FOUNDATION SCIENCE A

SEMINAR 1: DESCRIBING MOTION, KINEMATICS, AND CAUSING MOTION

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LEARNING OUTCOMES

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- To understand the types of motions and their behaviours.
- To distinguish the difference between speed and velocity.
- To describe the acceleration and vector components of a given system.

QUESTION 1

You are driving home from school steadily at 95 $km \cdot h^{-1}$ for 130 km. It then begin to rain and you slow to 65 $km \cdot h^{-1}$. You arrive home after driving 3 hours and 20 minutes.

(a) How far is your hometown from school?

(b) What was your average speed?

QUESTION 1: ANSWERS

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The time for the first part of the trip is calculated from the initial speed and the first distance.

$$\overline{v_1} = \frac{\Delta x_1}{\Delta t_1} \qquad \Delta t_1 = \frac{\Delta x_1}{\overline{v_1}} = \frac{130\ \text{km}}{95\ \text{km}\cdot\text{h}^{-1}} \qquad \Delta t_1 = 1.37\ \text{h} = 82\ \text{mins}$$

The time for the second part of the trip is now calculated.

$$\Delta t_1 = \Delta t_{total} - \Delta t_1 = 3.33\ \text{h} - 1.37\ \text{h} = 1.96\ \text{h} \quad = 118\ \text{mins}$$

The distance for the second part of the trip is calculated from the average speed for that part of the trip and the time for that part of the trip.

$$\overline{v_2} = \frac{\Delta x_2}{\Delta t_2} \qquad \Delta x_2 = \overline{v_1}\ \Delta t_2 \qquad = (65\ \text{km}\cdot\text{h}^{-1})\ (1.96\ \text{h}) = 127.5\ \text{km}$$

QUESTION 1: ANSWERS

(*a*) The total distance is then

$$\Delta x_{total} = \Delta x_1 + \Delta x_2 = 130 \text{ km} + 127.5 \text{ km} = 257.5 \text{ km}$$

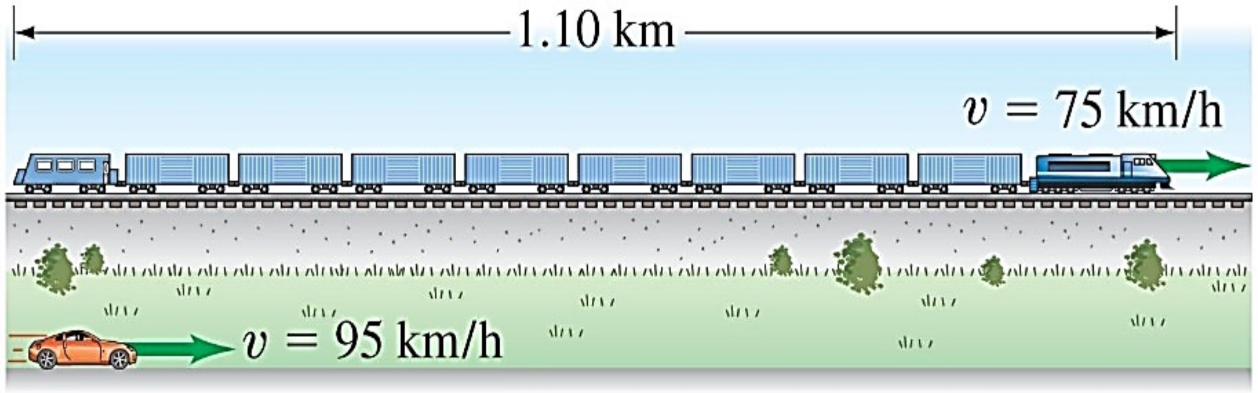
(*b*) The average speed is NOT the average of the two speeds.
Use the definition of average speed:

$$\bar{v} = \frac{\Delta x_{total}}{\Delta t_{total}} = \frac{257.5 \text{ km}}{3.33 \text{ h}} = 77 \text{ km}\cdot\text{h}^{-1}$$

QUESTION 2

An automobile traveling 95 km·h^{-1} overtakes a 1.10 km long train traveling in the same direction on a track parallel to the road. If the train's speed is 75 km·h^{-1}, how long does it take the car to pass it, and how far will the car have travelled in this time?

What are the results if the car and train are traveling in opposite directions?



