



Physics. *You work it out.*

Crossing Paths

A Level

Further A

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A person is walking northwards with velocity $\underline{v} = 1.0\hat{j} \text{ m s}^{-1}$ from a point $\underline{r} = 500\hat{i} \text{ m}$. At the same time a second person starts walking from a point $\underline{s} = -500\hat{i} + 500\hat{j} \text{ m}$ with velocity $\underline{u} = 1.0\hat{i} + u_y\hat{j} \text{ m s}^{-1}$.

Part A

Time Taken

Find the time T in seconds that passes between the walkers setting off, and their paths crossing.

Part B

Required Speed

Find the speed u_y required for the two people to meet.

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Vector Equations of Motion 2

A Level



In one dimension, motion with constant acceleration is modelled with the *suvat* equations. There are analogous vector equations for motion with constant acceleration in two or three dimensions:

$$\underline{v} = \underline{u} + \underline{a}t \qquad \underline{s} = \frac{1}{2}(\underline{u} + \underline{v})t \qquad \underline{s} = \underline{u}t + \frac{1}{2}\underline{a}t^2$$

In these equations the acceleration is \underline{a} and the time over which the acceleration takes place is t . The initial velocity is \underline{u} , the final velocity is \underline{v} , and \underline{s} is the change in displacement during the period of acceleration.

(The equivalent expression to $v^2 = u^2 + 2as$ involves the scalar product and is not needed in this question.)

Part A Find an expression for velocity

A particle moves in the x - y plane with the constant acceleration $\begin{pmatrix} 4 \\ 2 \end{pmatrix} \text{ m s}^{-2}$. Find an expression for the velocity of the particle after t s given that it has velocity $\begin{pmatrix} -19 \\ -10 \end{pmatrix} \text{ m s}^{-1}$ initially.

Give an expression for the x component of the velocity.

The following symbols may be useful: t

Give an expression for the y component of the velocity.

The following symbols may be useful: t

Part B Find a position

A horse is running in a large, flat, rectangular field. The field is modelled using the x - y plane, with the origin at one corner. When the horse is at the position $\underline{p} = 50\underline{i} + 70\underline{j}$ relative to the origin it is moving with a velocity of $\begin{pmatrix} 12 \\ -6 \end{pmatrix} \text{ m s}^{-1}$. The horse slows down with a deceleration of $\begin{pmatrix} 4 \\ -2 \end{pmatrix} \text{ m s}^{-2}$.

What is the position of the horse relative to the origin after 3 seconds?

Give your answer in the form $a\underline{i} + b\underline{j}$.

The following symbols may be useful: \underline{i} , \underline{j}

Part C Find a value of t

At time $t = 0 \text{ s}$ a particle is at the origin, moving with a velocity \underline{u}_1 . The particle accelerates for 4 s with acceleration $\begin{pmatrix} 10 \\ 16 \end{pmatrix} \text{ m s}^{-2}$. When $t = 4 \text{ s}$, the particle has a displacement of $\begin{pmatrix} 240 \\ 384 \end{pmatrix} \text{ m}$ from the origin.

Suppose instead that the particle starts at the origin at time $t = 0 \text{ s}$ moving with the velocity $-\underline{u}_1$. If the particle accelerates with acceleration $\begin{pmatrix} 10 \\ 16 \end{pmatrix} \text{ m s}^{-2}$ it will still arrive at the point $\begin{pmatrix} 240 \\ 384 \end{pmatrix} \text{ m}$. At what time t does this occur?

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Vectors & Calculus 2i

A Level



A projectile has velocity $\begin{pmatrix} A \\ 5 - gt \end{pmatrix} \text{ m s}^{-1}$.

Part A Displacement

Given that the particle is at $\begin{pmatrix} 5 \\ 10 \end{pmatrix}$ when $t = 0$.

Find an expression for the x -component of the particle's displacement, in metres, as a function of t .

The following symbols may be useful: A , g , t

Find an expression for the y -component of the particle's displacement, in metres, as a function of t .

The following symbols may be useful: A , g , t

Part B Force

Find an expression for the force on the particle, given that it has mass m kg. Give your answer in the form $a\mathbf{i} + b\mathbf{j}$ where \mathbf{i} and \mathbf{j} are unit vectors in the x and y directions respectively.

The following symbols may be useful: A , g , \mathbf{i} , \mathbf{j} , m

Part C **Value of A**

The projectile hits a target at the coordinates $\begin{pmatrix} 20 \\ 0 \end{pmatrix}$.

What is the value of A ? Give your answer to 2 significant figures. In your calculation, use the approximation $g \simeq 10 \text{ m s}^{-2}$ and assume that the target is hit at $t > 0$.

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Gameboard:

STEM SMART Single Maths Week 41 - Further Kinematics

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Vectors & Calculus 1i

A Level



A planet moves through space. The force on the planet is given by

$$\underline{\boldsymbol{F}} = \begin{pmatrix} -mAB^2 \cos Bt \\ -mAB^2 \sin Bt \end{pmatrix}$$

where A and B are numerical constants and m is the mass of the planet.

Part A Velocity

Given that the velocity of the planet when $t = 0$ is $\begin{pmatrix} 0 \\ AB \end{pmatrix}$.

Find an expression for the x -component of the velocity of the planet as a function of time.

The following symbols may be useful: A , B , $\cos()$, $\sin()$, t , $\tan()$

Find an expression for the y -component of the velocity of the planet as a function of time.

The following symbols may be useful: A , B , $\cos()$, $\sin()$, t , $\tan()$

Part B Displacement

Given that the displacement of the planet when $t = 0$ is $\begin{pmatrix} A \\ 0 \end{pmatrix}$.

Find an expression for the x -component of the displacement of the planet as a function of time.

The following symbols may be useful: A , B , $\cos()$, $\sin()$, t , $\tan()$

Find an expression for the y -component of the displacement of the planet as a function of time.

The following symbols may be useful: A , B , $\cos()$, $\sin()$, t , $\tan()$

Part C Modulus

Find an expression for the modulus of the displacement. Simplify your answer as far as possible.

The following symbols may be useful: A , B , $\cos()$, $\sin()$, t , $\tan()$

Part D Shape of path

What is the shape of the path that the planet follows?

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Particles Moving on a Surface

A Level



A particle Q of mass 0.2 kg is projected horizontally with velocity 4 m s^{-1} from a fixed point A on a smooth horizontal surface. At time $t \text{ s}$ after projection Q is $x \text{ m}$ from A and is moving away from A with velocity $v \text{ m s}^{-1}$. There is a force of $3 \cos 2t \text{ N}$ acting on Q in the positive x -direction.

Part A Expression for velocity

Find an expression for the velocity of Q at time t .

The following symbols may be useful: $\cos()$, $\sin()$, t , $\tan()$, v

Part B Maximum and minimum

State the maximum value of the velocity of Q as t varies. Give your answer to 3 significant figures.

State the minimum value of the velocity of Q as t varies. Give your answer to 2 significant figures.

Part C Average velocity

Find the average velocity of Q between the times $t = \pi$ and $t = \frac{3}{2}\pi$. Give your answer to 3 significant figures.

Part D Particle's velocity

A particle P moves in a plane. Its displacement from the starting point, \underline{R} , varies with time, t , as follows:

$$\underline{R} = \begin{pmatrix} 2t^2 \sin \pi t - 1 \\ 1 + t^3 \end{pmatrix}$$

Where displacement is measured in metres and time is measured in seconds.

What is the x -component of the particle's velocity?

The following symbols may be useful: `cos()`, `pi`, `sin()`, `t`, `tan()`

What is the y -component of the particle's velocity?

The following symbols may be useful: `cos()`, `pi`, `sin()`, `t`, `tan()`

Part E Speed of particle

Find the speed of the particle when $t = 2$. Give your answer to 3 significant figures.

Gameboard:

STEM SMART Double Maths 23 - Vector Equations of Motion

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Vector Equations of Motion 1

A Level



This question looks at three different uses of calculus in vector problems.

Part A Integrating to find particle displacement

A particle moves in the x - y plane with velocity $\underline{v} = \begin{pmatrix} 2te^{-2t^2} \\ 3te^{-4t^2} \end{pmatrix}$. Find an expression for the displacement of the particle at time t , given that the particle is at the origin when $t = 0$.

Enter an expression for the x component of the displacement.

The following symbols may be useful: e , t

Enter an expression for the y component of the displacement.

The following symbols may be useful: t

Part B Finding a maximum speed

At a time t s a particle moves in the x - y plane with velocity $\underline{v} = \begin{pmatrix} 2te^{-2t^2} \\ 3 \end{pmatrix} \text{ m s}^{-1}$. What is the maximum speed of the particle? Give your answer as an expression in terms of e .

The following symbols may be useful: e

Part C **Distance of closest approach to the origin**

The displacement of a particle is given by the expression $\underline{s} = \begin{pmatrix} e^{3t} \\ e^{6t} - 5 \end{pmatrix}$. Find the shortest distance between the particle and the origin during the particle's motion. Give your answer in the form $\frac{\sqrt{a}}{2}$.

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