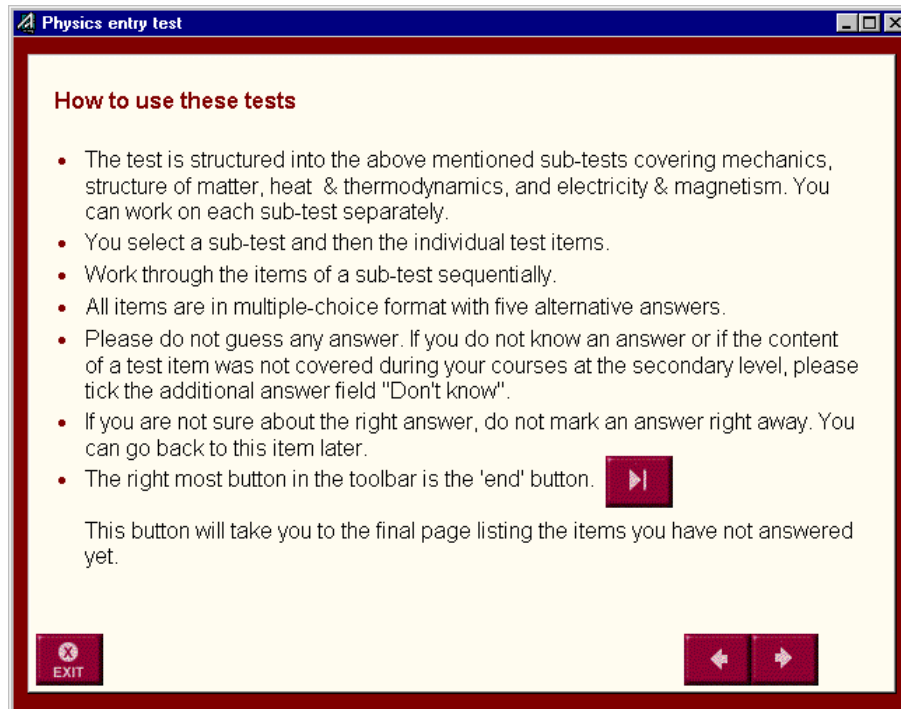
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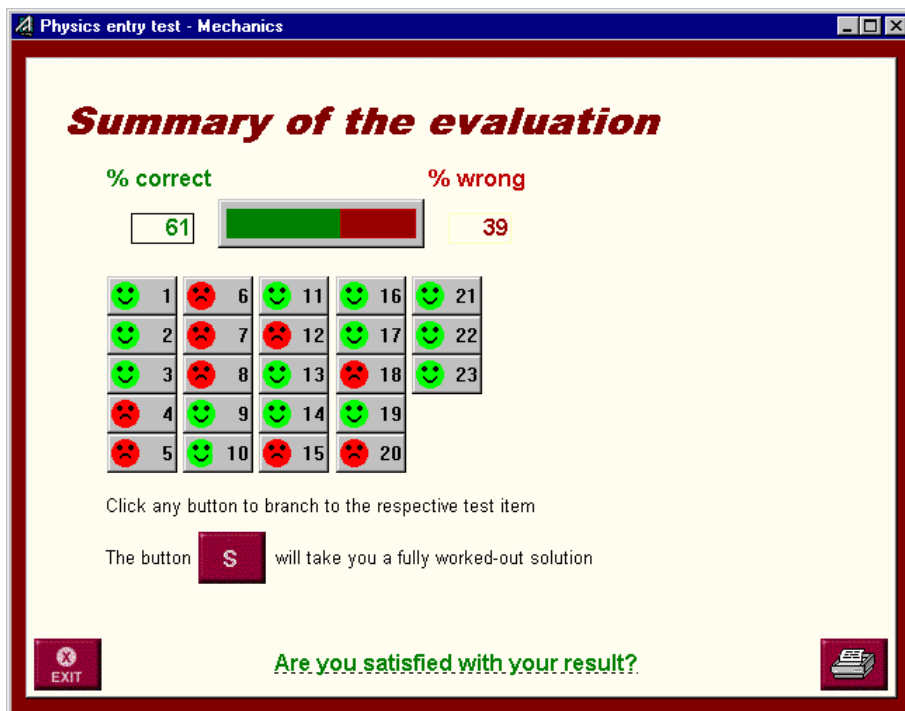
H.H.: [hh@pelikan.cologne.de](mailto:hh@pelikan.cologne.de)