QUESTION 2: ANSWERS

For the car to pass the train, the car must travel the length of the train AND the distance the car travels. The distance the car travels can thus be written as either of the following equations.

$$d_{car} = \overline{v_1}t = (95\ \text{km}\cdot\text{h}^{-1})t \qquad \text{OR} \qquad d_{car} = l_{train} + v_{train}t = 1.10\ \text{km} + (75\ \text{km}\cdot\text{h}^{-1})t$$

To solve these for time, equate EITHER of these of these expressions for the distance the car travels

$$95\ \text{km}\cdot\text{h}^{-1} = 1.10\ \text{km} + (75\ \text{km}\cdot\text{h}^{-1})t \qquad t = \frac{1.1\ \text{km}}{20\ \text{km}\cdot\text{h}^{-1}} \qquad t = 0.055\ \text{h} = 3.3\ \text{mins}$$

$$\text{d} = (95\ \text{km}\cdot\text{h}^{-1})(0.055\ \text{h}) \qquad \text{d} = 5.2\ \text{km}$$

QUESTION 2: ANSWERS

If the train is travelling in the opposite direction to the car, then the car must travel the length of the train MINUS the distance the train travels. Thus, the distance the car travels can be written as either of the following equations.

d_{car} = (95 km·h^{-1})t OR d_{car} = 1.10 km – (75 km · h^{-1})t

(95 km·h^{-1}) t = 1.10 km – (75 km·h^{-1})t

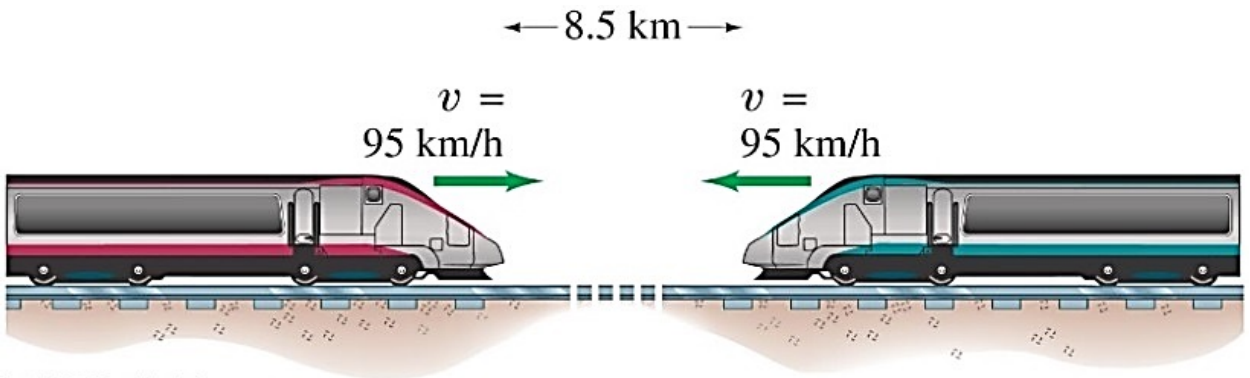
$t = \frac{1.1\ \text{km}}{170\ \text{km·h}^{-1}}$ = 6.47 x 10^{-3} h = 23.3 s

d = (95 km · h^{-1})(6.47 x 10−3 h)

d = 0.61 km

QUESTION 3

Two locomotives approach each other on parallel tracks. Each has a speed of 95 km·h^{-1} with respect to the ground. If they are initially 8.5 km apart, how long will it be before they reach each other?



QUESTION 3: ANSWERS

Since the locotomotives have the same speed, they each travel half the distance, 4.25 km. Find the time of travel from the average speed:

$$\bar{v} = \frac{\Delta x}{\Delta t}$$

$$\Delta t = \frac{\Delta x}{\bar{v}} = \frac{4.25\ \mathrm{km}}{95\ \mathrm{km{\cdot}h^{-1}}}$$

$$= 0.0447\ \mathrm{h} = 2.68\ \mathrm{mins}$$

QUESTION 4

A sports car moving at constant speed travels 110 m in 5.0 s. If it then brakes and comes to a stop in 4.0 s, what is the magnitude of its acceleration in m·s^{-2}, and in *g*'s? (*g* = 9.80 m·s^{-2})

The initial velocity of the car is the average speed of the car before it brakes (-ve acceleration).

$$\overline{v_0} = \frac{\Delta x}{\Delta t}$$

$$= \frac{110\ m}{5.0\ s}$$

$$= 22\ \text{m·s}^{-1}$$

QUESTION 4: ANSWERS

The final speed is $v = 0$ m·s^{-1}, and the time to stop is 4.0 s.

$$v = v_0 + at$$

$$a = \frac{v - v_0}{t} = \frac{0 - 22\ \mathrm{m{\cdot}s^{-1}}}{4.0\ s} = -5.5\ \mathrm{m{\cdot}s^{-2}}$$

Thus the magnitude of the acceleration is -5.5 m·s^{-2} or

$$g = \frac{(-5.5\ \mathrm{m{\cdot}s^{-2}})(1g)}{9.80\ \mathrm{m{\cdot}s^{-2}}} = -0.56\ g$$

QUESTION 5

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A light plane must reach a speed of 32 m·s^{-1} for takeoff.

How long a runway is needed if the (constant) acceleration is 3.0 m·s^{-2}?

Assume that the plane starts from rest. The runway distance is found by $x - x_0$.

Thus,

$$v^2 = v_0^2 + 2a(x - x_0)$$

$$x - x_0 = \frac{v^2 - v_0^2}{2a} = \frac{32 - 0 \text{ m}^2 \cdot \text{s}^{-2}}{2(3.0 \text{ m} \cdot \text{s}^{-2})} = 1.7 \times 10^2 \text{ m}$$

QUESTION 6

An inattentive driver is traveling 18.0 m·s^{-1} when they notices a red light ahead. The car is capable of decelerating at a rate of 3.65 m·s^{-2}.

If it takes the driver 0.200 s to get the brakes on and the car is 20.0 m from the intersection when the driver sees the light, will the driver be able to stop in time?

Calculate the distance that the car travels during the reaction time and the deceleration.

$$\Delta x_1 = v_0 \Delta t = (18.0\ \text{m·s}^{-1})(0.200\ \text{s}) = 3.6\ \text{m}$$

$$v^2 = v_0^2 + 2a\Delta x_2$$

$$\Delta x_2 = \frac{v^2 - v_0^2}{2a} = \frac{(0 - 18\ \mathrm{m \cdot s^{-1}})^2}{2(-3.65\ \mathrm{m \cdot s^{-2}})} = 44.4\ \mathrm{m}$$

Therefore,
the driver **will NOT be able to stop in time.**

QUESTION 7

A stone is dropped from the top of a cliff. It is seen to hit the ground below after 3.75 s.

How high is the cliff?

Choose downwards to be the +ve direction, and take $y_0 = 0\ \mathrm{m}$ to be the top of the cliff. The initial velocity $v_0 = 0\ \mathrm{m} \cdot \mathrm{s}^{-1}$ and the acceleration, a = 9.80 $\mathrm{m{\cdot}s^{-2}}$

$$y = y_0 + v_o t + \frac{1}{2} a t^2$$

$$y - 0 = 0 + \frac{1}{2}(9.80\ \mathrm{m} \cdot \mathrm{s}^{-2})(3.75\ \mathrm{s})^2$$

$$y = 68.9\ \mathrm{m}$$

QUESTION 8

A ball player catches a ball 3.2 s after throwing it vertically upward.

With what speed did he throw it, and what height did it reach?

Choose upwards to be the +ve direction, and take $y_0 = 0\ \mathrm{m}$ to be the height from which the ball is thrown. The acceleration, -a, = -9.80 m · s^{-2} . The displacement upon catching the ball is zero, assuming it was caught at the same height from which it was thrown. The initial velocity can be calculated as follows:

$$y = y_0 + v_o t + \frac{1}{2} a t^2$$

$$v_o = \frac{y - y_0 - \frac{1}{2} a t^2}{t} = -\frac{1}{2} a t^2 = -\frac{1}{2}(-9.80\ \mathrm{m \cdot s^{-2}})(3.2\ \mathrm{s}) = 15.68\ \mathrm{m \cdot s^{-1}}$$

QUESTION 8:

With a final velocity of v = 0 m · s^{-1} at the top of the path, the height can be calculated as:

$$v^2 = v_0{}^2 + 2a(\mathrm{y} - \mathrm{y}_0)$$

$$y = y_0 + \frac{v^2 - v_0{}^2}{2a}$$

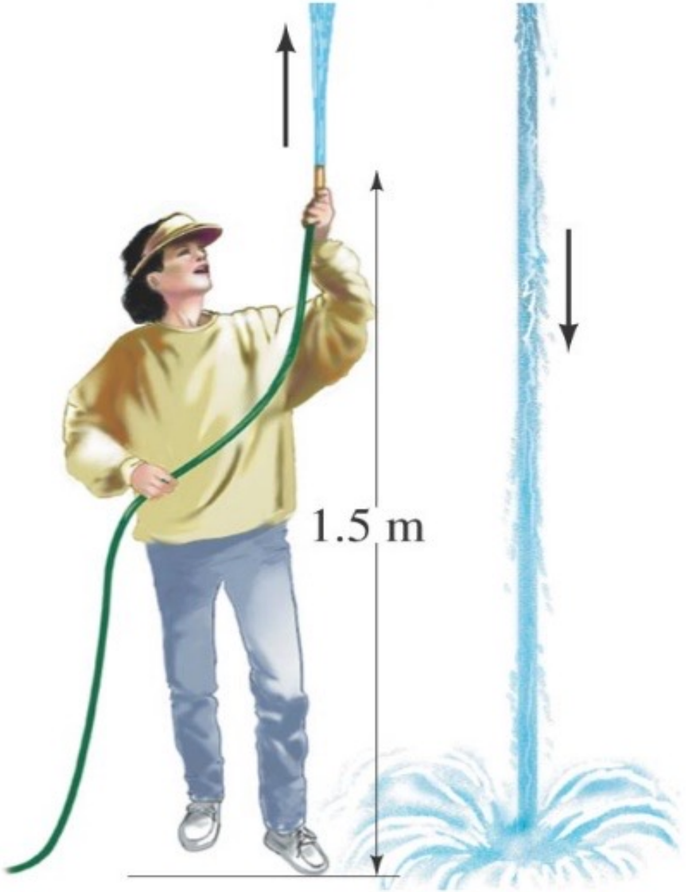
$$= \frac{(0 - 15.68\ \mathrm{m \cdot s^{-1}})^2}{2(-9.80\ \mathrm{m \cdot s^{-2}})}$$

$$y = 12.54\ \mathrm{m}$$

QUESTION 9

Suppose you adjust your garden hose nozzle for a hard stream of water. You point the nozzle vertically upward at a height of 1.5 m above the ground. When you quickly turn off the nozzle, you hear the water striking the ground next to you for another 2.0 s.

What is the water speed as it leaves the nozzle?



QUESTION 9: ANSWERS

Choose upward to be the +ve direction, and y_0 = 0 m to be the location of the nozzle. The initial velocity = v_0 , the acceleration is a = -9.8 m.s^{-2}, the final location is y = -1.5 m, and the time of flight is t = 2.0 s.

$$y = y_0 + v_o t + \frac{1}{2} at^2$$

$$v_o = \frac{y - y_0 - \frac{1}{2} at^2}{t}$$

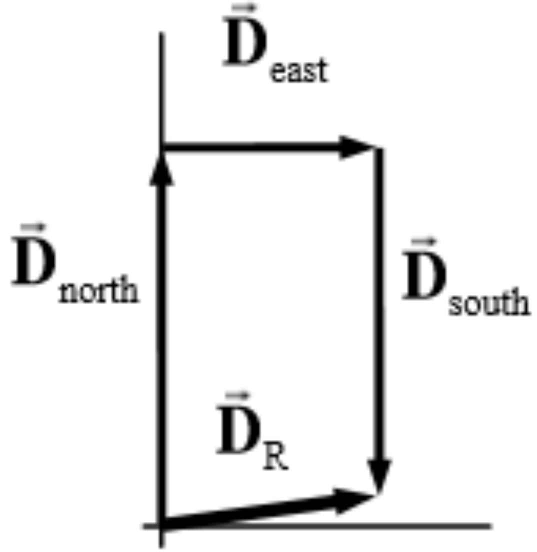
$$v_o = \frac{-1.5\ \mathrm{m} - \frac{1}{2}\left(-9.80\ \mathrm{m{\cdot}s^{-1}}\right)(2.0\ \mathrm{m})^2}{2.0\ \mathrm{s}}$$

v_o = 9.1 m · s^{-1}

QUESTION 10

A delivery truck travels 28 blocks North, 16 blocks East, and 26 blocks South. Assuming the blocks are of equal length, what is its final displacement from the origin?

The truck has a displacement of $\mathbf{28 + (-26) = 2}$ blocks North and 16 blocks East.



The resultant vector has the magnitude of:

$$\sqrt{2^2 + 16^2} = 16.1 \text{ blocks}$$

The resultant vector has the direction of:

$\tan^{-1} = 2/16 = 7°$ North of East

QUESTION 11

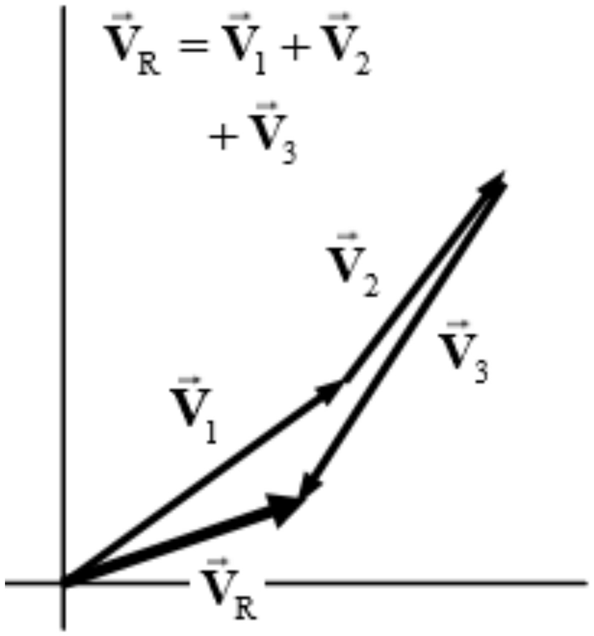
Graphically determine the resultant of the following three vector displacements:

(1) 24 m, 36° North of East;

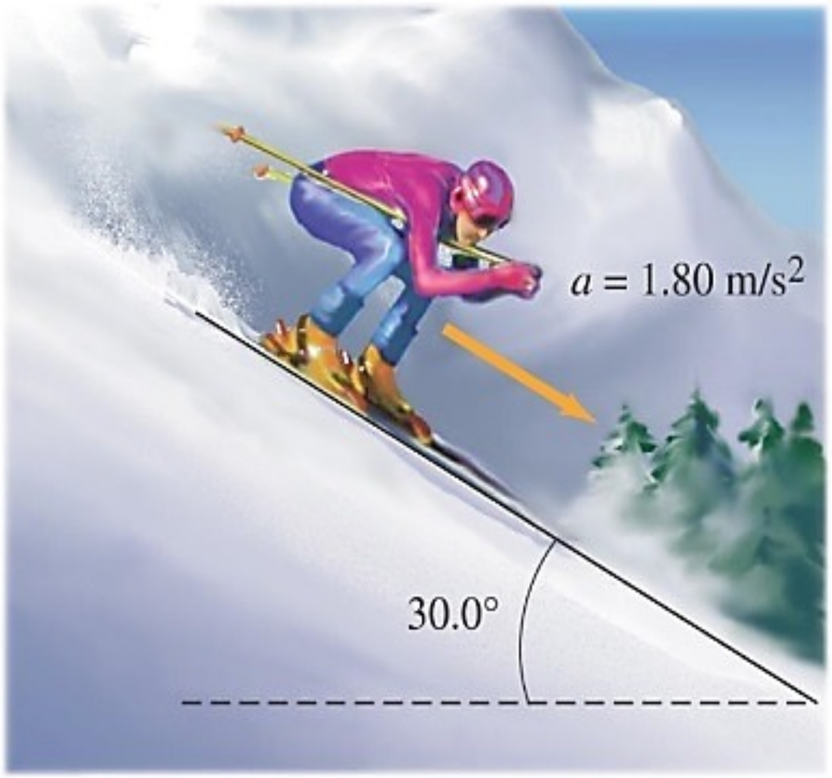
(2) 18 m, 37° East of North; and

(3) 26 m, 33° West of South.

The vectors for this question are drawn approximately to scale.
The resultant length has a length of 17.5 m and a direction of 19° North of East.
If the calculations are done, the actual resultant should be 17 m at 23° North of East.



QUESTION 12



(a) **A skier is accelerating down a 30.0° hill at 1.80 $m.s^{-2}$ What is the vertical component of their acceleration?**

(b) **How long will it take the skier to reach the bottom of the hill, assuming they starts from rest and accelerates uniformly, with an elevation change is 325 m?**

QUESTION 12: ANSWERS

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Choose downward to be the +ve direction, and the skier's acceleration is directed along the slope.

(a) The vertical component of acceleration is directed downward, and it's magnitude will be given by

$$a_y = a\sin\theta \quad = (1.80\ \mathrm{m}\cdot\mathrm{s}^{-2})(\sin 30°\ ) = 0.90\ \mathrm{m}\cdot\mathrm{s}^{-2}$$

(b) The time to reach the bottom of the hill is calculated as follows

$$y = y_0 + v_{yo}t + \frac{1}{2}a_y t^2 \qquad 325\ \mathrm{m} = 0 + 0 + \frac{1}{2}(0.90\ \mathrm{m}\cdot\mathrm{s}^{-2})(t)^2$$

$$t = \sqrt{\frac{2(325\ \mathrm{m})}{0.90\ \mathrm{m}\cdot\mathrm{s}^{-2}}} \qquad t = 26.9\ \mathrm{s}$$

DROP-IN SESSION FOR Q&A: