Study Focus 4 Problems - Used in Webinar on the 24th September 2025

Warm Up Problems

1. It takes 20 minutes to fill a bath tub by running the hot water tap. It takes 15 minutes to fill the same bath tub by running the cold water tap. It takes 10 minutes to drain the bath tub by removing the plug.

   If both taps are running and the plug is removed, how long will it take to fill the bath tub?

2. Find the height of the triangle drawn in Figure 1 if $a = 9\,\text{cm}$, $b = 16\,\text{cm}$ and $c = 25\,\text{cm}$. Note: the triangle is not drawn to scale!

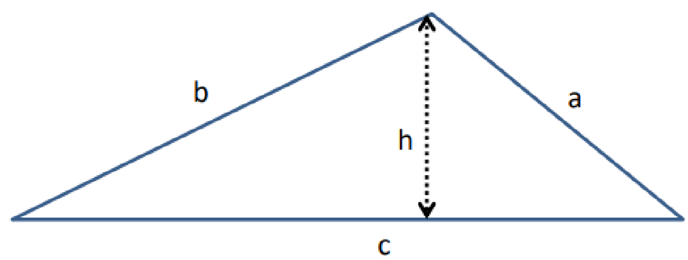

Figure 1: A triangle with lengths $a = 9\,\text{cm}$, $b = 16\,\text{cm}$ and $c = 25\,\text{cm}$.

3. A family exercise their dog in the following way:

   - The parents sit on a bench while the children walk to a rock a distance D away, calling to the dog as they walk.
   - The parents and the children alternately call the dog, who runs from one group to the other and back again.
   - The children then walk back to their parents, still calling the dog on their way back.

If the dog travels at a constant speed v_d and the children at a constant speed v_c (with $v_c < v_d$), calculate how far the dog runs in total.

4. There are 3 cards hidden under a cloth on a table. It is known that one card is white on both sides, one is black on both sides and the other is black on one side and white on the other.

   I select a card at random and its upper face is white. What are the odds that its other side is also white?

Introductory Problems

5. The faster I swing a pendulum around my head, the closer the string gets to being perfectly horizontal.

   (a) With the aid of a clear diagram, explain why this is the case.

   (b) How fast must the pendulum mass be travelling for the string to be exactly horizontal?

6. Assume that the Earth is a perfect sphere of radius 6400 km, spinning on its axis. When a person stands on some weighing scales at the North Pole, the scales read 800 N.

   We will now think about what would happen if the person were to stand on the scales at different points around the globe.

   (a) First qualitatively: if the person were to weigh themselves at the equator, would the reading on the scales be higher, lower, or the same value?

   (b) Now quantitatively: calculate the difference in the reading on the scales if the person were to weigh themselves at the equator compared to the reading at the North Pole.

   (c) What would the reading on the scales be if the person were to weigh themselves in Oxford, which has a latitude of 51.8° North?

7. The Earth is actually an oblate spheroid – that is, its equatorial diameter is larger than its North-to-South diameter.

   (a) How would this affect the person's weight at the equator and at the poles?

   (b) Suggest why the Earth is this shape.

Further Problems

8. Determine the length of a day in which a person standing on the equator would appear weightless.

9. Newton's cannon is a thought-experiment whereby a cannon ball is fired horizontally from a high mountain top at varying speeds. If the cannon ball is fired at or above some critical velocity v, the surface of the Earth will curve away faster than the ball falls back to Earth – the cannon ball would now be in orbit.

   (a) Determine the orbital velocity. You may assume its orbital radius is 6400 km and ignore air resistance.

   (b) Hence, or otherwise, determine the period of the orbit.

10. A penny dropped from the top of the Burj Khalifa (height 828 m) in Dubai (latitude 25° North) will miss a target directly below it. Why? By what distance will the penny miss the target?

Hints to Circular Motion Problems

Warm Up Problems

1. This is a very similar question to the problem about Hayley and Rob painting a house from Workbook 1, so any techniques used to tackle that question will come in handy here. In particular, a rate of flow problem such as this is very similar to combining resistors in parallel.

2. In theory, this problem could be solved by a primary school student! Do not be tricked into recognising a 3-4-5 Pythagorean triple.

3. Thinking back to the question about the pirate, ninja and parrot from Workbook 1, there is a similarly quick way to solve this – do not try to break it down into too many steps. Nothing more than GCSE Physics and clear thinking is required. Note that all the speeds are constant.

4. If you're familiar with the classic Monty Hall problem, similar thinking should help here. You may think that you have an equal chance of picking any of the three cards – this was true, but looking does more than just eliminate the black card. It may help to label each side from 1 to 6 and assign odds that way.

Introductory Problems

5. Draw a free body diagram to show the forces acting on the mass. There are only two, but you also know the direction of the resultant force.

6. (a) Recall that scales work by measuring the contact force that they provide on the person standing on them. Draw a free body diagram for the person. Consider whether or not the person is accelerating in each scenario and use Newton's laws.

(b) Remember that the centripetal force is the resultant force – it is always provided by something else.

(c) The equator is at a latitude of 0° and the North Pole is at a latitude of 90°. Have you drawn a cross-section of the Earth and included a right-angled triangle? In which direction does your weight and contact force act? Do you need an additional force? What would happen if you were on an ice-rink?

7. (a) It is helpful to know Newton's law of gravitation:

$$F = \frac{GMm}{r^2} \tag{1}$$

How does the gravitational field strength vary with distance from the centre of mass?

(b) Have you ever seen a chef making a pizza base? Similar physics is involved here.

Further Problems

8. What is the condition on the contact force that leads to the experience of weightlessness? How is the resultant force dependent on the period?

9. If there is only one force acting on an object in a circular orbit, this force must also be the centripetal force.

10. This is a synoptic question – circular motion and...what else is involved? Can you work out the difference in linear speed between the top and bottom of the building?