**Question 1: Linear Acceleration**

Please remember to photocopy 4 pages onto one sheet by going A3→A4 and using back to back on the photocopier

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**Acceleration is the rate of change of velocity with respect to time\*.**

The unit of acceleration is the metre per second squared (m s-2, or m/s2 ).

**Equations of Motion\***

When an object (with ***initial velocity u***) moves in a straight line with ***constant acceleration a***, its ***displacement s*** from its starting point, and its ***final velocity v***, change with ***time t***.

Note that both **v** and **u** are instantaneous velocities.

The following equations tell us how these quantities are related:

v = final velocity

**v = u + at**

**s = ut + ½ at2**

**v2 = u2 + 2as**

u = initial velocity

a = acceleration

s= displacement (not distance)

t = time

**Procedure for solving problems using equations of motion.**

1. Write down v, u, a, s and t underneath each other on the left hand side of the page, filling in the quantities you know, and put a question mark beside the quantity you are looking for.
2. Write down the three equations of motion every time.
3. Decide which of the three equations has only one unknown in it.
4. Substitute in the known values in to this equation and solve to find the unknown.

**Velocity – Time graphs** (for an object travelling with constant acceleration)

If a graph is drawn of Velocity (y-axis) against Time (x-axis), the slope of the graph is the acceleration of the object.

**Note that the area under each section of the graph corresponds to the distance travelled in that section**

**Introduction – Questions taken from Leaving Cert Physics Exam Papers**

1. [2005 OL]

A car accelerates from 10 m s−1 to 30 m s−1 in 5 seconds. What is its acceleration?

1. [2002 OL]

An aircraft was travelling at a speed of 60 m s-1 when it landed on a runway. It took two minutes to stop. Calculate the acceleration of the aircraft while coming to a stop.

1. [2004 OL]

A cheetah can go from rest up to a velocity of 28 m s−1 in just 4 seconds and stay running at this velocity for a further 10 seconds.

1. Sketch a velocity−time graph to show the variation of velocity with time for the cheetah during these 14 seconds.
2. Calculate the acceleration of the cheetah during the first 4 seconds.
3. [2008 OL]

A speedboat starts from rest and reaches a velocity of 20 m s−1 in 10 seconds.

It continues at this velocity for a further 5 seconds.

The speedboat then comes to a stop in the next 4 seconds.

1. Draw a velocity-time graph to show the variation of velocity of the boat during its journey.
2. Use your graph to estimate the velocity of the speedboat after 6 seconds.
3. Calculate the acceleration of the boat during the first 10 seconds.
4. What was the distance travelled by the boat when it was moving at a constant velocity?
5. [2007]

A car is travelling at a velocity of 25 m s-1 when the engine is then turned off; calculate how far the car will travel before coming to rest if the deceleration is 1.47 ms-2?

1. [2009]

A skateboarder starts from rest at the top of a ramp and accelerates down it. The ramp is 25 m long and the skateboarder has a velocity of 12.2 m s–1 at the bottom of the ramp.

Calculate the average acceleration of the skateboarder on the ramp.

1. [2009 OL]

A train started from a station and accelerated at 0.5 m s−2 to reach its top speed of 50 m s−1 and maintained this speed for 90 minutes.

As the train approached the next station the driver applied the brakes uniformly to bring the train to a stop in a distance of 500 m.

1. Calculate how long it took the train to reach its top speed.
2. Calculate how far it travelled at its top speed.
3. Calculate the acceleration experienced by the train when the brakes were applied.

**Solutions**

1. v = u + at ⇒ a = ( v – u ) ÷ t ⇒ a = (30 – 10) ÷ 5 ⇒ a = 4 m s-2.
2. v = u + at  0 = 60 + a (120)  a = - 0.5 m s-2
3. See diagram
4. v = u + at ⇒ 28 = 0 + a (4) ⇒ a = 7 m s-2
5. 
6. 12 m s-1.
7. v = u + at but u = 0  a = v/t = 20/10 = 2 m s-2.
8. v = s/t  s = vt = 20 × 5 = 100 m
9. v 2 = u 2 + 2as

0 = 25 +2(-1.47) s or s = 213 m

1. v2= u2 + 2as ⇒ (12.2)2 = 0 +2a(25)

a = 2.98 m s–2

1. v = u + at

50 = 0 + 0.5t

t = 50/0.5 = 100 s

1. s = ut + ½ at2 (but a = 0)

s = 50 × (90×60) = 270000 m

1. v2 = u2 + 2as

0 = 502 + 2a(500)

a = −2500/1000 = − 2.5 m s-1

 **Exam Questions Ordinary Level – Worked Solutions**

**2009 OL**

3 points *p*, *q* and *r* lie on a straight level road.

Two cars, A and B, are moving towards each other on the road.

Car A passes *p* with speed 3 m/s and uniform acceleration of 2 m/s2 and at the same instant car B passes *r* with speed 5 m/s and uniform acceleration of 4 m/s2.

A and B pass each other at *q* seven seconds later.

Find

1. the speed of car A and the speed of car B at *q*.
2. |*pq*| and |*rq*|, the distances A and B have moved in these 7 s.
3. Car A stops accelerating at *q* and continues on to *r* at uniform speed.

Find, correct to one place of decimals, the total time for car A to travel from *p* to *r*.

**Solution**

1. v = u + at

vA = 3 + 2(7)

vA =17 m/s

v = u + at

vB = 5 + 4(7)

vB =33 m/s

1. s = ut + ½ at2

sA = 3(7) + ½ 2(49)

sA =70 m

s = ut + ½ at2

sB = 5(7) + ½ 4(49)

sB =133 m

1. s = ut + ½ at2

133 = 17(t) + 0

t = 7.8 s

total time = 14.8 s

**2008 OL**

Four points *a*, *b*, *c* and *d* lie on a straight level road.

A car, travelling with uniform retardation, passes point *a* with a speed of 30 m/s and passes point *b* with a speed of 20 m/s.

The distance from *a* to *b* is 100 m. The car comes to rest at *d*.

Find

1. the uniform retardation of the car
2. the time taken to travel from *a* to *b*
3. the distance from *b* to *d*
4. the speed of the car at *c*, where *c* is the midpoint of [*bd*].

**Solution**

1. v2 = u2 + 2as

202 = 302 + 2(a)(100)

-500 = 200 a

a = - 2.5 m s-2

1. v = u + at

20 = 30 – 2.5 t

T = 4 s

1. v2 = u2 + 2as

02 = 202 + 2(-2.5)(s)

s = 80 m

1. v2 = u2 + 2as

 = 202 + 2(-2.5)(40)

 = 200

v = 10√ or 14.1 m s-1

**2007 OL**

A car travels from *p* to *q* along a straight level road.

It starts from rest at *p* and accelerates uniformly for 5 seconds to a speed of 15 m/s.

It then moves at a constant speed of 15 m/s for 20 seconds.

Finally the car decelerates uniformly from 15 m/s to rest at *q* in 3 seconds.

