Strategic homework redesign for enhanced learning

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1 Introduction

Homework assignments serve as a crucial component of the educational experience, influencing student learning and retention. The University of Calgary recently made the shift towards open-source textbooks for first year physics students, presenting an opportunity to reevaluate and enhance the structure of their homework. This will not only allow targeted changes to enhance student learning, but also economize student expenses by not having to pay for a textbook. While numerous studies focus on optimizing in class learning experiences (Freeman 2014), there are fewer that take the out of class experience into consideration. Students spend on average 6.5 ± 2.9 h a week studying and doing homework depending on exam schedules (Stewart et al., 2016), compared to just three hours of lecture time; it is imperative that optimizations be made to the structure of said homework, so the time spent working independently benefits the students as much as possible. This project serves to conduct a literature review of studies done on homework redesign for introductory physics courses and apply the results to create a homework assignment template that applies the best practices shown to improve student learning.

2 Literature Review

2.1 Methods

The literature review required a comprehensive search through academic databases using a combination of keywords relevant to educational strategies and physics education. It will include around ten applicable studies, all done on introductory level physics or engineering courses with a focus on Mastery Style Learning or Deliberate Practice. These can be defined as follows: Deliberate Practice – "The individualized training activities specially designed by a coach or teacher to improve specific aspects of an individual's performance through repetition and successive refinement" (Ericsson & Lehmannn, 1996). In the context of homework redesign from the literature review, this involves adding subskill progression questions prior to an exam-like question on homework assignments. This allows the students to perform short questions that allow for practice on the different subskills they will need to incorporate to complete the exam-like question. In contrast, Mastery Style requires students mastering (at least 90%) a task before progressing to the next (Bloom, 1968). In the context of homework redesign, this involves grouping different questions of around the same difficulty together, and only allowing student progress once they reach a certain mastery threshold. This ensures the students complete the difficulty level, master the questions at that level and then move on to more difficult questions as the assignment progresses. The search was refined to include peer-reviewed articles and case studies from the past two decades as well as utilizing specific keywords such as "mastery style", "deliberate practice" and "subskill progression" in order to find the most relevant studies. Papers on how to properly write a literature review were referenced, such as "How to do (or not to do) a critical literature review" (Jesson, 2006), providing valuable insight on the most effective ways to organize the findings in the studies cited.

2.2 Results

The literature review showed the positive impact of deliberate practice and mastery style questions on learning outcomes in physics education. For instance, in the course-wide transformations at Harvard Extension School, incorporating deliberate practice into homework assignments alongside active learning strategies in lectures led to notable improvements in student performance. In the introductory physics course sequences the study focused on, exam averages for cohorts (~200 students) employing these strategies saw increases from 70% to 82% in the physical sciences one course (fig 1) and 77% to 86% in the physical science two course (fig 2) showing a modest but statistically significant increase in performance without a significant rise in the reported homework time (Miller et al., 2021). The study also involved a targeted experiment for students in a physics extension course, in which only the homework transformations were involved. The results showed that those engaged with transformed homework structures significantly outperformed their peers on Tests of Learning (a ten-item test at the end of each unit designed to test student knowledge without affecting their final grade), scoring an average of 93.7% compared to 80.7% ($p < 0.001$) for traditional homework groups (fig 3). This too was achieved without a significant increase in independent study time

(Miller et al., 2021).

The literature review also showed other improvements to be considered, such as a study on the effects of multiple tries for online homework. The study showed conclusively that the optimal number of attempts compared to the performance of the students on the questions was five. Larger numbers of allowed attempts promoted unwanted student behavior and less allowed attempts did not give the students enough of a chance to learn from their mistakes and fix their solutions, leading to lower scores on the questions (Kortemeyer, 2015). Other studies looked at the efficacy of online vs on paper homework and saw no difference in student performance between the two (Bonham et al., 2003), while others saw an improvement in student learning from online work as opposed to on paper work (Cheng et al., 2004). A study at the University of Illinois held over the two fall semesters of 2014 and 2015 made significant modifications to preexisting mastery style homework implementation between the years to reduce student frustration and unproductive behavior (such as guessing, cycling through questions quickly, giving up on homework, not watching solution videos, etc.). They adjusted mastery thresholds (i.e., the level of understanding for a group of questions needed to progress through the next set) for question groups, graded the best mark of four attempts, assigned biweekly homework to reduce workload, and more. This saw a decrease of student self-reported frustration with the homework from 60% down to 30% between 2014 and 2015, as well as doubled the number of students viewing solutions to questions they answered incorrectly from 30% in 2014 to 60% in 2015. By making these changes and reducing frustration and utilization of the solution

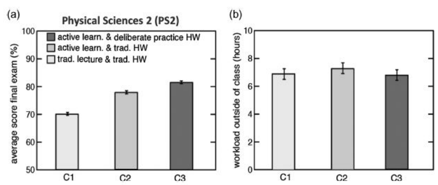

Figure 1: PS2 Results from Miller 2021

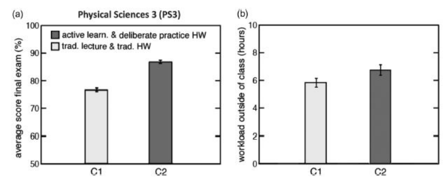

Figure 2: PS3 Results from Miller 2021

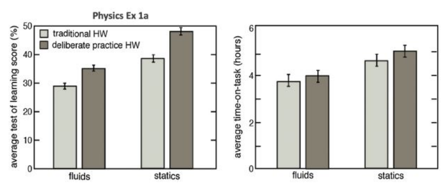

Figure 3: Ex 1a Results from Miller 2021

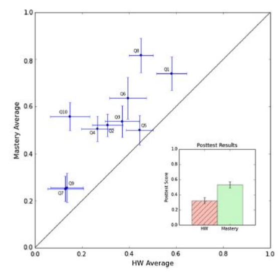

Figure 4: Post test score Results from Gladding 2015

videos, the students engaging in unproductive behavior dropped from 30% to 5% between the two years as well (Gutmann et al., 2018). The last major result to showcase is a massive 65% improvement in grades between mastery style groups and traditional homework groups shown in figure 4, by Gladding in 2015, though the authors mention that the traditional groups had unlimited question attempts and they believe that the students engaged in unproductive behavior which affected the scores.

The literature review revealed that research on homework optimization, specifically for physics education is quite emergent but it is not expansive, as the results found are particularly concentrated among a few research groups. The work done by Miller et al. (2021), Kortemeyer (2015), and Gutmann et al. (2015, 2018) for example, is pivotal; but it also shows the necessity for a broader range of studies to validate and generalize the findings. The implementation of the proposed homework assignment structure could serve as a case study for future work in this area. It is important to note that there are limitations to this study as well, for example, the mastery style studies incorporated narrated, animated solution sets to their question which would undoubtedly help students learn from their mistakes, but were not possible to implement within the schedule for this study.

3 Design Choices

3.1 Methods

The methodology implemented for the design choices of the homework assignment template draws upon the comprehensive results from the literature review. While most studies focused only on one specific change to the assignment structure, such as mastery style grouping, or deliberate practice subskill question integration, the assignment template created here will incorporate all relevant and useful pedagogical strategies shown to work. Referencing Jennson's 2006 article on how to write a literature review, the most important information from each study was summarized in structured tables. The information included what the theory or focus of the study was, the course type and level as well as the number of students partaking in the study. It included an extensive summary of the design choices of the study, the methods by which they reviewed their findings, such as assessing all students equally with the same tests, what statistical methods were used to aggregate the results, etc. And finally, particular emphasis was placed on the results of each study, keeping track of the percentage improvements on student performance, or lack thereof, as well as their statistical significance.

3.2 Results

The results of the homework design drew heavily on the summarized articles and the statistical significance of the pedagogy that showed positive results in the test groups. The results were aggregated and then applied in turn to the existing homework structure to make the necessary modifications. In general, the transformed homework takes a mix of mastery style and deliberate practice theories. The homework will still be submitted online for ease of use and efficiency and is supported by the findings that online homework has been shown to be equivalent to on paper homework, unless combined with interactive elements. (Cheng, 2004). The assignment structure will be composed of ten subskill questions that are non-ordered and not for marks, leading into fifteen assignment level questions grouped into three mastery levels of five questions each, inspired by the deliberate practice study by Miller et al. (2021). From the same results, subskill questions will have hints available, whereas the assignment questions will not; in practice, the subskill questions themselves are the hints for the assignment.

Students will need 80% mastery or need to hit the attempt limit for all questions in order to progress mastery levels, which was shown to reduce student frustration with the mastery applications in previous studies, where the mastery threshold was 100% (Gutmann, 2018). The attempt limit per question will be five, with the opportunity for students to retry the question and increase their previous mark if attempts are left, from the results of Kortemeyer (2015). The assignment workload should be set to biweekly assignments, as this was also shown to reduce student frustration and increase time management by Gutmann (2018). Lastly, though beyond the scope of this study, the average weekly student workload should be kept at around the same level as they had with traditional homework, though this would need to be tested.

