ANIMATIONS AND HEAT CONTROL USING A REHABILITATION ROBOT

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ABSTRACT

In the computer-aided multimedia learning environments are animations which are one of the most commonly used multimedia technologies. Animation is a live, striped, detailed production of the computer images. Animations show according to circumstances that some things are coming in sight, some things are disappearing and shapes or colours are getting changed. These changes may occure in the graphics as well as in the cartoons and pictures. The pictures and cartoons will not be named "animation" when they are not moving and showing no alteration. Because animations should not be moving constantly, should they stay in motion permanently? The materials along with their shapes to be used in the comparison experiment of the specific heats were shown as animations. The animation communicates with you in which steps should be followed in order to conduct the experiments properly. Additionally, the related literature on conceptual errors has been investigated in order to prevent possible misconceptions about this topic. In this way, it is aimed that the students will comprehend the experiment more easily. This paper presents a variable impedance control method, which is used to teach a lower limb rehabilitation robot how to imitate exercise motions applied to a patient by a physiotherapist. To achieve this task, the characteristics of physiotherapist's motion are investigated.

Keywords: Animation, Specific heat, Physics laboratory, Mechanical equivalent of the heat, Relationship between calories and joules.

1. INTRODUCTION

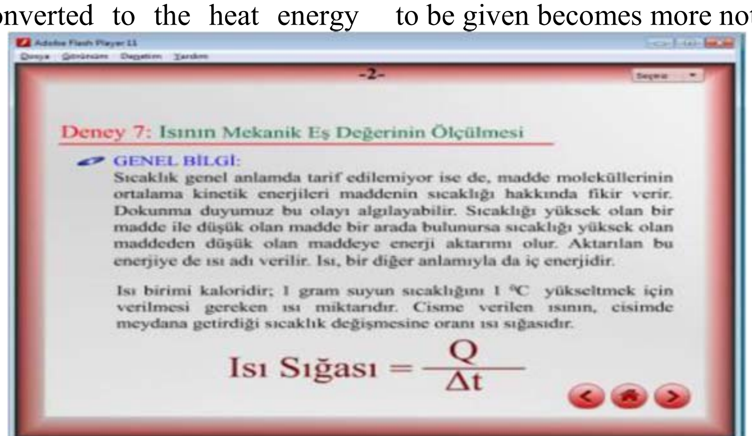
Teachers who have chosen to teach the traditional lecturing methods are causing the following students to be bored and lost their attentions in a very short time. Nevertheless, the lesson provides a significant contribution to focus students' attention on the lesson topic and eliminate the boredom when lectures are made impressive with spectacular animations [1]. In the study performed by Marshall and Shipman; unlike the texts, animations present some scientific events in a visual, interactive and multidimensional manner. Animations have brought a new concept to the lecturing in the science field with their interesting animated shows and have enriched students' imagination worlds. Through animations, many concepts in the teaching of the scientific facts can be explained in a way of attracting the students. In the science lecturing, observable alterations in the material (e.g. colour change, smell, boiling) are explained in two ways. The first type of lecturing is at the laboratory level and the second type is at the microscopic level. Lectures at the microscopic level are either explained by symbols and signs qualitatively, or mathematics quantitatively [2]. It is especially recommended that the animation method must be used in teaching and comprehending of many abstract concepts in science education so that the attention of the students may be caught. Moreover, it was stated that the lecturing with animations has a positive effect on the students according to other teaching methods [3]. The amount of people who are in need of being rehabilitated by a physiotherapist is increasing day by day. In order to address solutions for this necessity, robotic technologies in the field of rehabilitation have advanced considerably in an effort to satisfy expectations of patients who need physical therapy. In the last fifteen years, robotic systems for rehabilitation have been progressively investigated and developed. The primary goal of rehabilitation robots is to aid physiotherapists in the course of therapy by increasing quality and efficiency of the process. Effectiveness of using robots in rehabilitation has been shown with clinical results [1-3]. There are two main classifications of a rehabilitation program in general: *therapeutic modalities* and *therapeutic exercises*. While the goal of therapeutic modalities is to remove the effects of pain, spasm and edema, the ultimate aim of therapeutic exercises is to return injured patient to pre-injured healthy conditions and movement capabilities. In order to achieve complete treatment of patients, parameters that are given in a proper sequence below must be improved [4].

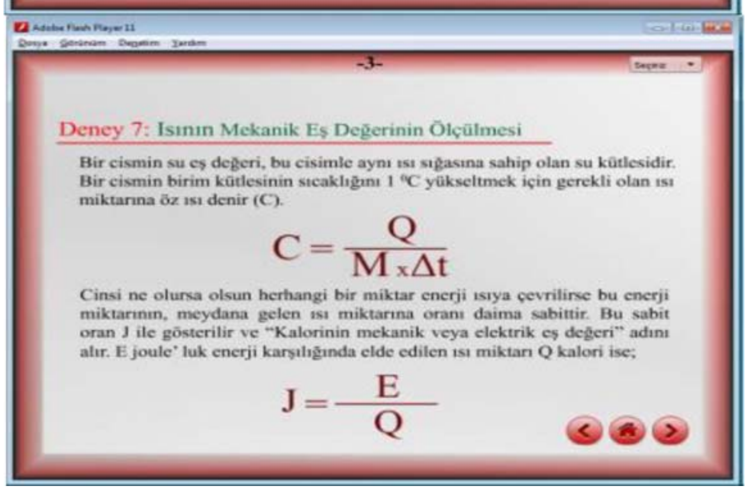
- ✓ Flexibility and range of motion.
- ✓ Strength and muscle endurance.
- ✓ Proprioception, coordination and agility.

2. ANIMATION DESIGN

The ratio of the energy amount to the amount of the generated heat remains always constant, if any energy is converted to the heat energy whatever the species. This constant rate is denoted by "*J*" and is known as the mechanical equivalent of the heat. In our experiment, studies were conducted to measure the mechanical equivalent of the heat, and the definitions and problems related to the topic were solved through animation. When the animations were constituted, attention has been taken that the animation is linked to the topic lectured and every animation in the study attracts the attention of the students. In this way, students were allowed to enjoy the topic. Care was taken to ensure that the colours and movements used in the animation are in a consistent shape on the screen that does not strain the eyes and the view is clear. In the animations, the natural tones and shapes appropriate to the age level of the students were used. The animations were visual, audio and practical constituted. Care has been taken to make it possible that the font is readable in terms of type, colour, size, and is easy to perceive the motion.

Each animation includes the forward and backward keys to enable the desired division transition. At the same time, very long texts were not preferred particularly. Thus, the information to be given becomes more noticeable [10].





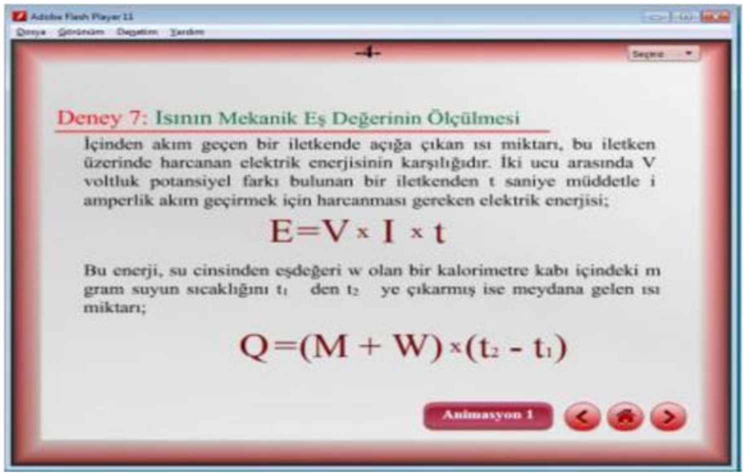


Fig 1. Definitions and formulas for measuring the mechanical equivalent of the heat

Fig. 1.a) gives the definition of the heat and its unit, the definition of the heat capacity and its formula. The experiment will be here easier to comprehend by remembering the knowledge that students have learned in the past. In the animation given in Fig. 1.b), the definition of the water equivalent of an object, the definition and formula of the specific heat, the definition and formula of the mechanical equivalent of the heat were given so that the subject can be better comprehended and the basic information can be reproduced. It was intended to visualize the topic about formulas of the electrical energy and the heat amount its equivalent is W for water that increases the temperature of m grams of water from t1 to t2 in the calorimeter vessel so that the students learn the topic more easily and keep it longer in their memory as animated in Fig. 1.c). Estimation of the impedance parameters that occur during patient-physiotherapist interaction plays an important role that provides smoothness and stability of motion during patient-robot interaction. Because of this reason, the impedance parameters of physiotherapist's arm have to be well estimated to achieve cooperative task between patient and robot. In this work, we propose to teach a rehabilitation robot how to model passive flexion-extension movements performed by a physiotherapist for knee. A variable impedance control is proposed to teach optimum impedance parameters for a suitable exercise. This method causes the robot and a lower limb on it to follow flexion-extension motion determined by the physiotherapist, thus the most appropriate impedance parameters of the robot can be obtained for exercise. The variable impedance control method is divided into two steps. In the first step, *learning phase*, we investigate impedance characteristics of the physiotherapist's arm during the treatment in order to generate the impedance parameters of the robot. In the second step, *treatment phase*, the impedance of the robot obtained in the first step is utilized to emulate a physiotherapist's arm effect, as if a physiotherapist is applying it on lower limb of a patient.

2.1. LEARNING PHASE

The proposed control method is based on adjusting impedance parameters, namely inertia and torsional damping coefficients of the robot, in terms of estimated stiffness coefficient of the physiotherapist's arm. We assume that the robot has only (t) inertia and $B(t)$ torsional damping impedance coefficient. (t) is the force that occurs due to robot-physiotherapist interaction, $T(t)$ is the torque that occurred by $FP(t)$ at O point of the robot, $\theta D(t)$ is desired angular position of the robot, because this position data is obtained when the robot is actuated with optimum impedance coefficients. Therefore, the mathematical model of the 1-DOF robot can be written in terms of joint space variables in (1).

$$TP(t)=IR(t)\ddot{\theta D}\ (t)+BR(t)\dot{\theta D}(t)$$

And the mathematical model of the physiotherapist's arm can be written in terms of workspace variables in (2), physiotherapist's arm has only (t) stiffness coefficient. (t) is position difference, which is along physiotherapist's arm. As can be seen from Fig. 2, L is the length between end-effector and point O.

$$FP(t)=KP(t)\ X(t)$$

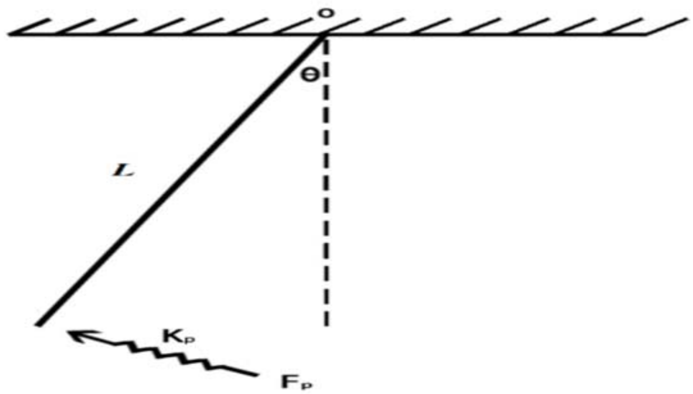


Figure 2. The robot modeled as a simple pendulum and physiotherapist's force on it.

2.2. TREATMENT PHASE

In this phase, the impedance parameters of the robot obtained in *learning phase* will enable us to determine the most appropriate angular position pattern $\theta D(t)$, as if a physiotherapist is applying the motion on lower limb of a patient. From (1), (8) and (9), we derive (t) parameter that provides the appropriate motion pattern for knee rehabilitation. Controller input to actuator and output torque which actuator produces for following $\theta D(t)$ are not the subjects of this study, it is only determined the most appropriate $\theta D(t)$ pattern for the patient according to estimated impedance parameters, $FP(t)$and $\theta R(t)$ data are shown in Fig.3. These data are used in (4) to estimate (t) parameter.

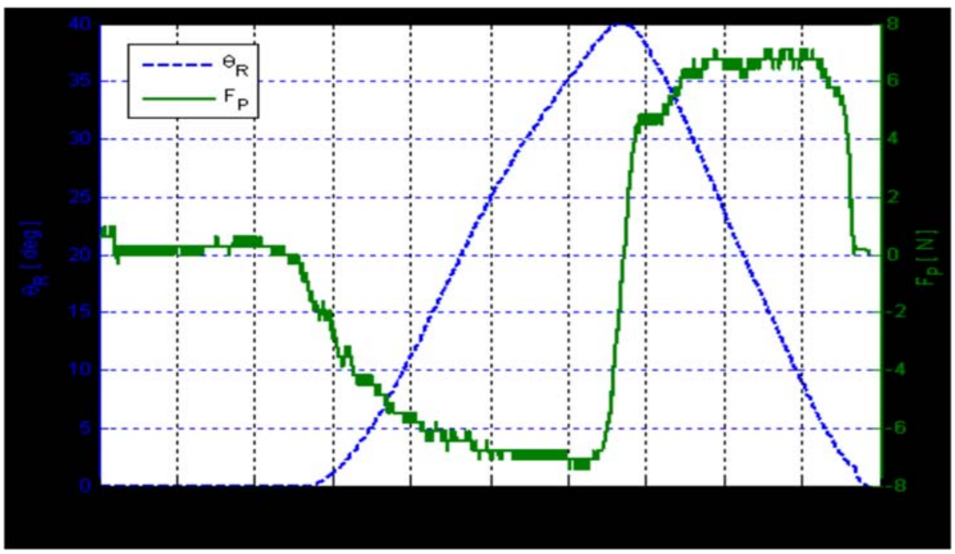


Figure 3. Real *FP(t)* and *ƟR(t)* data.

3. SIMULATION RESULTS

(t) is recorded angular position of a patient's knee and $F(t)$ is recorded force data during an exercise applied by a real physiotherapist, and these data are SHOWN from Fig.4, we assume that $KP(t)$, the stiffness of physiotherapist's arm can be thought as $KO(t)$, the robot's torsional stiffness that occurs at point O of the robot using (3), (4), (5), (6) and (7).

$$X(t)\text{= } L\ \theta R(t$$
$$FP(t)\text{=}KP(t)\ L\ \theta R(t$$
$$FP(t)\ L\text{=}TP(t$$
$$TP(t)\text{=}KO(t)\ \theta R(t)$$

Thus;

$$(t)\ L2\text{=}K(t)$$

In Fig. 4, a place is given to solve problem in the animation to better comprehend the experiment and to increase the memorability. In our problem was asked how many calories are required to increase 40 C degrees of the temperature of the 150 grams water. In the problem was the amount of the specific heat given as 1 cal/g. C degree. Therefore, it is desirable to provide students with an entertaining opportunity to learn more about the topic and to keep alive their interest to the lesson lectured.

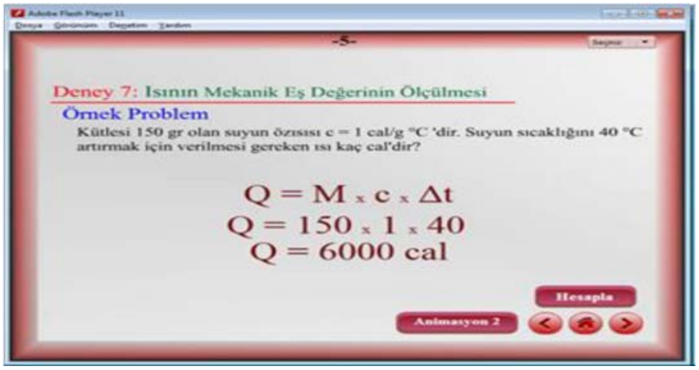


Fig. 4. Solution of the problem about measuring the mechanical equivalent of the heat

In this section, several α and β values we choose are tested to obtain the most appropriate $\theta D\ (t)$ pattern which follows $\theta R\ (t)$, $\theta D\ (t)$ patterns determined by different α and β values as can be seen in Fig.5. The values which can locate the error as possible as near zero will be used for experimental verification of simulation using Physiotherabot in future works. The experiment was repeated also for the copper, steel, marble substances, respectively. When you click the question mark on the animation, information about the specific heats of the iron, copper, steel and marble substances are available and these values are given to be 0,115 cal/g degree C, 0,090 cal/g degree C, 0,122 cal/g degree C and 0,200 cal/g degree C, respectively. At the end of calculations, it was observed that the material with a higher specific heat increases the temperature of the water more than other lowers. It is quoted and edited from the source specified in the design of the animation in Fig. 6 [12].

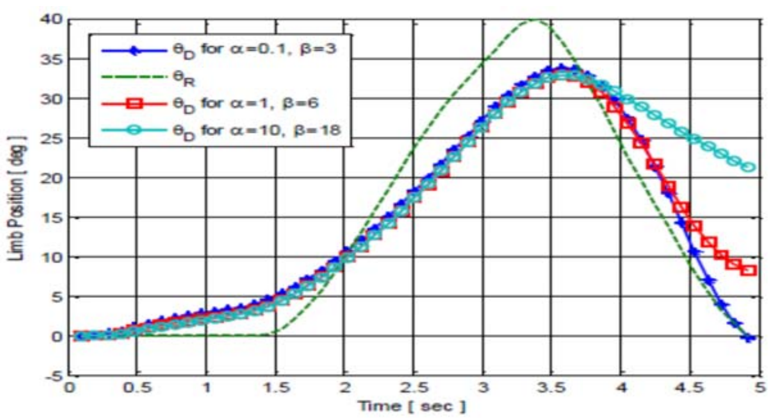


Figure 5. ϴD*(t)* and *ϴR(t)* parameter for α = 0.1 β = 3, α = 1 β = 6 and α = 10 β = 18.

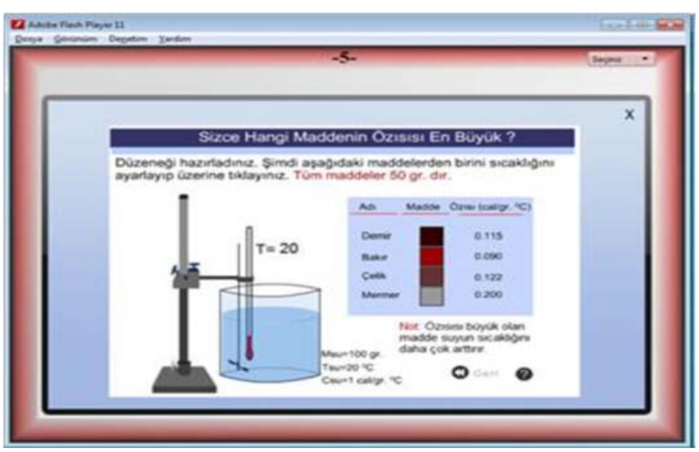


Fig. 6. Specific heat values of the different substances

4. CONCLUSION

Animations may be used by transferring them into the classroom environment to demonstrate and model phenomena and events that cannot be shown or applied in the classroom conditions. In addition, animations appeal to multiple sensory organs with dimensions of movement, colour and sound, making learning easier and providing students with a sense of liveliness and concrete and lasting learning. In order to increase the achievement of science and physics education to the desired level, the lessons should be carried out with a laboratory support. Some experiments cannot be accomplished in the laboratory due to lack of laboratory or high cost of the related experiments. In such cases, it is considered that the application of the experiments by the students prepared with animations will increase the success and decrease the misconceptions in the lessons. Computer laboratories are needed to use animation in the classroom. For this reason, schools not having computers need to be compensated for these shortcomings. For some difficult, expensive and dangerous experiments, the participants have emphasized that it is easier to animate the lesson topics and more useful to see the details of them. Teachers and students should be aware of the importance of animation in the science and physics education. Some of the students participated in the study have stated that they have wanted to prepare these and similar materials themselves. The effect of the animation materials may be investigated regarding to the achievement, motivation, concept teaching and misconceptions of the students. It is suggested that the animated and student centered teaching methods like this are used in other units of the physics lesson. Simulation results show that adjusting impedance parameters that are in terms of estimated stiffness parameter of the physiotherapist's arm enables us to create a physiotherapist effect for passive lower limb flexion-extension exercises. This method gives us an error (max. 7° for parameters α=0.1,β=3) which is acceptable for passive flexion-extension movements for lower limb rehabilitation as can be seen in Fig.5, thus we can say that modeling physiotherapist's arm as a single spring is sufficient at least for passive flexion-extension exercises in lower limbs.

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