1. Draw a speed-time graph of the motion of the car from *p* to *q*.
2. Find the uniform acceleration of the car.
3. Find the uniform deceleration of the car.
4. Find |*pq*|, the distance from *p* to *q*.
5. Find the speed of the car when it is 13.5 metres from *p*.

**Solution**

1. 
2. v = u + at

15 = 0 + 5 a

a = 3 m s-2

1. v = u + at

0 = 15 + 3a

a = - 5

deceleration is 5 m s-2

1. distance = ½ (5)(15) + (20)(15) + ½ (3)(15)

= 37.5 + 300 + 22.5

= 360 m

1. v2 = u2 + 2as

 = 0+ 2(3)(13.5)

 = 81 m

v = 9 m s-1

**2010 OL**

A car travels along a straight level road.

It passes a point *P* at a speed of 12 m s-1 and accelerates uniformly for 6 seconds to a speed of 30 m s-1.

It then travels at a constant speed of 30 m s-1 for 15 seconds.

Finally the car decelerates uniformly from 30 m s-1 to rest at a point *Q*.

The car travels 45 metres while decelerating.

Find

1. the acceleration
2. the deceleration
3. |PQ|, the distance from P to Q
4. the average speed of the car as it travels from P to Q.

**2006 OL**

A car travels along a straight level road.

It passes a point *p* at a speed of 10 m/s and accelerates uniformly for 5 seconds to a speed of 30 m/s.

It then moves at a constant speed of 30 m/s for 9 seconds.

Finally the car decelerates uniformly from 30 m/s to rest at point *q* in 6 seconds.

Find

1. the acceleration
2. the deceleration
3. *pq* , the distance from *p* to *q*
4. the average speed of the car as it travels from *p* to *q*.

**2005 OL**

A particle travels from *p* to *q* in a straight line. It starts from rest at *p* and accelerates uniformly to its maximum speed of 20 m/s in 10 seconds. The particle maintains this speed of 20 m/s for 15 seconds before decelerating uniformly to rest at *q* in a further 20 seconds.

1. Draw a speed-time graph of the motion of the particle from *p* to *q*.
2. Find the uniform acceleration of the particle.
3. Find the uniform deceleration of the particle.
4. Find ⏐*pq*⏐, the distance from *p* to *q*.
5. Find the average speed of the particle as it moves from *p* to *q,* giving your answer in the form a/b where *a*, *b* ∈ N.

**2004 OL**

Three points a, b and c, lie on a straight level road such that ⏐ab⏐=⏐bc⏐= 100 m.

A car, travelling with uniform retardation, passes point a with a speed of 20 m/s and passes point b with a speed of 15 m/s.

1. Find the uniform retardation of the car.
2. Find the time it takes the car to travel from a to b, giving your answer as a fraction.
3. Find the speed of the car as it passes c, giving your answer in the form p q , where p, q ∈ **N**.
4. How much further, after passing c, will the car travel before coming to rest?

Give your answer to the nearest metre.

**2003 OL**

A car travels from p to q on a straight level road. It passes p with a speed of 4 m/s and accelerates uniformly to its maximum speed of 8 m/s in 4 seconds. The car maintains this speed of 8 m/s for 6 seconds before decelerating uniformly to rest at q.

The car takes 12 seconds to travel from p to q.

1. Draw a speed-time graph of the motion of the car from p to q.
2. Find the uniform acceleration of the car.
3. Find the uniform deceleration of the car.
4. Find ⏐pq⏐, the distance from p to q.
5. Another car travels the same distance from p to q in the same time of 12 seconds.

This car starts from rest at p and accelerates uniformly to its maximum speed of v m/s and then immediately decelerates uniformly to rest at q.

Find v, the maximum speed of this car, giving your answer as a fraction.

**2002 OL**

A train stops at stations P and Q which are 2000 metres apart.

The train accelerates uniformly from rest at P, reaching a speed of 20 m/s in 10 seconds.

The train maintains this speed of 20 m/s before decelerating uniformly at 0.5 m/s2 , coming to rest at Q.

1. Find the acceleration of the train.
2. Find the time for which the train is decelerating.
3. Find the distance and the time for which the train is travelling at constant speed.
4. Draw an accurate speed-time graph of the motion of the train from P to Q.

**2001 OL**

Two points, p and q, lie on a straight stretch of level road.

Car A passes the point p with a speed of 2 m/s travelling towards q and accelerating uniformly at 2 m/s2.

As car A passes p, car B passes the point q with a speed of 1 m/s travelling towards p and accelerating uniformly at 3 m/s2 .

The two cars meet after 10 seconds.

1. Find the speed of each car when they meet.
2. Find the distance each car has travelled during these 10 seconds.
3. Suppose now that the speed of car A when passing point p is u m/s instead of 2 m/s, while the speed of car B passing point q and the acceleration of each car remain unchanged.

If the time taken for the two cars to meet in this case is 8 seconds, find the value of u.

**2000 OL**

A car is travelling on a straight stretch of level road [ *pq* ]. The car passes the point *p* with a speed of 5 m/s and accelerates uniformly to its maximum speed of 20 m/s in a time of

6 seconds. The car continues with this maximum speed for 30 seconds before decelerating uniformly to rest at *q* in a further 4 seconds.

1. Draw a speed-time graph of the motion of the car from *p* to *q*.

Hence, or otherwise, find

1. the uniform acceleration of the car
2. the uniform deceleration of the car
3. | *pq* | , the distance from *p* to *q* .
4. Another car, with acceleration and deceleration the same as in **(i)** and **(ii)** above, starts from rest at *p* and accelerates uniformly to its maximum speed of 25 m/s. It continues with this maximum speed for a certain time and then decelerates uniformly to rest at *q*.

How long does it take this car to go from *p* to *q*?

**Answers to Ordinary Level Exam Questions**

**2010**

1. a = 3 m s-2
2. a = -10 m s-2
3. ⏐PQ⏐ = 621 m
4. Average speed = 25.875 m s-1

**2009**

1. VA = 17 m s-1, VB = 33 m s-1
2. SA = 70 m, SB = 133 m
3. t = 14.8 s

**2008**

1. Retardation = 2.5 m s-2
2. t = 4 s
3. s = 80 m
4. v = 14.1 m s-1

**2007**

1. a = 3 m s-2
2. a = - 5 m s-2
3. s = 360 m
4. v = 9 m s-1

**2006**

1. Acceleration = 4 m s-2
2. Deceleration = 5 m s-2
3. Distance = 460 m
4. Average speed = 23 m s-1

**2005**

1. a = 2 m s-2
2. Deceleration = 1 m s-2
3. s = 600 m
4. average speed = 40/3 m s-1

**2004**

1. Retardation = - 0.875 m s-2
2. t = 40/7 s
3. v = 5√2 m s-1
4. s = 29 m

**2003**

1. a = 1 m s-2
2. a = -4 m s-2
3. s = 80 m
4. v = 40/3 m s-1

**2002**

1. a = 2 m s-2
2. t = 40 s
3. t = 75s

**2001**

1. VA = 22 m s-1

VB = 31 m s-1

1. SA = 120 m

SB = 160 m

1. u = 14 m s-1

**2000**

1. Acceleration = 2.5 m s-2
2. Deceleration = 5 m s-2
3. Distance = 715 m
4. time = 36.1 s

**Higher Level**

**Vertical Motion; acceleration due to gravity( ‘*g*’)**

In the absence of air resistance, all objects near the Earth’s surface will fall with the same acceleration.

