Introductory Problem Set

Mechanics
Recommended time: 1 hour 30 minutes

Circa Tutors[1]

Notice for Students

How will the problem set be used? After each of the teaching days, students will be set a problem sheet based on the content covered. The problem set will provide the basis of discussions for small group teaching in the following session.
After completing the problem set, instructors will mark candidate's solutions and provide tailored feedback. The solutions will be discussed in the session so that students can clarify any points that they are unsure of.

Syllabus: The Physics PAT Syllabus has been included in grey boxes for reference. The questions have been designed to provide a comprehensive study of points in the syllabus.

Starred Questions: Some sections contain a (*) question. These questions are intended to provide a challenge and are at a higher level than the other questions.

Forces and Kinematics

> Distance, velocity, speed, acceleration, and the relationships between them, e.g. velocity as the rate of change of distance with time, acceleration as rate of change of velocity with time.
>
> Knowledge and use of equations such as speed = distance/time, acceleration = change in velocity/time or the SUVAT equations.

Kinematics (45 minutes)

1. Consider a particle that is accelerating uniformly in the x direction. Derive an expression for the displacement of an object in the n^{th} second of its motion. You should take the objects speed at $x = 0$ to be u and the acceleration to be a.
   [Hint: You should consider the 3^{rd} second of motion to be that between $t = 2$ and $t = 3$]

2. You should use your result from the previous question when answering the following question.

A particle moves 8m in its 2^{nd} second of motion and 14m in its 5^{th} second of motion. How far does the particle travel in its 9^{th} second of motion? You should assume that the particle accelerates uniformly.

3. At positions P, Q and R a particle has velocity v_P, v_Q and v_R respectively. Where $v_p, v_q, v_r > 0$. The particle starts at position P and accelerates uniformly towards point R. The distances PQ and PR are $x/3$ and x respectively as shown in figure 1. Find an expression for the particles velocity at Q in terms of v_P and v_R.

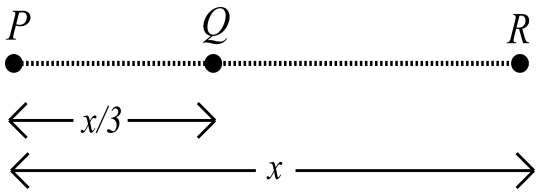

Figure 1: The particle starts at P and accelerates uniformly towards R

4. (*) Alice is sat by the side of the road next to a police car. At $t = 0$ s, the police officer inside the car spots a wanted criminal, turns on the car's sirens and accelerates from rest uniformly. The police car reaches the criminal and immediately turns off the sirens. Alice hears the siren from $t = 0$ s to $t = T$ s, after which she ceases to hear the siren.

   Find the distance d between the police cars initial position and the location of the criminal. Take the speed of sound to be c and the car's acceleration to be a.

   You should assume that the criminal is stationary, that Alice and the police car start from the same position and that this problem can therefore be treated as one dimensional.

Pulleys (45 minutes)

> Pulleys - including calculating the tension in a rope or the overall motion in a system of ropes and pulleys

1. Write brief notes on what is meant by the following:

   i) Atwood Machine

   ii) Conservation of string in the context of pulley problems

The Science Behind the PAT Course

Several highly cited academic papers show that spaced practice is much more efficient for long term retention than cramming large amounts of learning into one day. That is why our PAT courses include problem sheets that enable students to practice the skills they have learnt in the taught sessions at their own pace [Cognitive Research: Principles and Implications volume - Weinstein, Y., Madan, C.R. Sumeracki, M.A. Teaching the science of learning].

2. Find the acceleration of each of the masses and the tension in the string in the following setup. You should assume that the pulley is frictionless, that the string is massless and that the tension in the string is uniform.

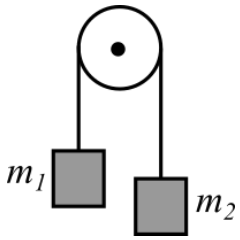

Figure 2: Pulley

3. (*) The following setup shows three masses. Find the tension in the string and the acceleration of each of the masses after the masses are released in terms of m_1, m_2, m_3 and g.

   Using your result, investigate what happens for limiting cases for the masses of m_1, m_2 and m_3. Do these results match what you expect?

   Comment on whether you would expect any vertical motion for m_3.

   You should assume that there is no friction between any of the surfaces, that the pulley is frictionless, that the string is massless, inextensible and that the tension in it is uniform

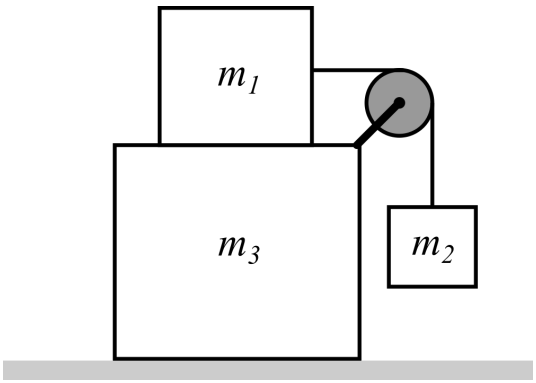

Figure 3: Pulley

Want more of these questions?

The Circa Tutors PAT course includes over 20 hours of taught sessions meaning that you will be able to practice questions on all areas of the syllabus.

The example class sheets include harder unseen questions which can be discussed with peers. This method of teaching is used at Cambridge and Oxford for the Physical Sciences as there is a large body of research showing that it is a very effective way to learn [Tullis, J.G., Goldstone, R.L. Why does peer instruction benefit student learning?].