**Figure 2:** Structure of the four blocks of the self-evaluation test; i.e. ‘introduction’; ‘components’; ‘evaluation’; and ‘worked-out solutions’ for self-directed learning.



**Figure 3:** The information page offers general introduction to the physics entry test; i.e. 'introductory remarks' (two pages); 'how to use the test' (shown is page 1 of 2), and notation used.



**Figure 4:** Component 'mechanics' - summary of an evaluation.

The bar depicts the percentage of correctly and incorrectly answered items. For each item of the test a (green) smiley face is shown for a correct answer and a (red) sad face for an incorrect answer. Branching to any desired item activates the original question plus the answer given (see Fig. 5) and presents the option of fully worked-out solutions. Button 'exit' exits to the main menu or end of the program, respectively. Button 'printer symbol' allows to print out the individual test results.



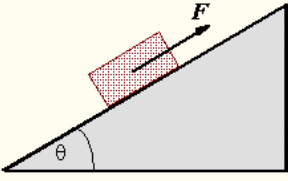
Physics entry test - Mechanics

## Mechanics

7

An object is pulled up an inclined frictionless plane (see sketch). The weight of the object is known.

If the body is moved to another point on the plane, what additional quantity must be known in order to calculate the work done?



The inclination angle $\theta$ of the plane	<input checked="" type="radio"/>
The absolute value $F$ of the force acting on the body	<input type="radio"/>
The speed with which the body is pulled	<input type="radio"/>
The downhill component of the weight	<input type="radio"/>
The height to which the object is lifted	<input type="radio"/>
Don't know	<input type="radio"/>

EXIT [Sad Face] S [Left Arrow] [Right Arrow] [Next Arrow]

**Figure 5:** Presentation of an incorrectly answered item (red sad face). As a reminder the previously ticketed wrong answer is shown. The navigation button ‘S’ calls up the fully worked out-solution of this item (presented in Fig. 6).

Physics entry test - Mechanics

### Solution

Work has to be done to lift an object of mass  $m$  in the gravitational field of the earth (acceleration of gravity  $g$ ).  
The work required depends **only on the total vertical displacement**, i.e. the difference between the final and initial height of the object.

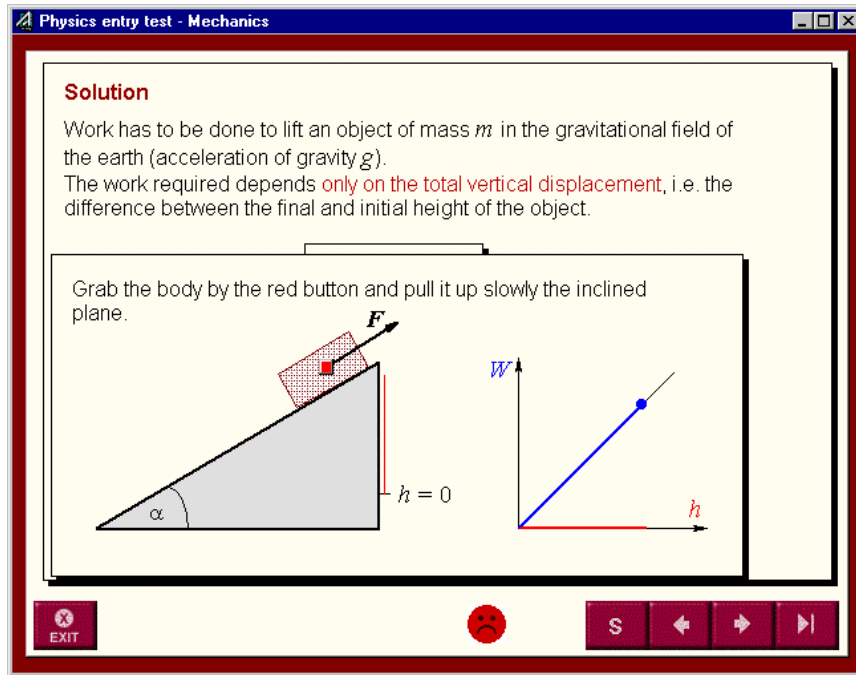
$$W = m g \Delta H$$

**Observe it!**

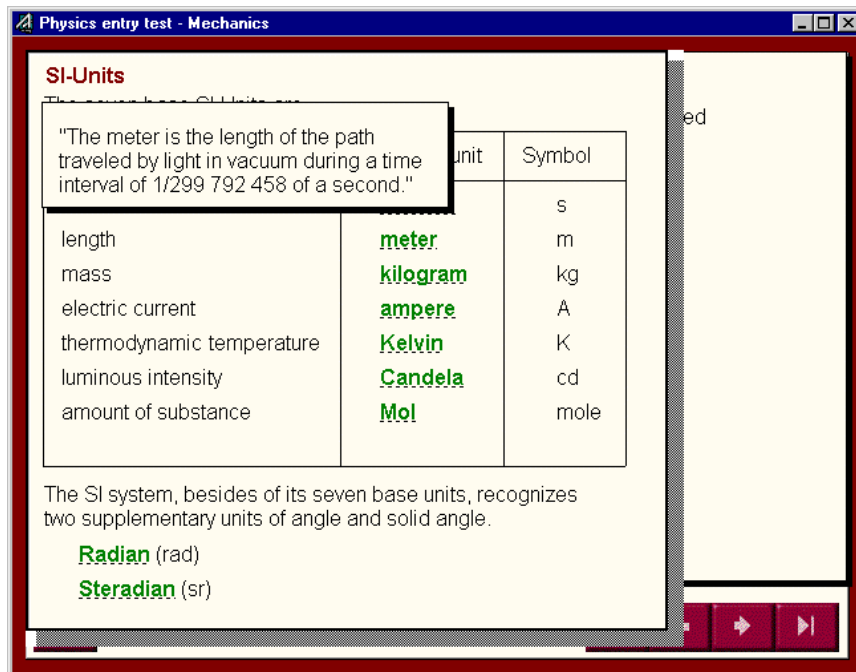
**Hint**  
The difference in height  $\Delta h$  is determined by the angle  $\theta$  of inclination and the length  $L$  of the inclined plane  $\Delta h = L \sin \theta$   
The angle of inclination  $\theta$  solely is not sufficient to calculate the work done.  
At any time the force to pull the body upwards the inclined plane must balance the component of the gravitational force in the direction of the inclined plane.

EXIT [Sad Face] S [Left Arrow] [Right Arrow] [Next Arrow]

**Figure 6:** Fully worked-out solution [component ‘mechanics’ - item 7 (presented in Fig. 5)].  
The hint refers explicitly to a misconception which lead to the wrong answer.  
The hot word ‘observe it’ calls up an animation to visualize dynamically the written statement (shown in Fig. 7).



**Figure 7:** Component ‘mechanics’ - item 7 (see also Figs. 5 & 6). Animation ‘work done on a body on an inclined plane’ (colours missing). The body can be grabbed by the (red) button in its center and pulled up the inclined plane. The height lifted is revealed (in red) on the right hand side of the inclined plane. In the diagram on the right the linear dependence of work done from the height lifted is dynamically presented.



**Figure 8:** Enhancing physics literacy and reinforcing basic knowledge. Whenever SI units are essential in an item a button ‘units’ pops up yielding to an overview of the SI system. The units themselves are designed as (underlined) hot words and the definition of respective unit is shown in the upper left corner. The example refers to base unit ‘length’, the name of unit ‘meter’, and its symbol ‘m’.