This acceleration is called **acceleration due to gravity**. Its symbol is ‘*g*’.

**The value of *g* on the surface of the Earth is 9.8 m s-2.**

We mention ‘on the surface of the earth’ because the value of g decreases as you move further away from the surface. We will see why when we study Gravitation.

We can now use this value when using equations of motion.

**Notes**

* Because we take the upward direction as positive, and because g is acting downwards, we take g to be minus (-) 9.8 m s-2 when answering maths questions (i.e. the initial velocity is usually opposite in direction to acceleration).
* If an object is released from rest it means that initial velocity is 0 (u = 0).
* At the highest point of a trajectory, the (instantaneous) velocity is zero (object is not moving upwards or downwards).
* Also at the highest point of the trajectory, while the velocity is zero, the object is still accelerating at -9.8 m s-2.

**Questions taken from Leaving Cert Physics Exam Papers**

1. [2005]

A basketball which was resting on a hoop falls to the ground 3.05 m below.

What is the maximum velocity of the ball as it falls?

1. [2006 OL]

An astronaut drops an object from a height of 1.6 m above the surface of the moon and the object takes 1.4 s to fall. Calculate the acceleration due to gravity on the surface of the moon.

1. [2003 OL]
2. An astronaut is on the surface of the moon, where the acceleration due to gravity is 1.6 m s–2.

The astronaut throws a stone straight up from the surface of the moon with an initial speed of 25 m s–1. Describe how the speed of the stone changes as it reaches its highest point.

1. Calculate the highest point reached by the stone.
2. Calculate how high the astronaut can throw the same stone with the same initial speed of 25 m s–1 when on the surface of the earth, where the acceleration due to gravity is 9.8 m s–2.
3. [2003]

A skydiver falls from an aircraft that is flying horizontally. He reaches a constant speed of 50 m s–1 after falling through a height of 1500 m. Calculate the average vertical acceleration of the skydiver.

1. [2006]

The student releases the ball when is it at A, which is 130 cm above the ground, and the ball travels vertically upwards at a velocity of 7 m s-1.

Calculate the maximum height, above the ground, the ball will reach.

1. [2006]

The student releases the ball when is it at A, which is 130 cm above the ground, and the ball travels vertically upwards at a velocity of 7 m s-1.

Calculate the time taken for the ball to hit the ground after its release from A.

**Solutions**

1. v2 = u2 +2as  v2 = 0 + 2(9.8)(3.05)  v2 = 59.78

v = 7.73 m s-1

1. s = 1.6 m, t = 1.4 s, u = 0. Substitute into the equation *s = ut + ½ at2* to get a = 1.6 m s-2.
2. It slows?
3. v2 = u2 + 2as  0 = (25)2 + 2 (-1.6) s  s = 195.3 m.
4. v2 = u2 + 2as  0 = (25)2 + 2 (-9.8) s  s = 31.9 m.
5. v 2= u2+2as  502 = 0 + (2)(a)(1500)  a = 0.83 m s-2
6. v2 = u2+ 2as  0 = (7)2 + 2(-9.8) s / s = 2.5(0) m  max. height = 2.5 + 1.30 / 3.8 m
7. s = ut + ½ at2

-1.30 = 7t – ½ (9.8)t2

t = 1.59 s

**Higher Level Applied Maths Exam Questions**

**Vertical Motion**

**Concept of t and (t+2)**

Ball A is thrown up into the air and two seconds later ball B is thrown up. The balls collide after a further t seconds.

Key: For the collision, A is in the air for t seconds and B is in the air for (t-2) seconds

*Or*

B is the air for t seconds and A is in the air for (t+2) seconds.

The second option is preferable because it’s easier to deal with ‘pluses’ than ‘minuses’.

Remember to take g as minus 9.8 m s-2.

**Two balls are thrown up and collide in the air**

Key: s1 = s2

If a ball is thrown up vertically its velocity at the very top is zero.

**Distance travelled**

You need to be able to distinguish between the concepts of distance and displacement.

On the way up, distance and displacement will be the same, but not when the ball is coming down (distance is total distance travelled, while displacement is only the height above the ground).

Note that in our equations of motion s always corresponds to displacement, not distance, although in most cases these will be the same.

If you are asked for distance travelled you will first have to establish whether the ball is on the way up or the way down. For this you will have to calculate the time of collision and the time taken to reach max. height.

**2012 (a)**

A particle falls from rest from a point *P*.

When it has fallen a distance 19·6 m a second particle is projected vertically downwards from *P* with initial velocity 39·2 m s−1.

The particles collide at a distance *d* from *P*.

Find the value of *d*.



**2011 (a)**

A particle is released from rest at *A* and falls vertically passing two points *B* and *C*.

It reaches *B* after *t* seconds and takes seconds to fall from *B* to *C*, a distance of 2.45 m.

Find the value of *t*.

**2009 (a)**

A particle is projected vertically upwards from the point p. At the same instant a second particle is let fall vertically from q.

The particles meet at r after 2 seconds.

The particles have equal speeds when they meet at r.

Prove that ⏐pr⏐ = 3⏐rq⏐ .

**2008 (a)**

A ball is thrown vertically upwards with an initial velocity of 39.2 m/s.

1. Find the time taken to reach the maximum height
2. Findthe distance travelled in 5 seconds.

**2007 (a)**

A particle is projected vertically downwards from the top of a tower with speed *u* m/s. It takes the particle 4 seconds to reach the bottom of the tower.

During the third second of its motion the particle travels 29.9 metres.

Find

1. the value of *u*
2. the height of the tower.

**2002 (a)**

A stone is thrown vertically upwards under gravity with a speed of u m/s from a point 30 metres above the horizontal ground. The stone hits the ground 5 seconds later.

1. Find the value of u.
2. Find the speed with which the stone hits the ground.

**2001 (b)**

A particle is projected vertically upwards with an initial velocity of u m/s and another particle is projected vertically upwards from the same point and with the same initial velocity T seconds later.

1. Show that the particles will meet () seconds from the instant of projection of the first particle
2. Show that the particles will meet at a height of  metres.

**2004 (a)**

A ball is thrown vertically upwards with an initial velocity of 20 m/s.

One second later, another ball is thrown vertically upwards from the same point with an initial velocity of u m/s.

The balls collide after a further 2 seconds.

1. Show that u = 17.75.
2. Find the distance travelled by each ball before the collision, giving your answers correct to the nearest metre.

**1993 (b)**

A particle P is projected vertically upwards from the ground with an initial velocity of 47 m/s.

Two seconds later another particle Q is projected vertically upwards from the same point with initial velocity 64.6 m/s.

Calculate

1. how long Q is in motion before it collides with P.
2. the height at which the collision occurs.

**1992 (a)**

A balloon ascends vertically at a uniform speed.

7.2 seconds after it leaves the ground a particle is let fall from the balloon.

The particle takes 9 seconds to reach the ground.

Calculate the height from which the particle was dropped.

**1991 (b)**

A particle *P* is projected vertically upwards with an initial velocity *u* and two seconds later a second particle *Q* is projected vertically upwards from the same point with initial velocity 1.5*u*.

Calculate, in terms of *u*, how long *Q* is in motion before it collides with *P* and prove that |*u*| > 9.8.

**1990 (a)**

A particle is projected vertically upwards with velocity *u* m/s and is at a height *h* after *t*1 and *t*2 seconds respectively. Prove that *t*1 **.** *t*2 = 

**1975**

A particle falls freely under gravity from rest at a point *p*.

After it has fallen for one second another particle is projected vertically downwards from *p* with a speed of 14.7 m/s.

By considering the relative motion of the particles, or otherwise, find the time and distance from *p* at which they collide.

Show the motion of both on a time-velocity graph.

**Common Initial Velocity**

**Train-track questions**

Here the acceleration is constant throughout and we are given information about different stages.

Usually we are given information on two sections of an objects travel; the first is from the beginning, and another section is straight after.

We need to get an equation for both and solve, but to do this the variables (particularly u) must represent the same number for both equations.

The only way to do this is to make the second equation represent the first *two* sections, i.e. bring it back to the beginning. This means the distance s must be the distance from the beginning.

**2010 (b)**

A particle passes *P* with speed 20 ms-1 and moves in a straight line to *Q* with uniform acceleration.

In the first second of its motion after passing *P* it travels 25 m.

In the last 3 seconds of its motion before reaching *Q* it travels of ⏐PQ⏐.

Find the distance from *P* to *Q*.

**2003 (a)**

The points p, q and r all lie in a straight line.

A train passes point p with speed u m/s.

The train is travelling with uniform retardation f m/s2.

The train takes 10 seconds to travel from p to q and 15 seconds to travel from q to r, where | pq| = | qr | = 125 metres.

1. Show that f = 
2. The train comes to rest s metres after passing r. Find s, giving your answer correct to the nearest metre.

**2002 (b)**

A particle, with initial speed u, moves in a straight line with constant acceleration.

During the time interval from 0 to t, the particle travels a distance p.

During the time interval from t to 2t, the particle travels a distance q.

During the time interval from 2t to 3t, the particle travels a distance r.

Show that 2q = p + r.

Show that the particle travels a further distance 2r − q in the time interval from 3t to 4t.

**1996 (a)**

A particle starts from rest and moves in a straight line with uniform acceleration.

It passes three points *a*, *b* and *c* where |*ab*| = 105m and |*bc*| = 63m.

If it takes 6 seconds to travel from *a* to *b* and 2 seconds to travel from *b* to *c* find

1. its acceleration
2. the distance of *a* from the starting position.

**1995 (a)**

A particle moving in a straight line with constant acceleration passes three points *p*, *q*, *r* and has speeds *u* and 7*u* at *p* and *r* respectively.

1. Find its speed at *q* the mid-point of [*pr*] in terms of *u*.
2. Show that the time from *p* to *q* is twice that from *q* to *r*.

**1993 (a)**

A particle moving in a straight line travels 30 m, 54 m and 51 m in successive intervals of 4, 3 and 2 seconds.

1. Verify that the particle is moving with uniform acceleration
2. Draw an accurate speed-time graph of the motion.

**1988 (a)**

A particle moving in a straight line with uniform acceleration describes 23 m in the fifth second of its motion and 31 m in the seventh second.

Calculate its initial velocity.

**1988 (b)**

A particle falls from rest from a point *o*, passing three points *a*, *b*, and *c*, the distances *ab* and *bc* being equal. If the particle takes 3 seconds to pass from *a* to *b* and 2 seconds from *b* to *c*, calculate |*ab*|.

**2000 (a)**

A stone projected vertically upwards with an initial speed of u m/s rises 70 m in the first t seconds and another 50 m in the next t seconds. Find the value of u.

**1995 (b)**

A juggler throws up six balls, one after the other at equal intervals of time *t*, each to a height of 3 m.

The first ball returns to his hand *t* seconds after the sixth was thrown up and is immediately thrown to the same height, and so on continually.

(Assume that each ball moves vertically).

Find

1. the initial velocity of each ball.
2. the time *t*.
3. the heights of the other balls when any one reaches the juggler’s hand.

**1986 (b)**

A particle starting from rest at *p* moves in a straight line to *q* with uniform acceleration.

In the first second it travels 5 m.

In the last three seconds of its motion before reaching *q* it travels of |*pq*|.

Find the time in seconds from *p* to *q*.

**1985**

A bus 12.5m long travels with constant acceleration.

The front of the bus passes a point, p, with speed u while the rear of the bus passes p with speed v.

Find in terms of u and v

1. the time taken by the bus to pass p.
2. what fraction of the length of the bus passes the point p in half this time.

**1974**

A sprinter runs a race with constant acceleration *k* throughout.

During the race he passes four posts *a*, *b*, *c*, *d* in a straight line such that |*ab*| = |*bc*| = |*cd*| = 36 m.

If the sprinter takes 3 seconds to run from *a* to *b* and 2 seconds to run from *b* to *c*, find how long, to the nearest tenth of a second, it takes him to run from *c* to *d*.

**Fnet = ma**

Usually these are quite straightforward.

Where the objects are moving up a slope should use the line of slope as the x-axis, which means that you will have to calculate the component of gravity in that direction also.

**2004 (b)**

A car of mass 1200 kg tows a caravan of mass 900 kg first along a horizontal road with acceleration *f* and then up an incline α to the horizontal road at uniform speed.

The force exerted by the engine is 2700 N.

Friction and air resistance amount to 150 N on the car and 240 N on the caravan.

1. Calculate the acceleration, *f*, of the car along the horizontal road.
2. Calculate the value of α, to the nearest degree.

**1999 (a)**

A car of mass 1500 kg travels up a slope of gradient sin-1 against a constant resistance of 0.2 N per kilogram.

Find

1. the constant force required to produce a slope an acceleration of 0.1 m/s2.
2. the power which is developed when the speed is 20 m/s.

**2005 (b)**

A mass of 8 kg falls freely from rest.

After 5 s the mass penetrates sand.

The sand offers a constant resistance and brings the mass to rest in 0.01 s.

1. Find the constant resistance of the sand
2. Find the distance the mass penetrates into the sand.

**1994 (b)**

In a lift, moving upwards with acceleration *f*, a spring balance indicates an object to have a weight of 98 N. When the lift is moving downwards with acceleration 2*f* the weight appears to be 68.8 N. Calculate

1. the actual weight .
2. the downward acceleration of the lift.

**1982 (b)**

A particle of mass 3 grammes falls from rest from a height of 0**.**4 m on to a soft material into which it sinks 0**.**0245 m.

Neglecting air resistance, calculate the constant resistance of the material.

**1970**

A bullet of mass *m* is fired with speed *v* into a fixed block of wood and is brought to rest in a distance *d*. Find the resistance to motion assuming it to be constant.

Another bullet also of mass *m* is then fired with speed 2*v* into another fixed block of thickness 2*d*, which offers the same resistance as the first block.

Find the speed with which the bullet emerges, and the time it takes to pass through the block.

**Multi-stage Problems: Velocity-Time graphs**

1. **Acceleration – constant velocity – deceleration**

If there are a number of different accelerations, use a velocity-time diagram.

You need to be pretty nifty with algebra to solve these guys.

You will most likely have to make use of the fact that the area under each section = distance travelled.

Write out as many relevant equations as you can to begin with.

You will usually need to incorporate information from the acceleration/deceleration section below also.

1. **Acceleration / deceleration**

****

Consider the diagram above

Let’s call the acceleration *a* and the deceleration *b*.

1. By definition: acceleration *a* = v/t

But also from the diagram above (and using trigonometry): tan α = v/t1

Therefore *a* = v/t1

Similarly *b* = v/t2

1. Acceleration a = tan

Acceleration b = tan

1. Let’s assume that we are told in a question that the deceleration is twice the acceleration.

This means:

* t1 is twice t2.
* t1 is two thirds of the total time T, t2 is one third of the total time T.

i.e. t1 = t2 =

* Area 1 is twice Area 2 {assuming we are starting from rest and finishing at rest}.
* Angle 2 = twice Angle 1 therefore β = 2α therefore tan β = 2 tan α
* a = v/t (if starting from rest)
* Final velocity v = at (if starting from rest)

**2011 (b)**

A car accelerates uniformly from rest to a speed *v* in *t*1 seconds.

It continues at this constant speed for *t* seconds and then decelerates uniformly to rest in *t*2 seconds.

The average speed for the journey is .

1. Draw a speed-time graph for the motion of the car.
2. Find *t*1 + *t*2 in terms of *t*.
3. If a speed limit of were to be applied, find in terms of *t* the least time the journey would have taken, assuming the same acceleration and deceleration as in part (ii).

**2009 (b)**

A train accelerates uniformly from rest to a speed v m/s with uniform acceleration f m/s2.

It then decelerates uniformly to rest with uniform retardation 2f m/s2.

The total distance travelled is d metres.

1. Draw a speed-time graph for the motion of the train.
2. If the average speed of the train for the whole journey is , find the value of f.

**2006** **(a)**

A lift starts from rest. For the first part of its descent it travels with uniform acceleration *f*. It then travels with uniform retardation 3*f* and comes to rest.

The total distance travelled is *d* and the total time taken is *t*.

1. Draw a speed-time graph for the motion.
2. Find *d* in terms of *f* and *t*.

**2007 (b)**

A train accelerates uniformly from rest to a speed *v* m/s.

It continues at this speed for a period of time and then decelerates uniformly to rest.

In travelling a total distance *d* metres the train accelerates through a distance *pd* metres and decelerates through a distance *qd* metres, where *p* < 1 and *q* < 1.

1. Draw a speed-time graph for the motion of the train.
2. If the average speed of the train for the whole journey is , find the value of *b*.

**2001 (a)**

Points p and q lie in a straight line, where |pq| = 1200 metres.

Starting from rest at p, a train accelerates at 1 m/s2 until it reaches the speed limit of 20 m/s.

It continues at this speed of 20 m/s and then decelerates at 2 m/s2, coming to rest at q.

1. Find the time it takes the train to go from p to q.
2. Find the shortest time it takes the train to go from rest at p to rest at q if there is no speed limit, assuming that the acceleration and deceleration remain unchanged at 1 m/s2 and 2 m/s2, respectively.

**2000 (b)**

A car, starting from rest and travelling from p to q on a straight level road, where ⏐pq ⏐= 10 000 m, reaches its maximum speed 25 m/s by constant acceleration in the first 500 m and continues at this maximum speed for the rest of the journey.

A second car, starting from rest and travelling from q to p, reaches the same maximum speed by constant acceleration in the first 250 m and continues at this maximum speed for the rest of the journey.

1. If the two cars start at the same time, after how many seconds do the two cars meet?
2. Find, also, the distance travelled by each car in that time.
3. the start of one car is delayed so that they meet each other exactly halfway between p and q, find which car is delayed and by how many seconds.

**1999 (b)**

A particle travels in a straight line with constant acceleration *f* for *2t* seconds and covers 15 metres. The particle then travels a further 55 metres at constant speed in *5t* seconds. Finally the particle is brought to rest by a constant retardation *3f*.

1. Draw a speed-time graph for the motion of the particle.
2. Find the initial velocity of the particle in terms of *t*.
3. Find the total distance travelled in metres, correct to two decimal places.

 **1997 (a)**

A particle, moving in a straight line, accelerates uniformly from rest to a speed *v* m/s. It continues at this constant speed for a time and then decelerates uniformly to rest, the magnitude of the deceleration being twice that of the acceleration. The distance travelled while accelerating is 6 m. The total distance travelled is 30m and the total time taken is 6 s.

1. Draw a speed-time graph and hence, or otherwise, find the value of *v*.
2. Calculate the distance travelled at *v* m/s.

**1996 (b)**

A lift starts from rest with constant acceleration 4m/s2. It then travels with uniform speed and finally comes to rest with constant retardation 4 m/s2. The total distance travelled is *d* and the total time taken is *t*.

1. Draw a speed-time graph.
2. Show that the time for which it travelled with uniform speed is 

**1998 (a)**

A train accelerates uniformly from rest to a speed *v* m/s. It continues at this constant speed for a period of time and then decelerates uniformly to rest. If the average speed for the whole journey is , find what fraction of the whole distance is described at constant speed.

**1994 (a)**

A lift, in continuous descent, had uniform acceleration of 0.6 m/s2 for the first part of its descent and a retardation of 0.8 m/s2 for the remainder.

The time, from rest to rest, was 14 seconds. Draw a time-velocity graph and hence, or otherwise, find the distance descended.

**1991 (a)**

A particle starts from rest at a point *p* and accelerates at 2 m/s2 until it reaches a speed *v* m/s.

It travels at this speed for 1 minute before decelerating at 1 m/s2 to rest at *q*.

The total time for the journey is 2 minutes.

1. Calculate the distance *pq*.
2. If a second particle starts from *p* at time *t* = 0 and moves along *pq* with speed (2*t* + 50) m/s, find the time taken to reach *q*.

**1990 (b)**

A car accelerates uniformly from rest to a speed *v* m/s. It continues at this constant speed for *t* seconds and then decelerates uniformly to rest. The average speed for the journey is .

1. Draw a speed-time graph and hence, or otherwise, prove that the time for the journey is 2*t* seconds.
2. If the car-driver had observed the speed limit of ½*v*, find the least time the journey would have taken, assuming the same acceleration and deceleration as in (i).

**1987 (a)**

The maximum acceleration of a body is 4 m/s2 and its maximum retardation is 8 m/s2.

What is the shortest time in which the body can travel a distance of 1200 m from rest to rest?

**1987 (b)**

A car, *A*, starts from a point *p* with initial velocity of 8 m/s and then travels with a uniform acceleration of 4 m/s2.

Two seconds later a second car *B* starts from *p* with an initial velocity of 30 m/s and then moves with a uniform acceleration of 3 m/s2.

Show that after passing *A*, *B* will never be ahead by more than 74 m.

**1986 (a)**

A particle with speed 150 m/s begins to decelerate uniformly at a certain instant while another particle starts from rest 8 s later and accelerates uniformly.

When the second particle had travelled 135 m both particles have a speed of 30 m/s.

1. Show the motion of both particles on the same speed-time graph.
2. How many seconds after the commencement of deceleration does the first particle come to rest?

**1984**

The driver of a car travelling at 20 m/s sees a second car 120 m in front, travelling in the same direction at a uniform speed of 8 m/s.

1. What is the least retardation that must be applied to the faster car so as to avoid a collision?

If the actual retardation is 1 m/s2, calculate

1. the time interval, in seconds, for the faster car to reach a point 66 m behind the slower car.
2. the shortest distance between the cars.

**1983**

A train of length 120 m has an acceleration of 1 m/s2.

It meets another train of length 80 m travelling on a parallel track in the opposite direction with acceleration of 1.5 m/s2.

Their speeds at this moment are respectively 20 m/s and 25 m/s.

1. Show, by diagrams, the positions of the trains just before meeting and immediately after passing.
2. Find the time taken for the trains to pass each other.
3. If one of the trains, by applying breaks, were to cause an increase of 121/2 % in this time of passing, calculate to the nearest m/s2 the increase in its acceleration.

**1982 (a)**

A car *A* passes a point *p* on a straight road at a constant speed of 10 m/s.

At the same time another car *B* starts from rest at *p* with uniform acceleration 2**.**5 m/s2.

1. When and how far from *p* will *B* overtake *A*?
2. If *B* ceases to accelerate on overtaking, what time elapses between the two cars passing a point *q* three kilometres from *p*?

**1981**

A body starts from rest at *p*, travels in a straight line and then comes to rest at *q* which is 0**.**696 km from *p*. The time taken is 66 seconds.

For the first 10 seconds if has uniform acceleration a1.

It then travels at constant speed and is finally brought to rest by a uniform deceleration a2 acting for 6 seconds.

1. Calculate a1 and a2.
2. If the journey from rest at *p* to rest at *q* had been travelled with no interval of constant speed, but subject to a1 for time t1 followed by a2 for time t2, show that the time for the journey is 8 seconds.

**1979 (a)**

How may a velocity-time graph be used to find the distance travelled in a given time?

An athlete runs 100 m in 12 seconds.

Starting from rest, he accelerates uniformly to a speed of 10 m/s, and then continues at that speed.

Calculate the acceleration.

**1979 (b)**

A body starting from rest travels in a straight line, first with uniform acceleration *a* and then with uniform deceleration *b*.

It comes to rest when it has covered a total distance *d*.

If the overall time for the journey is *T*, show that

**1978**

A driver starts from rest at P and travels with a uniform acceleration of *a* m/s2 for *T* seconds.

He continues with uniform velocity for 3*T* seconds and then decelerates uniformly to rest at Q in a further 2*T* seconds.

Express the distance PQ in terms of *a* and *T*.

Another driver can accelerate at 2*a* m/s2 and can decelerate at 4*a* m/s2.

Find, in terms of *T*, the least time in which this driver can cover the distance PQ from rest to rest

1. subject to a speed limit of 3*a*T m/s
2. subject to a speed limit of 5*a*T m/s.

**1977**

A car starts from rest at P and moves with constant acceleration *k* m/s2.

Three seconds later another car passes through P travelling in the same direction with constant speed *u* m/s, where *u* > 3*k*.

1. Draw a velocity/time graph for the two cars, using the same axes and the same scales.
2. Hence or otherwise, show that the second car will just catch up on the first if *u* = 6*k* and that it will not catch up on it if *u* < 6*k*.
3. If *u* > 6*k*, find the greatest distance the second car will be ahead of the first.

**1976**

Show that, if a particle is moving in a straight line with constant acceleration *k* and initial speed *u*, then the distance travelled in time *t* is given by *s* = *ut* + ½ *kt* 2.

Two points *a* and *b* are a distance *l* apart.

A particle starts from *a* and moves towards *b* in a straight line with initial velocity *u* and constant acceleration *k*.

A second particle starts at the same time from *b* and moves towards *a* with initial velocity *u* and constant deceleration *k*.

Find the time in terms of *u*, *l*, at which the particles collide, and the condition satisfied by *u*, *k*, *l*, if this occurs before the second particle returns to *b*.

**1973**

A cyclist has a maximum acceleration of 2 m/s2, a maximum speed of 15 m/s and a maximum deceleration of 4 m/s2.

The cyclist wishes to travel a distance s from rest to rest in the shortest time.

Find the time taken in the two cases

1. s =105 m
2. s = 54 m.

Draw a rough velocity-time graph for each case and explain why 843/5 m is a critical distance

**1972**

A racing car covers a journey of 8.8 km from rest to rest.

It accelerates uniformly the first minute to reach its maximum speed of 40 m/s, it holds this speed for a certain time and then slows uniformly to rest with a retardation of magnitude three times that of the acceleration.

1. Draw a rough velocity-time graph and find the distances travelled in the three stages of the journey and the total time taken.
2. If the maximum speed over the final kilometre of the journey had been restricted to 20 m/s, show that the time taken from rest to rest would have been at least 22·5 seconds longer than before, assuming the same rates of acceleration and deceleration as before.

**1971**

Explain how a graph of velocity plotted against time can be used to calculate acceleration and distance travelled, with particular reference to motion with constant acceleration.

A pigeon in flight releases a small stone from its beak at a height of 50 metres when its velocity is *u*. If the stone takes 3½ seconds to reach the ground, show that the direction of *u* is not horizontal and compute the greatest height reached by the stone after release.

(Give your answer correct to the nearest tenth or 0·1 of a metre.)

**General Questions**

**Constant acceleration**

If acceleration is constant throughout then use equations of motion rather than a diagram.

**2012 (b)**

A car, starts from rest at *A*, and accelerates uniformly at 1 m s−2 along a straight level road towards *B*, where │AB│= 1914 m.

When the car reaches its maximum speed of 32 m s−1, it continues at this speed for the rest of the journey.

At the same time as the car starts from *A* a bus passes *B* travelling towards *A* with a constant speed of 36 m s−1.

Twelve seconds later the bus starts todecelerate uniformly at 0·75 m s−2.

1. The car and the bus meet after *t* seconds. Find the value of *t*.
2. Find the distance between the car and the bus after 48 seconds.

**2010 (a)**

A car is travelling at a uniform speed of 14 m s-1 when the driver notices a traffic light turning red 98 m ahead.

Find the minimum constant deceleration required to stop the car at the traffic light,

1. if the driver immediately applies the brake
2. if the driver hesitates for 1 second before applying the brake.

**2005 (a)**

Car A and car B travel in the same direction along a horizontal straight road.

Each car is travelling at a uniform speed of 20 m/s.

Car A is at a distance of d metres in front of car B.

At a certain instant car A starts to brake with a constant retardation of 6 m/s2.

0.5 s later car B starts to brake with a constant retardation of 3 m/s2.

1. Find the distance travelled by car A before it comes to rest
2. Find the minimum value of d for car B not to collide with car A.

**2008 (b)**

Two particles P and Q, each having constant acceleration, are moving in the same direction along parallel lines. When P passes Q the speeds are 23 m/s and 5.5 m/s, respectively.

Two minutes later Q passes P, and Q is then moving at 65.5 m/s.

1. Findthe acceleration of P and the acceleration of Q
2. Find the speed of P when Q overtakes it
3. Find the distance P is ahead of Q when they are moving with equal speeds.

**2006 (b)**

Two trains P and Q, each of length 79.5 m, moving in opposite directions along parallel lines, meet at *o*, when their speeds are 15 m/s and 10 m/s respectively.

The acceleration of P is 0.3 m/s2 and the acceleration of Q is 0.2 m/s2.

It takes the trains *t* seconds to pass each other.

1. Find the distance travelled by each train in *t* seconds.
2. Hence, or otherwise, calculate the value of *t*.
3. How long does it take for 2/5 of the length of train Q to pass the point *o*?

**2003 (b)**

A man runs at constant speed to catch a bus. At the instant the man is 40 metres from the bus, it begins to accelerate uniformly from rest away from him. The man just catches the bus 20 seconds later.

1. Find the constant speed of the man.
2. If the constant speed of the man had instead been 3 m/s, show that the closest he gets to the bus is 17.5 metres.

**1998 (b)**

Car A, moving with uniform acceleration m/s2 passes a point *p* with speed 9*u* m/s. Three seconds later Car B, moving with uniform acceleration m/s2 passes the same point with speed 5*u* m/s. B overtakes A when their speeds are 6.5 m/s and 5.4 m/s respectively.

Find

1. the value of *u* and the value of *b*.
2. the distance travelled from *p* until overtaking occurs.

**1997 (b)**

Two points *p* and *q* are a distance *d* apart. A particle starts from *p* and moves towards *q* with initial velocity 2*u* and uniform acceleration *f*. A second particle starts at the same time from *q* and moves towards *p* with initial velocity 3*u* and uniform deceleration *f* . Prove that

1. the particles collide after seconds
2. if the particles collide before the second particle comes to instantaneous rest, then *fd* <15*u*2
3. if *fd* = 30*u*2 then the second particle has returned to *q* before the collision.

**1992 (b)**

Two particles P and Q are moving in the same direction along parallel straight lines.

Their accelerations are 5 m/s2 and 4 m/s2, respectively.

At a certain instant P has a velocity 1 m/s and Q is 25.5 m behind P moving with velocity 11 m/s.

1. Prove that Q will overtake P and that P will in turn overtake Q.
2. When Q is in front of P find the greatest distance between the particles.

**1989**

Two cars A and B, each 5 m in length, travel with constant velocity 20 m/s along a straight level road.

The front of car A is 15 m directly behind the rear of car B.

Immediately on reaching a point *P* each car decelerates at 4 m/s2.

1. Show that A collides with B.
2. At what distance from *P* does the collision occur?
3. Show the motion of both cars on the same speed-time graph.

**1978 (a)**

Two particles A and B are moving along two perpendicular lines towards a point *O* with constant velocities of 1**.**2 m/s and 1**.**6 m/s respectively.

When A is 12 metres from *O*, B is 20 metres from *O*.

Find the distance between them when they are nearest to each other.

**Answering higher level exam questions**

There are usually many ways to answer these questions; I went with the methods outlined in the marking schemes.

**2009 (a)**

Use v = u + at for both particles. Then use v2 = u2 + 2as for both particles to get the required expression.

**2009 (b)**

1. Velocity-time graph
2. You need to play around with lots of algebra. Get an expression for total time in terms of v and f, then use the fact that average speed = total distance/total time to get an answer of f = 1 m s-2.

**2008 (a)**

1. Straightforward. Ans: t = 4 s.
2. Need to distinguish between the concepts of distance and displacement.

On the way up, distance and displacement will be the same, but in this question after 5 seconds the ball will have been on its way down for 1 sec (how do we know this?), so we need to establish how far it will have travelled in the fifth second and add this on to the maximum height.

Ans: total distance = 83.3 m

**2008 (b)**

1. You know v, u and t for Q (t is when Q passes P), so use this to work out a.

Now use this to work out s (distance from the beginning to where Q passes P).

Now for P you have this same s, plus u and t, so use this to work out a for P.

Ans: aQ = 0.5 m s-2, aP = 5/24 m s-2.

1. Use v = u + at to find v for P. Ans: vP = 48 m s-2.
2. “*When”* they are moving at equal speeds ⇒ vP = vQ so get an expression for both and equate.

Use this to find t. Sub into expressions for SP and SQ and subtract one from the other to find the distance between them.

Ans: distance = 525 m

**2007 (a)**

1. It’s not obvious, but this is a ‘Train-track’ type question.

During the third second of its motion the particle travels 29.9 metres.

We can get an expression for h - the distance travelled in the first 2 seconds: we know u, a and t.

We can then do the same for the distance travelled in the first 3 seconds. S in this case is (h + 29.9) m.

Ans: u = 5.4 m s-1

1. Straightforward. Ans: s = 100 m.

**2007 (b)**

1. Straightforward.
2. Tricky: One car – two accelerations

You need to remember that , so we need to find an expression for this in relation to the information supplied, and then compare that to the expression they give us.

For each section write down the relationship between velocity, distance and time

To find the total time you need to find an expression for each of the 3 individual times (in terms of velocity and distance).

Then it’s just messy algebra to finish it out.

Ans: b = 1

**2006 (a)**

Acceleration / deceleration type question.

1. Straightforward
2. Messy algebra. Ans: d = 3/8 ft2

**2006 (b)**

1. Straightforward.
2. Straightforward once you draw a diagram to help you verify that SP + SQ = 159. Then solve. Ans: t = 6 s.
3. Straightforward. Ans: t = 3.1 s.