To give details on subskill integration, the subskills need to be relatively short, target only one subskill at a time, and target relative subskills the students need to apply to the assignment they are working on (Miller et al., 2021). As we can see in figure 5, a mastery level three question would incorporate several subskills in its solution. The question calls for knowledge of energy transfer in pendulums, one-dimensional general energy transformations, energy signage, as well as work done by friction on rough surfaces. This is a multi-step problem, but the students would already have completed the steps separately, in different questions while working on the subskill portion of the assessment.

Based on the results from the literature survey, a rough estimate can be made about the expected improvement in student grades on post-assessments with the implementation of this homework template. The main theories that inspired the changes were mastery and deliberate practice. The improvement in student grade from each trial and each study from these two was added up, and a weighted average was done on the results. Sixty percent of the weight went to deliberate practice and forty percent of the weight was for mastery style learning, due to the fact that

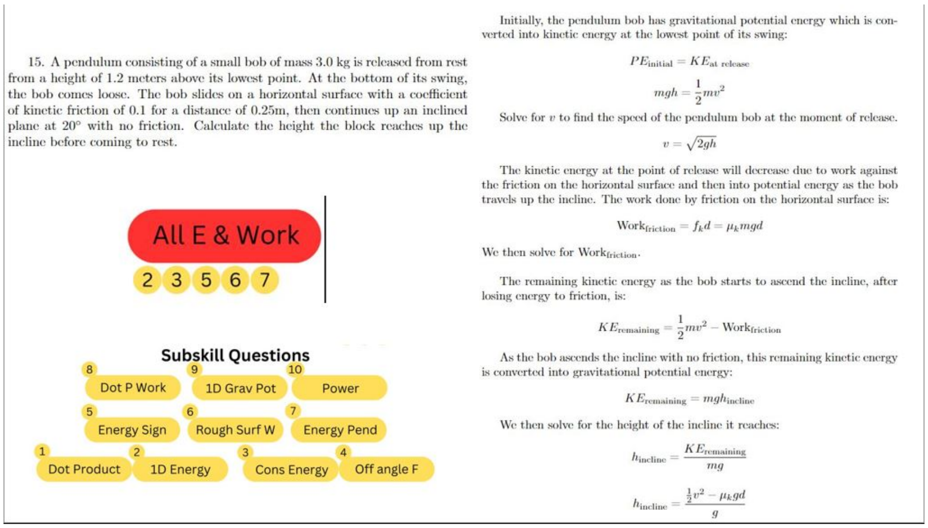

Figure 5: Question 15 from assignment, with illustration on how subskills feed into steps for solving the question

the mastery studies incorporated narrated animated solutions to the mastery sets of questions, and that would have gone beyond the limits of this study. After the calculation, the expectation is of around a 12% improvement in student test marks.

4 Conclusion

In conclusion, there is a substantial gap in literature focusing on homework improvements, especially compared to that focusing on active learning strategies in the classroom. As mentioned in the introduction, students spend three times more time studying alone than in lecture, and the meta-analysis by Freeman et al. (2014) on 225 studies showed that active learning in lectures can improve student grades by 6%. The results from this literature review show similar if not higher gains from homework transformations as well. The best practice would be to incorporate both into the pedagogy for each specific course so students benefit from their time both in lecture and out, and this study should serve as a template for future work in the area.

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APPENDIX A - Assignment

Learning Goals

Work Principle: Students will be able to apply to calculate the work done on objects by various forces, including gravitational, spring, and frictional forces.

Energy Transformation and Conservation: Students will be able to calculate the transfer of energy between kinetic and potential energy in systems and use the work energy principle.

Gravitational Potential Energy: Students will be able to understand and calculate the change in gravitational potential energy of objects in various scenarios.

Spring Potential Energy: Students will be able to calculate the potential energy stored in a spring when it is compressed or stretched from its equilibrium position.

Power: Students will be able to calculate power using the work principle, for various situations involving rate of energy transfer.

SubSkill Questions

1. **Dot Products:** Consider two vectors $\mathbf{A}$ with components $A_i = 3$ and $A_j = 4$, and $\mathbf{B}$ with components $B_i = 4$ and $B_j = -3$. Calculate the dot product $\mathbf{A} \cdot \mathbf{B}$.

2. **Work done in one-dimensional potential energy situations - Pendulum:** A pendulum bob of mass 0.5 kg is raised to a height of 0.2 m above its lowest point. Calculate the work done against gravity to raise the bob.

3. **Conservation of energy:** A mass of 1 kg slides down a frictionless inclined plane of height 2 m. Calculate its speed at the bottom of the incline.

4. **Components of forces off angle:** A force of 10 N acts at an angle of $17°$ to the horizontal. Calculate the horizontal and vertical components of this force.

5. **Signage on energy transfer/work:** A worker pushes a box with a force of 100 N horizontally, moving it 5 m to the right. Calculate the work done by the worker on the box.

6. **Moving onto rough surface and stopping:** A box slides into a rough surface with a speed of 2 m/s and stops after 4 m. Calculate the work done by friction on the box.

7. **Energy conversion in simple pendulum:** At the lowest point of its swing, a pendulum bob with mass 0.3 kg has a speed of 2 m/s. How much potential energy does it have when it is moving at 1.2 m/s?.

8. **Calculating the dot product for work:** A force $\mathbf{F} = (3\,\mathrm{i} + 4\,\mathrm{j})$ N acts on an object, displacing it by $\mathbf{d} = (8\,\mathrm{i} + 6\,\mathrm{j})$ m. Calculate the work done by the force on the object.

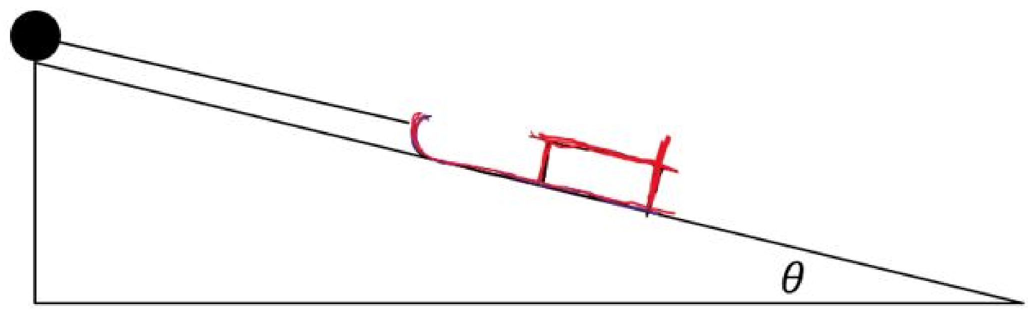
9. **Gravitational potential energy:** What is the gravitational potential of a satellite in geosynchronous orbit above the earth at an altitude of 250km?

10. **Power** A hiker with mass 70kg walks up a mountain at a constant pace, and gains 150m in elevation over the course of 10 minutes. What is the average power he is exerting while hiking?

Mastery Levels

Level 1

1. A sled of mass m is pulled up an inclined slope by a winch at a steady speed v for time t. The sled is attached to the winch by a light rope. The incline of the slope is θ and there is friction between the sled and the slope.
What is the correct equation for work done by the gravitational force on the sled?



2. A strong athlete stretches a spring an extra 27.6 cm beyond its initial length. How much energy did they transfer to the spring if the spring constant is 56.9 N/cm? Give your answer in Joules to one decimal place.

3. A meteoroid is heading straight for Earth with a speed of 16.5 km/s relative to the center of Earth as it crosses our Moon's orbit (a distance of 3.84×10^8 m from the Earth's center). What is its speed when it hits the surface of the Earth? (note: the mass of the Earth is 5.97×10^{24} kg and its radius is 6.37×10^6 m). Give your answer in km/s to 1 decimal place. You can neglect the effects of the Moon, the Earth's atmosphere, and any motion of the Earth.

4. A car needs to generate 59.2 hp of Power in order to maintain a constant velocity of 91.8 km/hr on a straight flat road. What is the magnitude of the total resistive force acting on the car (due to rolling friction, air resistance, etc.)? Give your answer in Newtons as an integer. (1 hp = 746 W).

5. In the presence of air drag, an object of mass $m = 0.096$ kg falls from height of 18.50 m to 8.50 m with the terminal speed v_T. How much work did the drag force do on the object? Give your answer in Joules to two decimal places. Sign

matters.

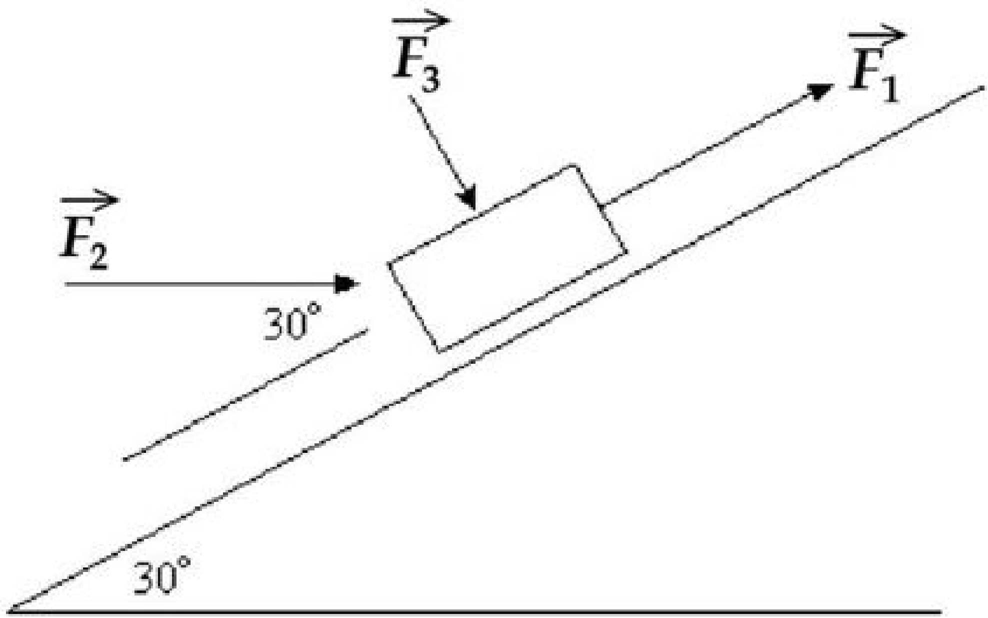
Level 2

6. It requires 50.5 J of work to stretch an ideal massless spring from $s = 1.7$ m to $s = 3.2$ m. The equilibrium position of the spring is $s = 0$ m. What is the value of the spring constant of this spring? Give your answer in N/m to 1 decimal place.

7. A car of mass 1900.0 kg accelerates from rest to 25.0 m/s in 10.0 s with negligible friction and negligible air resistance. What is the average power delivered by the engine? Give your answer in Horsepower to 1 decimal place (note: 1 hp = 746 W).

8. Consider a pebble of mass $m = 38.00$ g launched from initial height $h = 6.40$ m above the ground with speed $v = 6.50$ m/s at an angle $\theta = 42$ degrees above the horizontal. Just before the pebble hits the ground, it has a speed of $v = 10.00$ m/s. What is the Work done on the pebble by an external resistive force (e.g., air drag)? Give your answer in Joules to two decimal places. (reminder: sign is important).

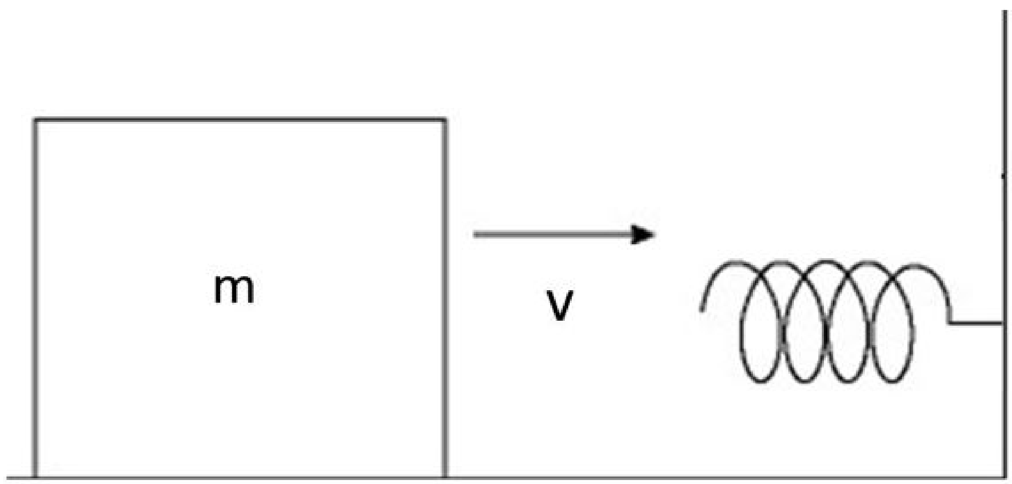
9. Three forces act on an object with a mass of 2.00 kg which can move along a frictionless inclined plane as shown in the figure. $F_1 = 32.5$ N, $F_2 = 47.5$ N, $F_3 = 10.0$ N. Acting together, the forces move the object a distance of 0.3 m along the surface of the inclined plane in the upward direction. Calculate the amount of work done by F_2. Give your answer in Joules to 1 decimal place.



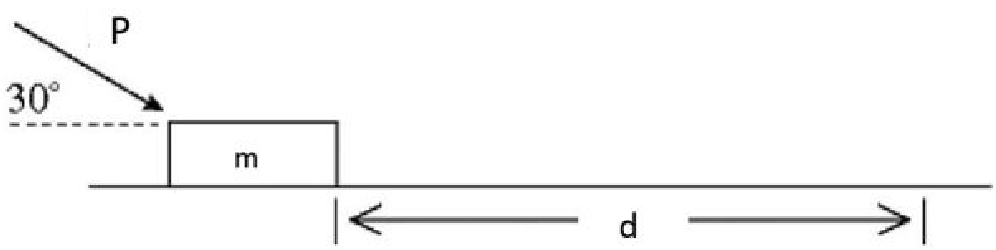
10. A block with a mass of 4.0 kg slides along a frictionless surface at a speed of 5.0 m/s and collides with a massless spring attached to a wall. The block comes to a complete stop after compressing the spring to its maximum distance of 0.25 m. Calculate the spring constant of the spring. Give your answer in N/m to one decimal place.

Level 3

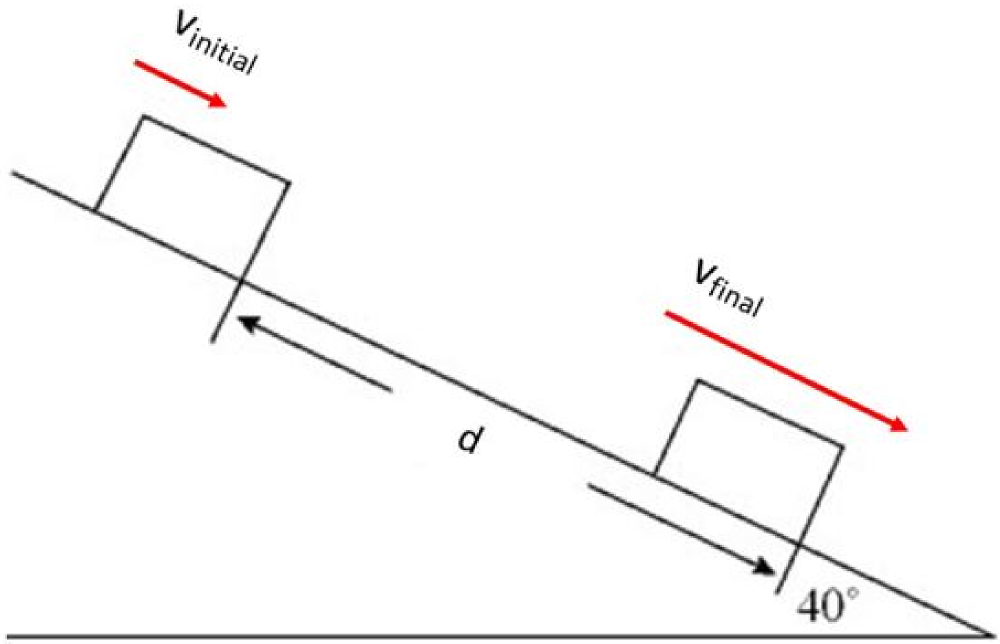
11. A block of mass 5.2 kg is moving at 9.8 m/s along a horizontal frictionless surface toward a massless spring that is attached to a wall as shown in the figure. After the block collides with the spring the spring is compressed to a maximum distance of 6.0 m. What was the speed of the block when it was still moving but the spring was compressed to only one-half of the maximum distance? Give your answer in m/s to 1 decimal place.



12. A constant external force $P = 167.5$ N is applied to a box whose mass is 18.0 kg which is on a rough horizontal surface as shown in the figure. While the force pushes the box a distance of 8.0 m, the speed changes from 0.3 m/s to 2.0 m/s. How much work is done by the force of friction during this process? Give your answer in Joules to one decimal place. (reminder: sign is important).



13. A block of mass 6.0 kg is sliding down a rough incline as shown in the figure. As the block moves a distance 1.7 m down the incline, its speed increases from 2.5 m/s to 3.4 m/s. How much work is done by the force of gravity on the block over this distance? Give your answer in Joules to one decimal place.



14. A block of mass 12.00 kg is sliding down a rough incline as shown in the figure in the previous question. As the block moves a distance 1.80 m down the incline, its speed increases from 1.50 m/s to 4.40 m/s. What is the coefficient of kinetic friction? Give your answer to two decimal places.

15. A pendulum consisting of a small bob of mass 3.0 kg is released from rest from a height of 1.2 meters above its lowest point. At the bottom of its swing, the bob comes loose. The bob slides on a horizontal surface with a coefficient of kinetic friction of 0.1 for a distance of 0.25m, then continues up an inclined plane at 20° with no friction. Calculate the height the block reaches up the incline before coming to rest.

SubSkill Solutions (hints unordered)

1. **Dot Products Solution:**

$$\mathbf{A} \cdot \mathbf{B} = A_i B_i + A_j B_j = (3)(4) + (4)(-3) = 12 - 12 = 0$$

Hints:

- Remember the formula for the dot product: $\mathbf{A} \cdot \mathbf{B} = A_i B_i + A_j B_j$.

2. **Work done in one-dimensional potential energy situations - Pendulum Solution:**

$$W = mgh = (0.5)(9.8)(0.2) = 0.981\,\text{J}$$

Hints:

- Work done against gravity is given by the change in gravitational potential energy.

3. **Conservation of energy from potential, kinetic, elastic Solution:**

$$v = \sqrt{2gh} = \sqrt{(2)(9.81)(2)} = \sqrt{39.2}\,\text{m/s}$$

Hints:

- Remember the conservation of energy: potential energy at the top converts to kinetic energy at the bottom.
- Kinetic energy formula: $\frac{1}{2}mv^2$, and potential energy formula: mgh.

4. **Components of forces off angle Solution:**

$$F_{\text{horizontal}} = F\cos(\theta) = 10\cos(17°)$$

$$F_{\text{vertical}} = F\sin(\theta) = 10\sin(17°)$$

Hints:

- Remember the unit circle, the horizontal component of an angle is given by the cosine · hypotenuse.
- Similarly, the vertical component is given by the sine · hypotenuse.

5. **Signage on energy transfer/work Solution:**

$$W = Fd = 100 \cdot 5 = 500\,\text{J}$$

Hints:

- Work formula: $W = Fd$.
- The direction of force application and displacement matters, since we denote "to the right" as positive in our coordinate basis, the movement along that direction remains positive. Since the force and displacement vectors point in that direction, the work vector does also, thus it is positive..

6. **Moving onto rough surface and stopping Solution:**

$$W_{\text{friction}} = -\Delta KE = -\left(\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2\right) = -\left(0 - \frac{1}{2}(2)(2)^2\right) = 4\,\text{J}$$

Hints:

- The work done by friction is the negative change in kinetic energy.
- Initial kinetic energy can be calculated using $\frac{1}{2}mv_i^2$ and the final kinetic energy is $\frac{1}{2}mv_f^2$.

7. **Energy conversion in simple pendulum Solution:** At the lowest point, all the energy is kinetic:

$$KE_{\text{initial}} = \frac{1}{2}mv_{\text{initial}}^2 = \frac{1}{2}(0.3)(2)^2 = 0.6\,\text{J}$$

.
When the pendulum is moving at 1.2 m/s, its kinetic energy is

$$KE = \frac{1}{2}mv^2 = \frac{1}{2}(0.3)(1.2)^2 = 0.216\,\text{J}$$

.
The difference in kinetic energy must have been converted to potential energy:

$$PE = KE_{\text{initial}} - KE = 0.6 - 0.216 = 0.384\,\text{J}$$

.
Hints:

- Calculate the initial kinetic energy at the lowest point using $KE = \frac{1}{2}mv^2$.
- Subtract the kinetic energy at 1.2 m/s from the initial kinetic energy to find the potential energy.

8. **Calculating the dot product for work Solution:** The work done by the force on the object is calculated using the dot product of the force vector and the displacement vector:

$$W = \mathbf{F} \cdot \mathbf{d} = (3\,\mathbf{i} + 4\,\mathbf{j}) \cdot (8\,\mathbf{i} + 6\,\mathbf{j}) = (3)(8) + (4)(6) = 24 + 24 = 48\,\mathbf{J}$$

Hints:

- Remember the formula for the dot product: $\mathbf{A} \cdot \mathbf{B} = A_x B_x + A_y B_y$.
- Multiply the corresponding components of the force and displacement vectors and add them to find the work done.

9. **Gravitational Potential of a Satellite in Geosynchronous Orbit Solution:** The gravitational potential V at the altitude of the satellite is calculated using the formula for gravitational potential energy per unit mass:

$$V = -\frac{GM}{r}$$

the gravitational potential V is:

$$V = -\frac{6.674 \times 10^{-11} \times 5.972 \times 10^{24}}{6.371 \times 10^{6} + 250,000} = 6.02 \times 10^{7} J$$

Hints:

- Remember the potential energy only depends on the mass of the earth, not the mass of the satellite.

10. Power

The work done by the hiker is equal to the gravitational potential energy gained, calculated as:

$$\text{Work} = mgh = (70\,\text{kg}) \times (9.8\,\text{m/s}^2) \times (150\,\text{m})$$

$$\text{Work} = 70 \times 9.8 \times 150 = 102900\,\text{Joules}$$

The average power exerted by the hiker is the work done divided by the time taken. Given the time of 10 minutes, or 600 seconds:

$$\text{Power} = \frac{\text{Work}}{\text{time}} = \frac{102900\,\text{J}}{600\,\text{s}}$$

$$\text{Power} = 171.5\,\text{Watts}$$

Hints:

- Remember that power is the rate of doing work or transferring energy, measured in Watts (W), where $1W = 1J/s$.
- Convert time into seconds when calculating power to maintain SI units.

Select Level 2 and 3 Solutions

10. Level 2

The initial kinetic energy (KE) of the block is given by $KE = \frac{1}{2}mv^2$, and the potential energy stored in the spring (PE_{spring}) at maximum compression is given by $PE_{\text{spring}} = \frac{1}{2}kx^2$, where k is the spring constant. Since $KE = PE_{\text{spring}}$ at the point of maximum compression, we can set these two expressions equal to each other and solve for k.

$$\frac{1}{2}mv^2 = \frac{1}{2}kx^2$$

$$k = \frac{mv^2}{x^2}$$

15. Level 3

Initially, the pendulum bob has gravitational potential energy which is converted into kinetic energy at the lowest point of its swing:

$$PE_{\text{initial}} = KE_{\text{at release}}$$

$$mgh = \frac{1}{2}mv^2$$

Solve for v to find the speed of the pendulum bob at the moment of release.

$$v = \sqrt{2gh}$$

The kinetic energy at the point of release will decrease due to work against the friction on the horizontal surface and then into potential energy as the bob travels up the incline. The work done by friction on the horizontal surface is:

$$\text{Work}_{\text{friction}} = f_k d = \mu_k mgd$$

We then solve for $\text{Work}_{\text{friction}}$.

The remaining kinetic energy as the bob starts to ascend the incline, after losing energy to friction, is:

$$KE_{\text{remaining}} = \frac{1}{2}mv^2 - \text{Work}_{\text{friction}}$$

As the bob ascends the incline with no friction, this remaining kinetic energy is converted into gravitational potential energy:

$$KE_{\text{remaining}} = mgh_{\text{incline}}$$

We then solve for the height of the incline it reaches:

$$h_{\text{incline}} = \frac{KE_{\text{remaining}}}{mg}$$

$$h_{\text{incline}} = \frac{\frac{1}{2}v^2 - \mu_k gd}{g}$$

APPENDIX B - Summary of findings from studies

Study Author and Year	**Main Findings**
Miller 2021	Active learning strategies and deliberate practice applied to homework in physics courses at Harvard Extension School increased exam performance over three years. Students spent roughly the same amount of time on homework.
Gladding 2015	Mastery-style online homework with narrated feedback improved post-test performance in an introductory physics course. Mastery approach led to more efficient learning and better retention of material compared to traditional homework styles.
Evans 2017	A controlled study comparing mastery-style and traditional homework in introductory physics showed that mastery-style can be beneficial for weaker students in near-transfer problems, although overall differences in performance were mixed across different trials.
Gutmann 2018	Adjustments in mastery-style homework, such as limiting attempts and modifying feedback, reduced student frustration and improved engagement and learning outcomes in an introductory physics course.
Kortemeyer 2015	In an introductory calculus-based physics course, limiting the number of attempts for each homework question to five was found to be optimal. Unlimited attempts led to poorer learning outcomes due to increased guessing behavior.
Stewart 2016	A long-term study of behavioral self-regulation in a physics course showed that students adjusted their study time based on performance and showed the average time students spent studying weekly to be 6.5hrs.
Guthrie 2020	Comparison of mastery-style and traditional homework in a junior physics course showed that structured mastery learning could enhance understanding if initial assessments were used to unlock subsequent learning content.
Cheng 2004	Online homework showed significant improvement in student learning if paired with interactive engagement methods.