**2005 (a)**

1. Straightforward (once you note that the acceleration is minus). Ans: s = 33.3 m
2. Note that there are two distances to take into account here. The first is to do with reaction-time distance, and the second is the normal stopping distance. Add these together but remember that you have to subtract the first distance of 33.3 m because the first car will have moved on by this distance. Ans: s = 43.3 m.

**2005 (b)**

1. Straightforward once you are familiar with the concept of Fnet = ma.

To find out the forces acting on the mass in the sand you will need to work out its acceleration. Before you can do this you will first need to note that its initial velocity for the second stage (when it’s in the sand) will be the same as its final velocity in the air. So that gives you u; you know v = 0 and t = 0.01. From that you can work out acceleration a.

Then it’s just Forcedown – Forceup = ma, where Forcedown = mg, and Forceup is due to resistance of the sand, which is what you are looking for.

Ans: R = 39278.4 N.

1. Straightforward. Ans: s = 0.245 m.

**2004 (a)**

1. Straightforward. s1 = s2. Note that first ball is in the air for 3 seconds and second ball is in the air for 2 seconds.

Ans: u = 17.75 ms-1.

1. You first have to establish for each ball whether it will be on the way up or the way down. Hint: look at their initial velocities and the time they taken to reach max. height. Draw a diagram for each ball to help you.

Ans: Ball A = 25 m, ball B = 16 m.

**2004 (b)**

1. Straightforward once you are familiar with Fnet = ma.

Ans: f = 1.1 m s-2

1. Similar to (i), except in this case the car and caravan are going uphill so you will have to and also resolve the weight into components along the plane and perpendicular to the plane, and proceed accordingly.

Ans: α = 60.

**2003 (a)**

1. Straightforward train-track question.
2. Straightforward once you remember that all numbers must be in relation to point p, so total distance travelled before coming to rest is (250 + s). Remember also that a = -3.

Ans: s = 51 m.

**2003 (b)**

1. Man just catches bus, so at this time vMan = vbus. Also when the man catches up with the bus he will hae travelled 40 m more than the bus, so sMan = (40 + sBus).You will need to play around with the various equations of motion and use lots of algebra to solve.

Ans: u = 4 m s-1.

1. Find the distance between them means find get an expression for the distance travelled by both and subtract one from the other. In this case you are asked to find the minimum distance, so anytime maximum or minimum is asked for it usually means you have to differentiate and let your answer equal 0 to find t (remember from maths how to find the maximum or minimum point on a curve? – this is one of the most important applications of differentiation).

Ans: s = 17.5 m.

**2002 (a)**

1. Straightforward. Note s = -30. Ans: u = 18.5 ms-1.
2. Straightforward. Ans: speed = 30.5 m s-1 (remember strictly speaking ‘speed’ implies magnitude only, not direction, so we should ignore the minus sign).

**2002 (b)**

1. Train-track type question. Straightforward.
2. Straightforward.

**2001 (a)**

1. Velocity-time graph. Lots of algebra. See notes for answering this type of question above.

Ans: t = 75 seconds.

1. Acceleration-deceleration. Algebra. See notes above.

Ans: t = 60 seconds.

**2001 (b)**

1. Two balls are thrown up and collide in the air so remember that the key is s1 = s2. Remember also that if the second ball is in the air for t1 seconds, then the first ball (which is obviously in the air for longer) is in the air for (T + t1) seconds. Note also that you were asked for the time taken in relation to when the *first* particle was projected, so you may have to adjust your answer accordingly.
2. Sub value for time into expression for s.

**2000 (a)**

This involves a stone projected upwards, but is actually a type of train-track type question because all information must be with reference to the initial point of projection.

Ans: u = 56 m s-1.

**2000 (b)**

1. Velocity-time diagram

The cars are moving in opposite directions so when they meet the total distance travelled will be 10,000 m, i.e. sp + sq = 10,000 m.

Ans: t = 215 s, sp = 4875 m, sq = 5125 m.

1. Cars meet halfway ⇒ sp = sq.

Ans: t = 10 s.

**1999 (a)**

1. Straightforward Fnet = ma question using the line of slope as the x-axis.

Ans: F = 744 N

1. Power = Force × velocity

Ans: P = 14880 W

**1999 (b)**

1. Velocity-time graph
2. You need to play around with lots of algebra.

Ans: u = 4/t

1. Again, play around with the equations

Ans: Total distance = 75.76 m.

**1998 (a)**

1. Velocity-time graph. Very difficult algebra. Remember

**1998 (b)**

1. Straightforward in principle, although the algebra gets a little messy.

Ans: u = 0.1 m s-1, b = 1

1. Straightforward.

Ans: s = 94.5 m

**1997 (a)**

Straightforward if you begin by throwing down all the relationships between acceleration, velocity, time and distance as per revision notes. Then just play around with the equations.

1. Answer: v = 7.5 m/s
2. Answer: distance = 21 m

**1997 (b)**

1. Nice question, but could cause difficulty in that the questions wouldn’t be familiar. When particles collide then S1 + S2 = d.
2. Tricky to decipher the significance of the information. You’ve just worked out an expression for the time for collision – call this t1. Now work out an expression for the time for the second particle to come to instantaneous rest – call this t2.

Now let t1 < t2 to obtain the required expression.

1. If the second particle has returned to q then S2 = 0, so get the time for this and let it equal to t1 (time at which collision would have taken place) and obtain the required expression.

**1996 (a)**

1. Straightforward train-track type problem

Answer: a = 3.5 m s-2

1. Straightforward

Answer: s = 7 m

**1996 (b)**

1. Straightforward
2. Straightforward if you begin by throwing down all the relationships between acceleration, velocity, time and distance as per revision notes. Then just play around with the equations.

**1995 (a)**

A variation on the train-track problem. Use v2 = u2 + 2as for stage pq and stage qr.

Answer: v = 5u.

Straightforward. t1 = 4u/f and t2 = 2u/f.

**1995 (b)**

1. Straightforward.

Answer: u = √6 g

1. Straightforward.

Answer: t = 0.26 seconds

1. Strightforward.

Answer: S6 = S2 = 5/3, S5 = S3 = 8/3, S4 = 3

**Other miscellaneous points**

**Man just catches bus**

A man runs after a bus and *just* catches it.

Key: vMan = vBus. Why? It’s the word Just that’s crucial here. If the man was going quicker than the bus when he got up to it then you wouldn’t use the term “he *just* caught it”. On the other hand if the man was going slower than the bus then he wouldn’t catch up with it at all (at all).

**Greatest gap**

The greatest gap between them also occurs when vman = vBus  (because if their speeds are unequal then the gap is either increasing or decreasing). Another way of solving this is getting an expression for the distance between them (sBus – sman) and then differentiating and letting the answer = 0. i.e. d(sBus – sman)/dt = 0.

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‘Retardation’ is the scientific term for ‘deceleration’, i.e. acceleration is minus (strictly speaking we physicists would say that the car is simply accelerating in the ‘minus’ direction).

Power = Force × velocity: