How fast can things go solutions

Example 1.1: (1984 Question 1, 96%)

Use v = u + at
∴ 30 = 0 + a × 10
∴ a = 3 m s^{-2} (ANS)

Example 1.2: (1984 Question 2, 61%)

Use ΣF = ma
∴ $F_{Driving} - F_{Resistance}$ = ma
∴ $F_{Driving}$ – 500 = 2000 × 3
∴ $F_{Driving}$ = 6000 + 500
∴ $F_{Driving}$ = 6500 N (ANS)

Example 1.3: (1984 Question 3, 89%)

Use x = ut + ½at^2
∴ x = 0 + ½ × 3 × 10^2
∴ x = 150 m (ANS)

Example 1.4: (1984 Question 4, 65%)

Use WD = F × d
∴ WD = 6500 × 150
∴ WD = 975000
∴ WD = 9.8 × 10^5 J (ANS)

Example 1.5: (1984 Question 5, 56%)

Use Power = F × v
∴ P = 6500 × 20
∴ P = 130000
∴ P = 1.3 × 10^5 W (ANS)

Example 1.6: (2001 Question 1, 46%)

This question is designed to be a nice starter, so don't fall into the trap of making it too complicated. As you were reading the question, you should have highlighted the words "constant speed". This means that acceleration = 0,

∴ net force = 0 (ANS)

Example 1.7: (2001 Question 3, 58%)

When the rider is going down the hill at a constant speed, then the sum of the forces is again zero. So, the frictional forces opposing the motion (acting up the slope) must be equal to the weight component acting down the slope

∴ Frictional forces = mg sinθ
= 100 × 10 × sin15^0
= 258.8
= **259 N (ANS)**

Example 1.8: (2002 Question 7, 54%)

$a = \frac{\Delta v}{t} = \frac{11}{0.1}$
= 110 m s^{-2}
F = ma =1.30 × 10^3 × 110
= 1.43 × 10^5 N
[actually 1.4 × 10^5 N due to sig. figs]
∴143 kN (ANS)

Example 1.9: (2002 Question 8, 47%)

Crumple Zone enables passenger cell to travel a greater distance while stopping, in a longer time.
The change in momentum [$p_f - p_o$] is the same regardless of the time taken.
Longer time allows lower average force [same impulse – force × time]

Example 1.10: (1984 Question 28, 90%)

F = Σma
The net force = 45 – $F_{friction}$
= 45 – 30
= 15
∴ 15 = (10 + 20)a
∴ $a = \frac{15}{30}$
= **0.5 m s^{-2} (ANS)**

Example 1.11: (1984 Question 29, 21%)

The force exerted by the 20 kg mass on the I0 kg mass is equal and opposite to the force exerted by the 10 kg mass on the 20 kg mass. Since the 20 kg mass is accelerating at 0.5 m s^{-2}, the net force on it must be ΣF = ma.
∴ ΣF = 20 × 0.5 = 10N.

The frictional force of 20 N still needs to be overcome, so $F_{10 \text{ on } 20}$ = 10 + 20 = 30 N

∴ The force exerted by the 20 kg mass on the 10 kg mass = **30 N (ANS)**

Example 1.12: (2004 Question 1, 57%)

Use $h = ut + \frac{1}{2}at^2$
Where $u = 10\sin 30$, $a = -10\ m\ s^{-2}$, $t = 3.0\ s$

$\therefore h = 10 \times 0.5 \times 3 - (\frac{1}{2} \times 10 \times 3^2)$
$\therefore h = 15 - 45$
$\therefore h = -30$ m.

This answer is consistent as we have assumed the upwards is positive.

$\therefore$ **The height was 30 m (ANS)**

Example 1.13: (2004 Question 3, 40%)

The minimum speed (not zero because of the constant horizontal component) occurs at the top of the flight of the parcel. It will then continue to speed up.

$\therefore$ **B (ANS)**

Example 1.14: (2005 Question 4, 57%)

At t = 5 secs, the retarding force is 1.8 N (from graph)
$\Sigma F = ma$
$\therefore ma = mg - R$
$\therefore 0.2a = 0.2 \times 10 - 1.8$
$\therefore 0.2a = 2 - 1.8$
$\therefore 0.2a = 0.2$
$\therefore a =$ **1 m s^{-2} (ANS)**

Example 1.15: (1987 Question 13, 52%)

The weight of the 10 kg mass is 100 N.
$\therefore$ This weight force needs to accelerate both the mass and the door (at the same rate)
$\therefore 100 = \Sigma m \times a$
$\therefore 100 = 50 \times a$
$\therefore$ **a = 2 m s^{-2} (ANS)**

Example 1.16: (1987 Question 14, 79%)

Use $x = ut + \frac{1}{2}at^2$
where $u = 0$
$\therefore 1.0 = \frac{1}{2} \times 2 \times t^2$
$\therefore$ **t = 1.0 s (ANS)**

Example 1.17: (2008 Question 1, 50%)

$F_{ship} = F_{tug} - F_{resistance}$
$= 9 \times 10^4 - 2 \times 10^4$ (from the graph)
$= 7 \times 10^4$
$\therefore 7 \times 10^4 = 100 \times 10^4 \times a$

$\therefore$ **a = 0.07 m s^{-2} (ANS)**

Example 1.18: (2008 Question 2, 60%)

Constant speed $\Rightarrow \Sigma F = 0$
$\therefore F_{resistance} = 9 \times 10^4$ N
Using the graph

$\therefore$ **4 m s^{-1} (ANS)**

Example 1.19: (2010 Question 3, 35%)

Consider mass 2
$m_2g - T = m_2a$ (1)

Consider mass 1
$T = m_1a$ (2)

Combining gives
$m_2g - m_1a = m_2a$
$\therefore 0.1 \times 10 = (m_1 + m_2)a$
$= 0.5\ a$
$\therefore$ **a = 2 m s^{-2} (ANS)**

Example 1.20: (2011 Question 2, 55%)

The only force that we need to consider that is acting on the trailer is the tension.
Therefore T = ma
$\therefore T = 2000 \times 0.5$
$\therefore$ **T = 1000 N (ANS)**

Example 1.21: (2011 Question 7, 55%)

Use Newton's third law.
$\therefore F_{C\ on\ B} = -F_{B\ on\ C}$
The three forces acting on C are:
Its weight, mg
The normal reaction
The weight of A and B.
$\therefore F_{B\ on\ C} = (0.050 + 0.10) \times 10$
$\therefore F_{B\ on\ C} = 1.5$ N
$\therefore$ **$F_{C\ on\ B}$ = 1.5 N (upwards) (ANS)**

Example 1.22: (2011 Question 8, 50%)

The blocks will be in free fall, so their acceleration will be g.
$\therefore F_{B\ on\ C} = 0$, because they are both in free fall, and accelerating at the same rate.
$\therefore$ **$F_{B\ on\ C}$ = 0 (ANS)**

Example 1.23: (2012 Question 4b, 15%)

Newton's third law can be written in the form;
$\mathbf{F}_{A\ on\ B} = -\mathbf{F}_{B\ on\ A}$
Then the weight of sphere is
$F_{Earth\ on\ Sphere}$
In terms of Newtons action and reaction pairs, the 'reaction' will be
$\mathbf{F}_{Sphere\ on\ Earth}$ **UP (ANS)**

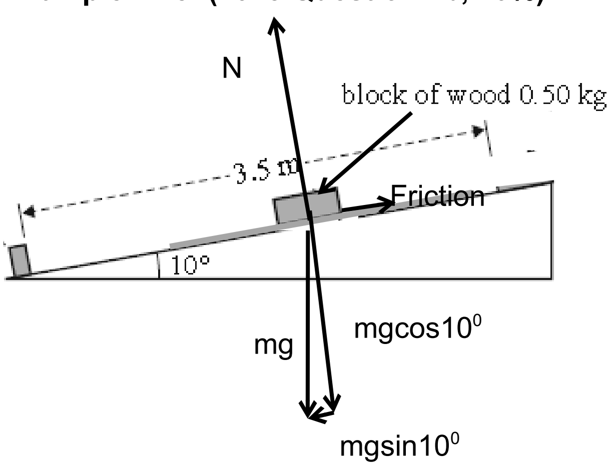
Example 1.24: (2012 Question 5d, 53%)

Rope 1 needs to provide the tension to accelerate both logs, so the tension in it will be greater than that of Rope 2.
∴ **Rope 1 (ANS)**

Use $\Sigma F = ma$
$\therefore T_1 - T_2 - 400 = 600a$
and
$T_2 - 400 = 600a$
$\therefore T_2 = 600a + 400$

$\therefore T_1 - (600a + 400) - 400 = 600a$
$\therefore T_1 = 600a + (600a + 400) + 400$
Use $T_1 = 2400$ N at its breaking point.
$\therefore 2400 = 1200a + 800$
$\therefore 1600 = 1200 \times a$
$\therefore$ **a = 1.33 m s^{-2} (ANS)**

Example 1.25: (2013 Question 1b, 40%)

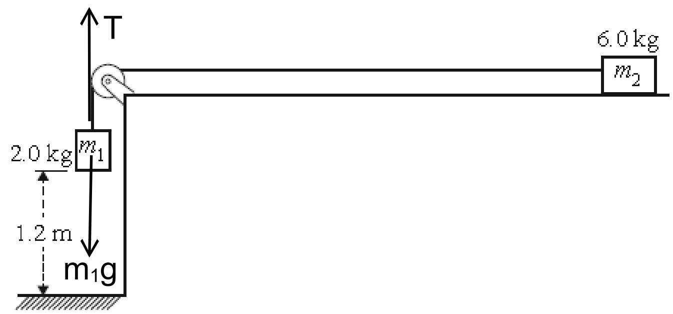


From the diagram we get
$\Sigma F = ma$
$\therefore 0.5a = mg\sin 10^0 - \text{Friction}$

Need to find 'a'.
Use $x = ut + \frac{1}{2}at^2$ to get
$3.5 = \frac{1}{2} \times a \times 6^2$
$\therefore a = 0.1944$

$\therefore 0.5 \times 0.1944 = 0.5 \times 10 \times \sin 10^0 - \text{Friction}$
$\therefore 0.0972 = 0.8682 - \text{Friction}$
$\therefore$ **Friction = 0.773 N (ANS)**

Example 1.26: (2013 Question 2b, 30%)



Use the equations $m_1a = m_1g - T$
and $T = m_2a$
$\therefore 2a = 20 - 6a$
$\therefore 8a = 20$
$\therefore a = 2.5\ ms^{-2}$
Substitute into $T = m_2a$
$\therefore T = 6 \times 2.5$
= 15 N (ANS)

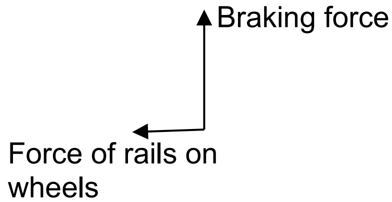
Example 1.27: (2014 Question 1b, 50%)
The tension in the coupling is the only force accelerating the two trucks.
$\therefore$ Use $T = \sum ma$
$= 2 \times 10 \times 10^3 \times 0.2$
= 4 × 10^3 N (ANS)

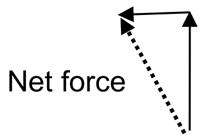
Example 1.28: (1992 Trial Question)

Since the car is moving in circular motion, the resultant force must be acting radially inwards. The air resistance is going to oppose the motion; hence, it has to be to the left. To obtain a resultant force, you need to add the forces that are acting together. This means that the 'Total force of road on tyres' plus the 'air resistance' need to combine to give a 'resultant force' that acts radially inwards.
∴**E (ANS)**

Example 1.29: (2005 Question 7, 33%)

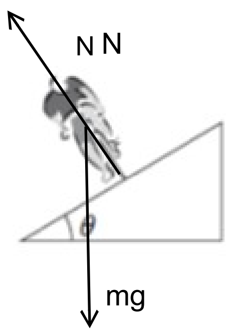
There are now two forces acting, the radially inwards force from the rails, and the braking force from the brakes.
The braking force is opposing the motion therefore acting backwards.





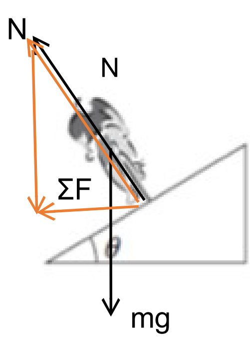
∴ **B (ANS)**

Example 1.30: (2010 Question 5, 45%)



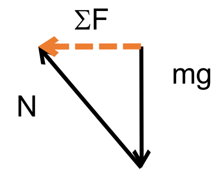
There are only **two** forces acting, the Weight, (drawn from the centre of mass) and the Normal (drawn perpendicular to the surface)

Example 1.31: (2011 Question 5, 50%)

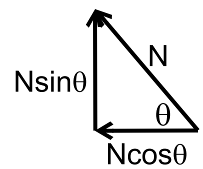


The only two forces acting are the weight force, acting down and the normal reaction from the surface, acting perpendicular to the surface.

They must add together to give the resultant force ΣF, which is radially inwards.



You could resolve the Normal vector into two components, one perpendicular and the other horizontal.



From this we get:

$N\sin\theta = mg$ and

$\frac{mv^2}{r} = N\cos\theta$

Example 1.32: (1977 Question 15, 76%)

If the object is released at the point P, it will go vertically up. Therefore it will land directly under the point P. This means that it will land a distance **r** from the point X.

∴ **"r" (ANS)**

Example 1.33: (1977 Question 16, 37%)

If the object is released at the point Q, it will be a projectile with an initial horizontal velocity of **v**. It will be launched from a height of 3**r**.

Use $x = ut + \frac{1}{2}gt^2$ to find how long it will take to land.

$\therefore 3r = 0 + \frac{1}{2}gt^2$

$\therefore 6r = gt^2$

$\therefore t^2 = \frac{6r}{g}$

$\therefore t = \sqrt{\frac{6r}{g}}$

To calculate the horizontal distance travelled in time 't', use d = vt.

$\therefore \mathbf{d = v\sqrt{\frac{6r}{g}}}$ **(ANS)**

Example 1.34: (1978 Question 18, 26%)

The force on the cage floor is equal and opposite to the force of the cage floor on the observer (N)

At the bottom $\Sigma F = N - mg = \frac{mv^2}{r}$

$\therefore N = mg + \frac{mv^2}{r}$

Therefore the observer will feel heavier at the bottom.

$\therefore$ B (ANS)

Example 1.35: (1978 Question 19, 24%)

The force on the cage floor is equal and opposite to the force of the cage floor on the observer (N)

At the top $\Sigma F = N + mg = \frac{mv^2}{r}$

$\therefore N = -(mg - \frac{mv^2}{r})$.

The negative sign indicates that the normal reaction is down.

The magnitude of the Normal reaction is $mg - \frac{mv^2}{r}$

At the bottom $\Sigma F = N - mg = \frac{mv^2}{r}$

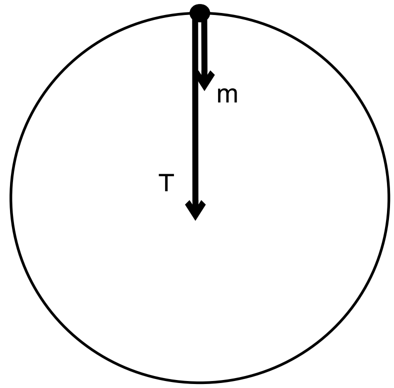
$\therefore N = mg + \frac{mv^2}{r}$

The difference between the top and the bottom is $\frac{2mv^2}{r}$

$\therefore$ A (ANS)

Example 1.36: (2012 Question 7c, 33%)

Consider the motion to be vertical, at **constant** speed.



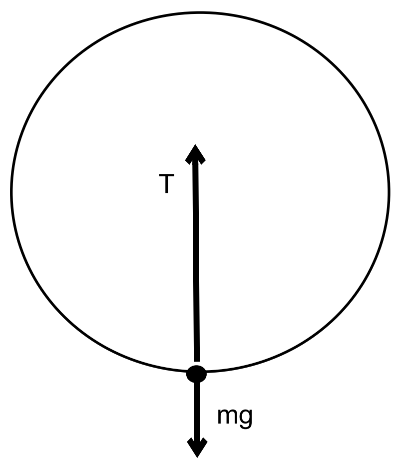
At the top of the path, there are two forces acting on the sphere, its weight, mg, and the tension from the string T.

$\therefore \Sigma F = ma$

Becomes $T + mg = \frac{mv^2}{r}$

$\therefore T = \frac{mv^2}{r} - mg$.

At the bottom of the circle, the situation looks like.



$\therefore \Sigma F = ma$

Becomes $T - mg = \frac{mv^2}{r}$

$\therefore T = \frac{mv^2}{r} + mg$.

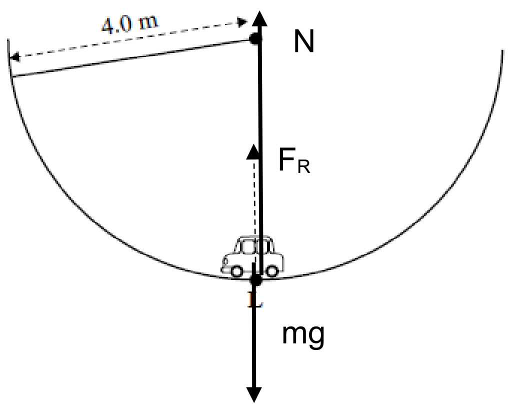
Since $\frac{mv^2}{r}$ is constant, the tension at the bottom is 2mg larger than the force at the top.

$\therefore$ the tension in the string is greater at the bottom of the circular path.

Example 1.37: (2013 Question 5b, 47%)

At the point S there are two forces acting on the mass. The weight is acting down, and the tension force is up.
Since the net force is up,
$\Sigma F = ma$
$\therefore ma = T - mg$
Use $a = \frac{v^2}{r}$
$= \frac{7^2}{1}$
$= 49 \text{ m s}^{-2}$
$\therefore 2.0 \times 49 = T - 2.0 \times 10$
$\therefore$ **T = 118 N (ANS)**

Example 1.38: (2015 Question 3b, 50%)



Use $F_R = ma$
$\therefore \frac{mv^2}{r} = N - mg$
$\therefore \frac{2 \times 6^2}{4} = N - 2 \times 10$
$\therefore N = 18 + 20$
$\therefore$ **N = 38 N (ANS)**

Example 1.39: (NSW 2000 Question 2)

For all circular motion the net force is radially inwards and the velocity is tangential.
$\therefore$ **A (ANS)**

Example 1.40: (1971 Question 4, 83%)

This requires you to express the KE in terms of the momentum and the mass.
Use the relationship $KE = \frac{p^2}{2m}$
$\therefore$ **K =** $\frac{p^2}{2m}$ **(ANS)**

Example 1.41: (1971 Question 5, 76%)

The total energy, T, is constant.
Initially U = 0, therefore
T = KE + PE
$\therefore$ T = KE + 0
$\therefore$ KE = T
$\therefore$ **A (ANS)**

Example 1.42: (1971 Question 6, 45%)

To find the velocity at the highest point, you need to also know the PE at that point. This is not given.
At the top, the vertical component of the velocity will be zero. The horizontal component will depend on the initial angle. This is not given.
$\therefore$ **F (ANS)**

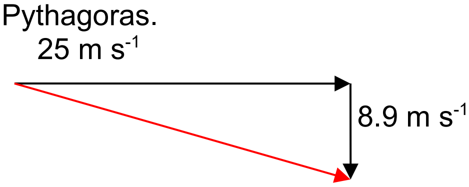
Example 1.43: (2002 Question 5, 47%)

The car must travel the 20 m horizontally while it 'falls' the 4 m vertically.

Time to fall [use $x = ut + \frac{1}{2}gt^2$]
=> t = 0.89 s
$v = \frac{x}{t} = \frac{20}{0.89}$
= 22.36 m s^{-1} (ANS)

Example 1.44: (2002 Question 6, 54%)

Have to use vectors to add the horizontal and vertical velocities OR use energy.
Vertical velocity is found using
$v = u + gt$
$\therefore v = 0 + 10 \times 0.89$
$\therefore v = 8.9 \text{ m s}^{-1}$
Use Pythagoras.



$25^2 + 8.9^2 = 625 + 79.2$
$= 704.2$
$\therefore v = 26.5 \text{ m s}^{-1}$
Energy conservation gives
KE + PE (initially) = KE (at end)
$\therefore \frac{1}{2} \times m \times 25^2 + m \times 10 \times 4$

$= \frac{1}{2} \times m \times v^2$

$\therefore v^2 = 705$

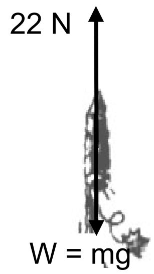
$\therefore$ **v = 26.5 m s^{-1} (ANS)**

Example 1.45: (2006 Question 6, 57%)

$\Sigma F = 22 - mg$

$= 22 - 0.5 \times 10$

= 17 N (ANS)



Example 1.46: (2006 Question 7, 57%)

The rocket has a constant acceleration given by; $a = \frac{F}{m} = \frac{17}{0.50} = 34 \text{ m s}^{-2}$

$\therefore x = ut + \frac{1}{2}at^2$

$\therefore x = 0 + \frac{1}{2} \times 34 \times (1.5)^2$

$\therefore x = 38.25$

$\therefore$ **x = 38 m (ANS)**

Example 1.47: (2006 Question 8, 33%)

To answer this question you need to separate the vertical motion form the horizontal motion.

Horizontal Since air resistance can be ignored, the only horizontal acceleration is due to the constant force of 22 N.

$\therefore v_H = u + at$

$\therefore v_H = 0 + 44 \times 1.5$

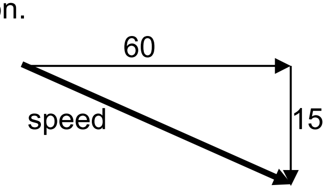
$\therefore v_H = 66 \text{ m s}^{-1}$

Vertical $v = u + gt$

$= 0 + 10 \times 1.5$

$= 15 \text{ m s}^{-1}$

Use vectors to add these and to find the direction.



$\therefore \text{speed} = \sqrt{60^2 + 15^2}$

= **67.7 m s^{-1} (ANS)**

The angle relative to the ground is θ

$\therefore \tan\theta = \frac{15}{60}$

$\therefore$ **θ = 12.8º (ANS)**

(Remember to have calculator in degree mode)

Example 1.48: (2007 Question 17, 53%)

Since the second paintball reaches the same height, it must take the same time as before to reach this height and then all back to the starting height.
The acceleration due to gravity is constant.

∴ A, C (ANS)

Example 1.49: (2008 Question 7, 57%)

Consider this motion in both the horizontal and the vertical directions.

Horizontal

Find the time it takes to travel the 72 m horizontally.

$v_{horizontal}$ = 30 cos(36.9)
= 24 m s^{-1}

Using v = $\frac{d}{t}$

∴ t = $\frac{72}{24}$ = 3 secs

Vertical

Use x = ut + $\frac{1}{2}gt^2$

= 18 × 3 – $\frac{1}{2}$ × 10 × 3^2
= 54 – 45
= 9 m (ANS)

Example 1.50: (2009 Question 11, 52%)

First step: assign a direction to be positive, take 'up' to be positive.
Second step: fill in the data table, (only working through to the top of the flight).

y = ??
u_y = 60 sin(30) = 30 m s^{-1}
v_y = ??
a_y = -10 m s^{-2}
t_y = 9 s

Third step: find an equation that does not involve the final velocity.

y = ut + $\frac{1}{2}gt^2$

y = 30 × 9 + $\frac{1}{2}$ × 10 × 9^2
∴ y = -135 m

The height of the cliff is 135 m.

∴ h = 135 m (ANS)

Example 1.51: (2013 Question 8b, 40%)

The horizontal component of the velocity will remain constant at

$v_H = 20 \cos 30^0$

$= 17.32 \text{ m s}^{-1}$

The vertical component will be

$v = u + gt$

on the way down, u = 0, g = 10, t = 2

$\therefore v = 20 \text{ m s}^{-1}$

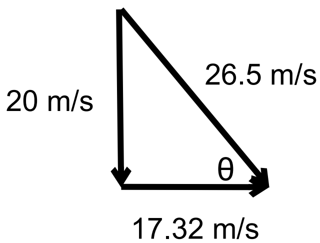
Use Pythagoras to find the magnitude of the velocity.

$\therefore 20^2 + 17.32^2 = v^2$

$\therefore v^2 = 700$

$\therefore v = 26.5 \text{ m s}^{-1}$

To find the angle use



Use $\tan\theta = \frac{20}{17.32}$

$\therefore \theta = 49.1^0$

$\therefore$ v= 26.5 m s^{-1} at an angle of 49.1^0

$\therefore$ 26.5 m s^{-1} 49.1^0 (ANS)

Example 1.52: (2015 Question 5b, 50%)

Find the time taken to get to the point G, by using the initial horizontal speed.

In the horizontal direction

$d = v \times t$

$\therefore 173 = 40 \cos 30^0 \times t$

$\therefore t = 4.99$

$\therefore t = 5.$

Use $h = ut - ½ \times g \times t^2$ to get the vertical position of the ball at 5 seconds.

$\therefore h = 20 \times 5 - ½ \times 10 \times 5^2$

$\therefore h = -25$ m

$\therefore$ 25 m (ANS)

Example 1.53: (2005 Question 8, 65%)

You must convert all masses into kilograms. Find the initial and final momenta.

$m_{car}u_{car} + m_{truck}u_{truck} = (m_{car} + m_{truck})v_f$

$\therefore 1000 \times 0 + 3000 \times u_{truck} = (1000 + 3000) \times 7$

$\therefore 3000u_{truck} = 4000 \times 7$

$u_{truck} = \frac{28000}{3000}$

$u_{truck} = 9.3$

$\therefore$ v = 9.3 m s^{-1} (ANS)

Example 1.54: (2005 Question 9, 65%)

Momentum is conserved in all collisions. In elastic collisions mechanical energy is also conserved. In inelastic collisions mechanical energy is lost as heat and sound and energy used in deformation.

Example 1.55: (2012 Question 2, 30%)

Initial momentum is given by

$mv = 1.2 \times v$ to the right

The block rebounds, so its new momentum is to the left.

As the change in momentum of the 1.2 kg block is given by final momentum – initial momentum, when the change in direction is taken into consideration, this is effectively the scalar sum of the momenta, but to the left.

This will be greater than the initial momentum of the 1.2 kg mass.

From conservation of momentum, this change in momentum of the 1.2 kg mass must be equal to the change in momentum of the 2.4 kg mass.

Example 1.56: (2015 Question 1a, 45%)

Momentum is conserved, so the final momentum is equal to the initial momentum.

$p_i = 4.0 \times 8.0 + 8.0 \times 0$

$\therefore p_i = 32.0$

$\therefore p_f = 32.0$

$\therefore 32.0 = 8.0 \times v - 4.0 \times 2$

$\therefore 32 = 8v - 8$

$\therefore$ v = 5 m s^{-1} (ANS)

Example 1.57: (2002 Question 9, 76%)

Momentum is conserved

$\therefore 10\,000 \times 6 + 5\,000 \times 0 = 15\,000 \times v_f$

$\therefore v_f = \frac{60\,000}{15\,000}$

$\therefore$ v_f = 4 m s^{-1} (ANS)

Example 1.58: (2002 Question 10, 50%)

Impulse = change in momentum.
p_i = 60 000 N s, p_f = 40 000 N s
Δp = 20 000 N s
∴Total impulse = 2.0 x 10^4 N s (ANS)

Example 1.59: (2002 Question 11, 50%)

E_k before collision = ½ × 10000 × 6^2
= 180 000 J
E_k after collision = ½ × 15000 × 4^2
= 120 000 J

60 000 J of mechanical energy has been lost so interaction is not elastic.

Example 1.60: (2006 Question 10, 37%)

From conservation of momentum
$\Sigma p_i = \Sigma p_f$
∴6000 × 5 + M × 0 = (6000 + M) × 0.098
∴30000 = 588 + 0.098 × M
∴29412 = 0.098 M
∴ M = 300122
∴ M = 3.0 × 10^5 kg (ANS)

Example 1.61: (2006 Question 11, 37%)

F Δt = mΔv
∴ F × 20 = 6000 × (5 – 0.098)
∴ F = 6000 × 4.902 ÷ 20
∴ F = 1470.6 N
∴ F = 1.47 × 10^3 N (ANS)

Example 1.62: (2007 Question 3, 70%)

Momentum is conserved in all collisions. So the initial momentum must equal the final momentum.
Initial momentum is 2 × 3 + 1 × 0 = 6 Ns

Final momentum is 2 × x + 1 × 4 = 2x + 4
∴ 2x + 4 = 6
∴ x = 1
∴ the 2kg block is moving at 1 m s^{-1}.

Example 1.63: (2007 Question 5, 70%)

The impulse (change in momentum) is given by FΔt = mΔv

$$\therefore F = \frac{1\times 4}{0.01}$$
= 400 N (ANS)

Example 1.64: (2008 Question 8, 85%)

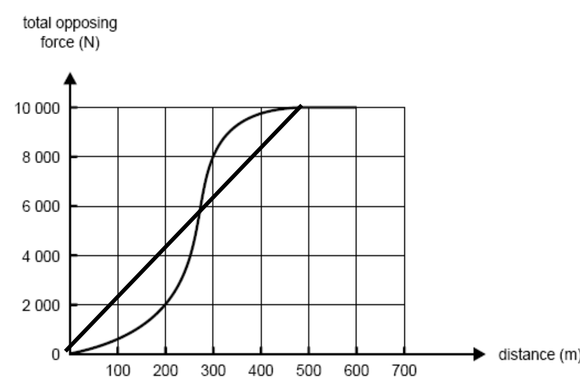
Momentum is conserved in this collision
∴ $p_i = p_f$
∴ 20 × 10^3 × 8 = 80 × 10^5 × v
∴ v = 2 m s^{-1} (ANS

Example 1.65: (2008 Question 9, 63%)

The impulse given to the locomotive by the trucks is equal and opposite to the impulse given to the trucks by the locomotive.
Impulse on trucks is change in momentum of trucks
= mΔv
= 60 × 10^3 × 2
= 1.2 × 10^5 kg m s^{-1} West (ANS)

Example 1.66: (1999 Question 5, 55%)

Work done = area under force v displacement graph.
The examiners actually want to make these exams to be straight forward, so these curves often have a very simple solution to them. The graph was specifically drawn to be symmetrical, to simplify the area calculation. If you drew a straight line from the origin to the coordinates (500, 10 000), you should see that the 'curve' is symmetrical.
This means that the shape is actually a triangle, so the area = ½ × (10 000 + 0) × 500
= 2.5 × 10^6



This can also be done by counting squares.
Each square is 2 000 × 100 = 200 000J
There are 13 squares
∴ WD = 13 × 200 000 = 2 600 000J
∴2.5 × 10^6 J (ANS)
A range of answers was accepted for this question.

Example 1.67: (2006 Question 3, 60%)

The work done by the force is the change in KE

$\therefore \Delta KE = KE_{final} - KE_{initial}$

$= -\frac{1}{2}(90 + 40) \times 6^2$

$= -2340$ J

Use the modulus

$\therefore F \times d = 2340$

$= (190 + 70) \times d$

$\therefore d = \frac{2340}{260}$

$\therefore$ **d = 9 m (ANS)**

Example 1.68: (2004 Pilot Question 14, 23%)

Initial energy = mgh.
We need to find 'h'.
Work done to overcome friction

$f \times d = 50 \times 6 = 300$ J

KE gained $= \frac{1}{2}mv^2$

$= \frac{1}{2} \times 30 \times 8^2$

$= 960$ J

So total work done by gravity

$= 300 + 960 = 1260$ J

$\therefore mgh = 1260$

$\therefore h = \frac{1260}{30 \times 10}$

= **4.2 m (ANS)**

Example 1.69: (2004 Pilot Question 15, 53%)

The KE of the of the box is given by

$KE = \frac{1}{2}mv^2$

$= \frac{1}{2} \times 30 \times 8^2$

$= 960$ J

Elastic potential of the spring is given by:

$E = \frac{1}{2}k(\Delta x)^2$

$\therefore \frac{1}{2} \times 30\,000 \times (\Delta x)^2 = 960$

(as no energy is lost sliding across the floor)

$\therefore 15\,000 \times (\Delta x)^2 = 960$

$\therefore x^2 = \frac{960}{15\,000}$

$\therefore$ **Δx = 0.25 m (ANS)**

Example 1.70: (2007 Question 9, 43%)

The extension (change in length) is

$0.6 - 0.4 = 0.2$ m

$F = k\Delta x$

$\therefore mg = k\Delta x$

On substitution, $m \times 10 = 20 \times 0.2$

$\therefore$ **m = 0.4 kg (ANS)**

Example 1.71: (2007 Question 10, 43%)

WD = area under the graph.
It is also given by

$\frac{1}{2}k(\Delta x_f)^2 - \frac{1}{2}k(\Delta x_i)^2$

$= \frac{1}{2} \times 20 \times 0.3^2 - \frac{1}{2} \times 20 \times 0.2^2$

= 0.5 J (ANS)

Example 1.72: (2007 Question 11, 47%)

Since we can ignore air resistance (stated in the question) the system does not lose energy.

$\therefore$ the total energy is constant.

$\therefore$ **D (ANS)**

Example 1.73: (2008 Question 12, 55%)

The energy stored in the spring is $\frac{1}{2}k(\Delta x)^2$

$= \frac{1}{2} \times 10 \times (0.2)^2$ (use metres)

= 0.2 J (ANS)

Example 1.74: (2008 Question 13, 40%)

The ball will be stationary (momentarily) at the top and the bottom of the oscillation. Therefore the KE will be zero at these points. The KE will be a maximum at the midpoint.

$\therefore$ **D (ANS)**

Example 1.75: (2008 Question 14, 50%)

The gravitational potential energy is measured from the point of release.

$\therefore$ at the bottom, PE = 0.

$\therefore$ **A (ANS)**

Example 1.76: (2009 Question 5, 55%)

The kinetic energy gained by the mass is the elastic energy that was stored in the spring.
The spring was compressed 10 cm.
From this we can find the following.

$\therefore \frac{1}{2}mv^2 = \frac{1}{2}k(\Delta x)^2$

$\therefore \frac{1}{2} \times 0.20 \times 5.0^2 = \frac{1}{2} \times k \times (0.10)^2$

$\therefore 2.5 = 0.005 \times k$

$\therefore$ **k = 500 N m^{-1} (ANS)**

Example 1.77: (2010 Question 14, 35%)

The total energy is the sum of the
$PE_{Elastic}$ + mgh.

$PE_{elastic} = \frac{1}{2}k(\Delta x)^2$

$= \frac{1}{2} \times k \times 0.4^2$

Also F = k × x

$\therefore 20 = k \times 0.4$

$\therefore$ k = 50

$\therefore PE_{elastic} = \frac{1}{2} \times 50 \times 0.4^2$

= 4 Joule (gain)

$PE_{gravitational}$ = mgh

= 2 × 10 × 0.4

= 8 Joule loss.

$\therefore$ Change in energy

= 4 J (ANS)

Example 1.78: (2010 Question 15, 55%)

The total energy will remain con stant throughout the interaction.

TE = KE + $PE_{elastic}$

$PE_{elastic}$ increases when the spring is compressed (in the middle of the interaction)

Therefore if $PE_{elastic}$ increases, KE must decrease.

$PE_{elastic}$ returns to zero after the interaction, therefore the KE will return to its initial value.

$\therefore$A (ANS)

Example 1.79: (2010 Question 17, 55%)

Momentum is ALWAYS conserved.

$\therefore$B (ANS)

Example 1.80: (2011 Question 16, 55%)

The force acting is mg = 1.0 × 10

= 10 N

The extension is 70 – 40 = 30 cm (0.3 m)

$F = k \times \Delta x$

$\therefore 10 = k \times 0.3$

$\therefore$ k = 33.3 N m^{-1} (ANS)

Example 1.81: (2011 Question 17, 42%)

The kinetic energy will start from zero, go to a maximum and then return to zero.

$\therefore$ D (ANS)

Example 1.82: (2011 Question 19, 46%)

The gravitational energy will start at a minimum, when L = 80 cm, and increase as L decreases to 60 cm.

$\therefore$ B (ANS)

Example 1.83: (2011 Question 20, 27%)

The strain energy is minimum (but not zero) at 60 cm. It will increase until 80 cm.

The increase is not linear as, $E = \frac{1}{2}k(\Delta x)^2$

$\therefore$ F (ANS)

Example 1.84: (2012 Question 1c, 55%)

Energy stored in the spring is given by

$E = \frac{1}{2}k(\Delta x)^2$

$\therefore 5.4 = \frac{1}{2} \times k \times 0.08^2$

(Make sure that you use Δx in metres)

$\therefore k = \frac{2 \times 5.4}{0.08^2}$

$\therefore$ k = 1688

$\therefore$ k = 1.7 x 10^3 N m^{-1} (ANS)

Example 1.85: (2013 Question 6a, 80%)

From the graph, at Z, the GPE is zero, so the total energy is 20 J

$\therefore$ 20 J (ANS)

Example 1.86: (2013 Question 6b, 45%)

This is a conservation of energy question. From the graph, at the point Y, the SPE = 5 J, the GPE = 10 J. Since the TE = 20 J, and remains constant, the KE must be 5 J.

$\therefore \frac{1}{2}mv^2 = 5$ J

$\therefore \frac{1}{2} \times 1 \times v^2 = 5$

$\therefore v^2 = 10$

$\therefore$ v = 3.16 m s^{-1} (ANS)

Example 1.87: (2013 Question 6c, 17%)

They have assumed that the SPE (Spring Potential Energy) at Q = 0.

This is not correct because the spring has already been extended from its original length of 2.0 m.

$SPE_Q = \frac{1}{2}k(\Delta x)^2$, where Δx = 0.5.

$\therefore SPE_Q = \frac{1}{2} \times 10 \times 0.5^2$

= 1.25 J

$\therefore$ TE_Q = 10 + 1.25 = 11.25J

$SPE_P = \frac{1}{2} k(\Delta x)^2$, where Δx = 1.5.

$\therefore SPE_P = \frac{1}{2} \times 10 \times 1.5^2$

= 11.25 J

$\therefore$ TE_P = 0 + 1.25

= 11.25 J

Example 1.88: (2014 Question 2a, 60%)

Use the equation $F = k \times \Delta x$

F = mg, so

$0.05 \times 10 = k \times 0.1$

$\therefore 0.5 / 0.1 = k$

$\therefore k = 5 \text{ N m}^{-1}$

$0.1 \times 10 = k \times 0.2$

$\therefore 0.1 / 0.2 = k$

$\therefore k = 5 \text{ N m}^{-1}$

$0.15 \times 10 = k \times 0.3$

$\therefore 0.15 / 0.3 = k$

$\therefore k = 5 \text{ N m}^{-1}$ (ANS)

Example 1.89: (2014 Question 2b, 20%)

If the four 50 g masses were allowed to hang under their weight, the spring would be extended to 80 cm.

If they are released from 40 cm, then the spring will extend 40 cm past the 80 cm point.

$\therefore$ the extension will be 80 cm.

$\therefore$ 0.8 m (ANS)

(This is on the assumption that the spring has not exceeded its elastic limit.)

Example 1.90: (2014 Question 2c, 35%)

The total energy is the sum of three forms of energy, spring potential energy, gravitational potential energy and Kinetic energy.

Since Jo is not including the kinetic energy, she is wrong, and the varying kinetic energy needs to be added to the other two to get a constant total energy at any point.

Example 1.91: (2014 Question 2d, 13%)

The maximum speed will occur in the middle of the oscillation.

This is when Δx = 0.4. This is when a = 0, because $\sum F = 0$.

At the lowest point, when it is momentarily stationary, the KE = 0. We also take this point to have GPE = 0.

$\text{Total Energy}_{(\text{lowest point})}$ = KE + GPE + SPE

$= 0 + 0 + ½ \times 5 \times 0.8^2$

$= 2.5 \times 0.64$

= 1.6

At Δx = 0.4

TE = KE + GPE + SPE

$1.6 = KE + 0.2 \times 10 \times 0.4 + ½ \times 5 \times 0.4^2$

$\therefore KE = 1.6 – (0.8 – 0.4)$

$\therefore$ KE = 0.4

$\therefore ½ \times 0.2 \times v^2 = 0.4$

$\therefore 0.1 \times v^2 = 0.4$

$\therefore v^2 = 4$

$\therefore v = 2 \text{ m s}^{-1}$ (ANS)

Example 1.92: (2015 Question 6c, 40%)

The total energy of the system = 16 J.

From $SPE = ½ k(\Delta x)^2$

$\therefore ½ \times 50 \times (0.8)^2$

$\therefore$ 16 J

The maximum KE is at the midpoint.

$\therefore TE = ½ k(\Delta x)^2 + ½ mv^2 + mgh$

Where Δx = 0.4m and the height above the lowest point is h = 0.4.

$\therefore 16 = ½\times50\times0.4^2 + ½\times2\times v^2 + 2\times10\times0.4$

$\therefore 16 = 4 + v^2 + 8$

$\therefore v^2 = 4$

$\therefore v = 2 \text{ m s}^{-1}$ (ANS)

Example 1.93: (2015 Question 6d, 35%)

At the top, the net force is down, as the mass is about to move downwards, hence accelerate downwards. This has a negative value (since upwards is positive). The mass reaches its maximum speed at 0.4 m. Therefore the acceleration is zero.

At the bottom, the mass is about to move upwards, therefore the acceleration is up (positive).

$\therefore$ C (ANS)

Example 1.94: (1969 Question 1, 80%)

Considering the downstream direction, the ferry travels 2 km due to the river flow.

At 4 km / hr, this means that the ferry was in the river for 30 mins.

In this time it travelled 1 km across the stream.

$\therefore$2 km /hr

$\therefore$ **C (ANS)**

Example 1.95: (1969 Question 2, 76%)

The ferry will take 30 mins to cross the river. See previous answer.

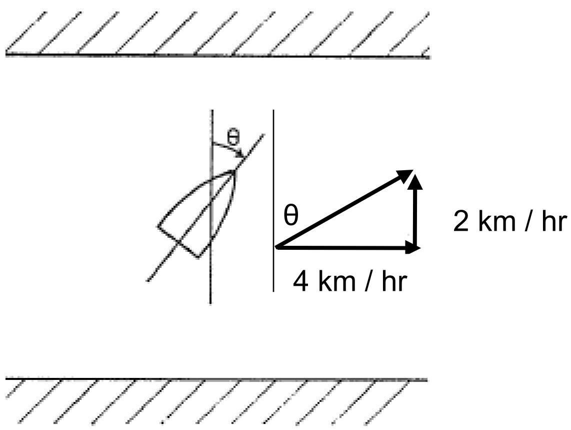
∴ **C (ANS)**

Example 1.96: (1969 Question 3, 74%)

In order for the boat to go directly across the river it needs to have a component of 4 upstream, and a component of 2 across stream.

The angle θ is given by $\tan\theta = \frac{4}{2}$

∴ **D (ANS)**

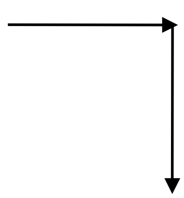


Example 1.97: (NSW 2000 Question 2, 66%)

Use $\text{velocity}_{B \text{ relative to } A} = \boldsymbol{v}_{ba} = \boldsymbol{v}_b - \boldsymbol{v}_a$.
Where $v_b = 20$ m s^{-1} East, and $v_a = 20$ m s^{-1} N.
To subtract vectors you add the inverse.

∴ $v_b - v_a = v_b + -v_a$.

∴ 20 m s^{-1} East + 20 m s^{-1} South.



The resultant is $20\sqrt{2}$ SE

∴ **C (ANS)**

Example 1.98: (NSW 2013 Question 8, 66%)

An inertial frame is a frame that is not accelerating.

∴ **D (ANS)**

Example 1.99: (2010 Question 5, 16%)

Carriage A is an inertial frame, so Newton's second law applies. Carriage B is decelerating, therefore it is not an inertial frame, so Newtons second law will not apply.

∴ **A (ANS)**

Example 1.100: (2012 Question 1, 25%)

Light is an electromagnetic radiation, where the changing electric field induces a changing magnetic field that induces a changing electric field etc.
We also know that light slows down when it is in a material with a refractive index greater than 1.
Therefore D is incorrect, as well as B and C.

∴ **A (ANS)**

The most common incorrect answer was D (72%).

Example 1.101: (2015 Question 2, 32%)

Light is an electromagnetic radiation, where the changing electric field induces a changing magnetic field that induces a changing electric field etc.

∴ **B (ANS)**

The most common incorrect answer was D (44%). (This is quite a poor response seeing this is a very similar question to 2012 Question 1.)

Example 1.102: (2008 Question 7, 72%)

The speed of sound is 340 m s^{-1}, but Trung is moving in the same direction as the sound at 40 m s^{-1}, therefore the relative speed of sound is 300 m s^{-1}. Mary would measure the speed of sound to be 340 + 40 m s^{-1} therefore 380 m s^{-1}.

∴ **B (ANS)**

Example 1.103: (2008 Question 8, 83%)

The speed of light in one medium is constant, at c.

∴ **B (ANS)**

Example 1.104: (2010 Question 1, 61%)

Jim is in the proper frame, so use

$t = \frac{d}{v}$ which becomes

$t = \frac{d}{c}$ for light

$\therefore t = \frac{1000}{3 \times 10^8}$

$\therefore t = 3.3 \times 10^{-6}$ s

∴ C (ANS)

Example 1.105: (2010 Question 2, 57%)

Susanna is in a moving frame of reference so her length will be contracted.

Use $L = \frac{L_0}{\gamma}$

In this case $\gamma = \frac{1}{\sqrt{1 - \frac{(0.9c)^2}{c^2}}}$

$\therefore \gamma = 2.294$

$\therefore L = \frac{1000}{2.294}$

$\therefore L = 436$ m

∴ A (ANS)

Example 1.106: (2010 Question 6, 56%)

The observers are in the proper frame, so use $d = v \times t$

$\therefore d = 0.85 \times 3 \times 10^8 \times 784 \times 10^{-6}$

$\therefore d = 199{,}920$ m

$\therefore d = 200$ km

∴B (ANS)

Example 1.107: (2010 Question 7, 54%)

The robot is in a moving frame relative to where the time was measured, therefore the robots time will be shorter.

In this case $\gamma = \frac{1}{\sqrt{1 - \frac{(0.85c)^2}{c^2}}}$

$\therefore \gamma = 1.90$

The time as measured by the robot is

$\frac{784}{1.90} = 413 \times 10^{-6}$ s

∴ A (ANS)

Example 1.108: (2010 Question 8, 31%)

Proper time is the measured by a clock and is the time between two events that occur at the same place as the clock.
This is true for the robot, but not the observers on the planet.

∴ D (ANS)

Example 1.109: (2010 Question 12, 75%)

The speed of the light is c. The speed of the dart is V + U, for a stationary observer on the ground.

∴ A (ANS)

Example 1.110: (NSW 2007 Question 2)

The length L is the true length of the spaceship, l_0 because it was measured in the same frame of reference as the space ship.
When the length of the spaceship is measured by an observer on the spaceship they will be in the same frame of reference and hence will measure the spaceship's length to be its true length, L, hence there will be no change.
However when observed on the planet, length contraction will occur and at the speed 0.95c, the length will be observed to be shorter than L.

∴ A (ANS)

Example 1.111: (NSW 2011 Question 9)

When observed by a stationary observer across the street, length contraction will have occurred. The spacecraft will be observed to be shorter in the direction of motion of the craft.

∴ B (ANS)

Example 1.112: (NSW 2014 Question 19)

To get a length contraction from 200 to 160 m, gamma need to be 1.25.

i.e. $L = \frac{L_0}{\gamma}$ becomes $\gamma = \frac{L_0}{L}$,

therefore $\gamma = \frac{200}{160}$.

$$1.25 = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$\therefore \sqrt{1-\frac{v^2}{c^2}} = \frac{1}{1.25}$$

$$\therefore 1-\frac{v^2}{c^2} = \frac{1}{(1.25)^2}$$

$$\therefore 1-\frac{v^2}{c^2} = 0.64$$

$$\therefore \frac{v^2}{c^2} = 0.36$$

$\therefore$ v = 0.6 c

∴ A (ANS)

Example 1.113: (2014 Question 4, 25%)

Radio signals are part of the EM spectrum, so they travel at c. The classical interpretation would have the speed of the radio wave signal travelling at a speed of *c* irrespective of the motion of the transmitter. The wavelength and frequency would vary in the forward and backward directions but the speed would not vary. Therefore, the speed relative to *Hector* would be *c* – 0.4*c* = 0.6*c.*

∴ A (ANS)

Example 1.114: (2014 Question 6, 37%)

Proper time is the measured by a clock and is the time between two events that occur at the same place as the clock.
Neither crew can measure proper time. There is no single observer can be in both places

∴ D (ANS)

Example 1.115: (2008 Question 1, 81%)

When observed by an observer on the rocket, length contraction will have occurred. The window will be observed to be shorter in the direction of motion.

∴ B (ANS)

Example 1.116: (2005 Question 2, 59%)

When you multiply or divide by 1, the value does not change.
The other way of thinking about this is that relativistic effect only occur at high speeds.
When the speed is close to zero, γ = 1

∴ C (ANS)

Example 1.117: (2005 Question 4, 62%)

To get a length contraction from 20 to 10 m, gamma need to be 2.

i.e. $L = \frac{L_0}{\gamma}$ becomes $\gamma = \frac{L_0}{L}$,

therefore $\gamma = \frac{20}{10}$.

$\therefore 2 = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$

$\therefore \sqrt{1-\frac{v^2}{c^2}} = \frac{1}{2}$

$\therefore 1-\frac{v^2}{c^2} = 0.25$

$\therefore \frac{v^2}{c^2} = 0.75$

$\therefore v = 0.87\ c$

∴ C (ANS)

Example 1.118: (2008 Question 9, 89%)

Roger measure the proper length, as he is stationary with respect to the ruler.

∴ C (ANS)

Example 1.119: (2011 Question 11, 43%)

Length can be observed to contract, so the proper length is always greater than or equal to all measurements made by other observers

∴ A (ANS)

Example 1.120: (2011 Question 9, 42%)

Use $t = \frac{d}{v}$ which becomes

$t = \frac{5.4\times10^{-3}}{2.5\times10^{8}}$

$\therefore t = 2.16 \times 10^{-11}$ s

The proper time is the time measured in the frame of the particle.

Use $t_0 = \frac{t}{\gamma}$

$\therefore t_0 = \frac{2.6\times10^{-11}}{1.81}$

$\therefore t_0 = 1.19 \times 10^{-11}$ s

∴ D (ANS)

Example 1.121: (2008 Question 10, 71%)

The increase in energy goes more in to mass energy than kinetic energy

∴ B (ANS)

Example 1.122: (2008 Question 11, 67%)

Use $\gamma = 4$

$\therefore 4 = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$

$\therefore \sqrt{1-\frac{v^2}{c^2}} = \frac{1}{4}$

$\therefore 1-\frac{v^2}{c^2} = \frac{1}{(4)^2}$

$\therefore 1-\frac{v^2}{c^2} = 0.0625$

$\therefore \frac{v^2}{c^2} = 0.9375$

$\therefore v = 0.968\ c$

∴ C (ANS)

Example 1.123: (2008 Question 12, 60%)

Use $L = \frac{L_0}{\gamma}$

$\therefore \gamma = 4$

$\therefore L = \frac{600}{4}$

$\therefore L = 150$ m

∴ D (ANS)

Example 1.124: (2012 Question 8, 46%)

Since $t = \gamma t_0$, therefore $t_0 = \frac{t}{\gamma}$ where t_0 is the proper time

γ is always greater than or equal to1.

Thus t_0 must be always less than *t*.

∴ A (ANS)

Example 1.125: (2010 Question 4, 69%)

The proper length is measured by an observer that is at rest relative to the object

∴ **B (ANS)**

Example 1.126: (2013 Question 8, 24%)

Time in a frame of reference that is moving will be observed to run slower than time in your own frame, proper time. Therefore proper time is the shortest time possible between two events, because otherwise the clocks will be observed to run slower.

∴ **C (ANS)**

Example 1.127: (2013 Question 11, 37%)

The satellite is travelling horizontally, so the speed in the vertical direction is zero. Therefore there will not be any length contraction in the vertical direction.

∴ **C (ANS)**

Example 1.128: (NSW 2001 Question 16a)

Time dilation

Example 1.129: (NSW 2001 Question 16b)

Use $t_0 = \frac{t}{\gamma}$

$\therefore \gamma = \frac{t}{t_0}$

$\therefore \gamma = \frac{5}{2.2}$

Use $\gamma = 2.27$

$$2.27 = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$\therefore \sqrt{1 - \frac{v^2}{c^2}} = \frac{1}{2.27}$$

$$\therefore 1 - \frac{v^2}{c^2} = \frac{1}{(2.27)^2}$$

$$\therefore 1 - \frac{v^2}{c^2} = 0.1936$$

$$\therefore \frac{v^2}{c^2} = 0.8064$$

∴ **v = 0.9 c (ANS)**

Example 1.130: (NSW 2016 Question 19)

In the muon's frame, lifetime is 2.2 μs, but in other frames clocks will be observed to run slower, so the muons lifetime will be greater.

$\therefore$ **A (ANS)**

Example 1.131: (2008 Question 13, 60%)

The initial mass = $1.673 \times 10^{-27} + 1.675 \times 10^{-27}$

$\therefore 3.348 \times 10^{-27.}$

Therefore the mass difference

$= 3.348 \times 10^{-27} - 3.344 \times 10^{-27}$

$= 0.004 \times 10^{-27}$ kg

Using $\Delta E = mc^2$.

$\therefore \Delta E = 0.004 \times 10^{-27} \times (3.0 \times 10^8)^2$

$= 0.036 \times 10^{-11}$

$= 3.6 \times 10^{-13}$ J.

$\therefore$**B (ANS)**

Example 1.132: (2010 Question 11, 34%)

Use KE = $(\gamma - 1)m_0c^2$ to get

$7.714 \times 10^{-10} = (\gamma - 1) \times 6.64424 \times 10^{-27} \times (3.0 \times 10^8)^2$

$$(\gamma - 1) = \frac{7.714 \times 10^{-10}}{5.9798 \times 10^{-10}}$$

$\therefore (\gamma - 1) = 1.29$

$\therefore \gamma = 2.29$

$$\therefore 2.29 = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$\therefore \sqrt{1 - \frac{v^2}{c^2}} = \frac{1}{2.29}$$

$$\therefore 1 - \frac{v^2}{c^2} = \frac{1}{(2.29)^2}$$

$$\therefore 1 - \frac{v^2}{c^2} = 0.1907$$

$$\therefore \frac{v^2}{c^2} = 0.8093$$

$\therefore v = 0.899\ c$

$\therefore$ **A (ANS)**

Example 1.133: (2011 Question 1, 39%)

For one proton use

Use KE = $(\gamma - 1)m_0c^2$ to get

$1.1 \times 10^{-6} = (\gamma - 1) \times 1.6726 \times 10^{-27} \times (3.0 \times 10^8)^2$

$$(\gamma - 1) = \frac{1.1 \times 10^{-6}}{1.50534 \times 10^{-10}}$$

$\therefore (\gamma - 1) = 7\ 307.3$

$\therefore \gamma = 7308.32$

Use $m = m_0\ \gamma$

$\therefore m = 1.6726 \times 10^{-27} \times 7308.32$

$\therefore m = 1.222 \times 10^{-23}$ kg

This needs to be doubled

$\therefore 2.4 \times 10^{-23}$ kg

$\therefore$ **B (ANS)**

Example 1.134: (2011 Question 3, 47%)

The change in KE is the work done.

KE = $(\gamma - 1)m_0c^2$

$\therefore \Delta KE = (\Delta\gamma)m_0c^2$

$\therefore WD = (1.1 - 1.05) \times 1.50 \times 10^{-10}$

$\therefore WD = 7.5 \times 10^{-12}$ J

$\therefore$ **C (ANS)**

Example 1.135: (2011 Question 10, 41%)

The best answer to this question is

$\therefore$ **C (ANS)**

Example 1.136: (2014 Question 11, 39%)

Use rest mass energy of one pion

= 2.25×10^{-11} J (from question 10)

The work done = $(\gamma - 1)m_0c^2$

$\therefore (3 - 1)\ m_0c^2 = 2\ m_0c^2$

$\therefore WD = 2 \times 2.25 \times 10^{-11}$

$\therefore WD = 4.5 \times 10^{-11}$

$\therefore$ **A (ANS)**

Example 1.137: (2015 Question 10, 43%)

It is probably best to eliminate the incorrect answers. (This is an unusual method in physics) A is incorrect, the mass can't increase (in its own frame). C does not make any allowance for the relativistic increase in mass, and the rest mass of as particle can't increase.

$\therefore$ **B (ANS)**

How do things move without contact solutions?

Example 2.1: (1975 Question 61, 73%)

The electric field is exerted an upward force to balance the weight.

$\therefore$ Eq = mg

$\therefore E = \frac{mg}{q}$

$\therefore E = \frac{1.6 \times 10^{-15} \times 10}{3.2 \times 10^{-19}}$

$\therefore$ E = 5 × 10^4 V m^{-1} (ANS)

Example 2.2: (1975 Question 62, 64%)

Use $E = \frac{V}{d}$

$\therefore 5 \times 10^4 \times d = 1000$

$\therefore$ d = 0.02 m (ANS)

Example 2.3: (1975 Question 63, 64%)

The force from the electric field is to the left, the weight is down.

$\therefore$ F (ANS)

Example 2.4: (NSW 2011 Question 19)

The electric field is the direction of the force on a positive charge. Therefore the force on the electron is down.

$\therefore$ D (ANS)

Example 2.5: (NSW 2012 Question 6)

If the charge doubled, so would the field. This would be represented by twice as many field lines in the same area.

$\therefore$ C (ANS)

Example 2.6: (NSW 2016 Question 5)

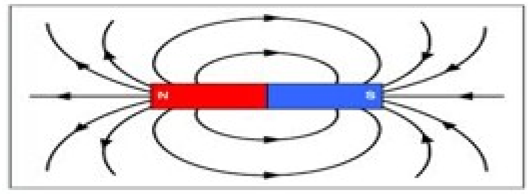
Use $E = \frac{V}{d}$

$\therefore E = \frac{15}{5 \times 10^{-3}}$

$\therefore E = 3 \times 10^3 \text{ V m}^{-1}$

$\therefore$ D (ANS)

Example 2.7: (2007 Question 1, 73%)

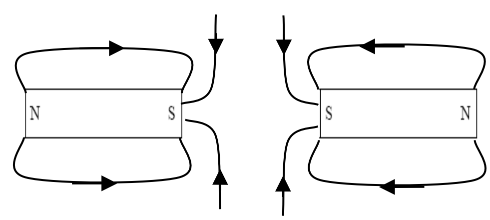


The lines leave the left North end, turn around and go either above or below the magnet towards the South end, then turn around and enter the South end. The arrows on the lines at either end should point to the left, while the arrows on the line above and below the magnet should point to the right.

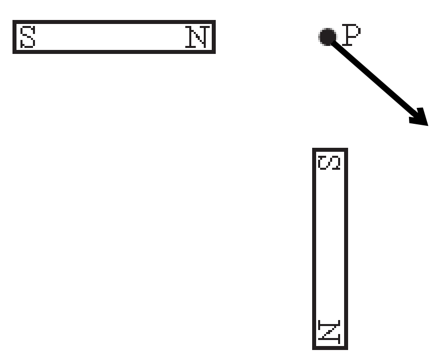
Examiner's comment

Although this was expected to be an easy introductory question, that was not the case. Common mistakes included field lines touching, crossing or joining together at the poles. Sometimes no complete field lines were shown, or the arrows were in the wrong direction.

Example 2.8: (2007 Question 2, 73%)



Example 2.9: (2011 Question 1, 44%)



The direction of the field is given by the sum of the fields from the horizontal magnet (to the right) and from the vertical magnet (down). The two components have the same size so the angle needed to be 45^0.

Examiner's comments
Many students drew the complete magnetic field instead of an arrow to indicate the direction of the field at point P. Student's understanding of how to add fields as vectors needs improvement.

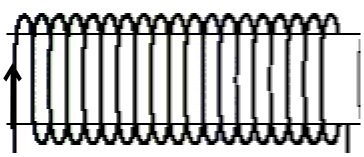
Example 2.10: (NSW 1996 Question 11)

Field lines around current carrying wires are typically drawn as concentric circles. With both currents in the same direction, the field at the midpoint between the wires must cancel to zero.

∴ **B (ANS)**

Example 2.11: (NSW 1997 Question 24)

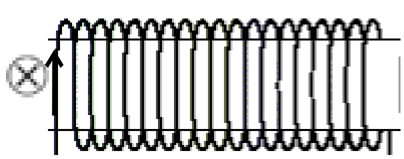
a.



b This is for a straight wire into the page with the current flowing into the page.

⊗

c. This is a combination of the previous two situations.



Example 2.12: (NSW 2000 Question 10)

Field lines around current carrying wires are typically drawn as concentric circles. When the current is into the page, the field will be

∴ **D (ANS)**

Example 2.13: (1970 Question 64, 48%)

The force on C due to A is larger than 4 × 10^{-5}, since the separation is less.

The separation is now $\frac{2}{3}$ of original so force has increased by a factor of $\frac{9}{4}$

∴ $F_{\text{on C due to A}}$ = 9 × 10^{-5} N to the right.

The $F_{\text{on C due to B}}$ will be 4 times this, as it is twice as close.

∴ $F_{\text{on C due to B}}$ = 36 × 10^{-5} N to the left.

Taking directions into consideration, the total force is (36 – 9) × 10^{-5} N to the left

∴ **2.7 × 10^{-4} N left (ANS)**

Example 2.14: (1970 Question 65, 56%)

The change in charge will change the direction of the force. They will now both act to the left. Therefore the net force (36 + 9) × 10^{-5} N to the left.

∴ **4.5 × 10^{-4} N left (ANS)**

Example 2.15: (1982 Question 51, 22%)

The force of Y on X is repulsive, the force of W on X is attractive.
The net force on X is to the left.
The force of Z on X needs to be attractive to overcome the repulsive force from Y.
Let us assume that the force from Y on X is of magnitude 1.
Since the force of Z on X is at an angle, the component of this force in the vertical is what is required. Since it acts at 45^0, the component is smaller. So the force needs to be $\sqrt{2}$ larger. It also acts from a greater distance, in fact the distance is $\sqrt{2}$ larger. Since the force varies as $1/r^2$ to have the same effect the force needs to be twice the size.

Therefore the effective force is × 2 × $\sqrt{2}$,

∴ +2.8 q.

∴ **D (ANS)**

Example 2.16: (1971 Question 67, 40%)

Since the large sphere is uncharged the force will be zero. The minimum separation is 11 cm.

∴ **A (ANS)**

Example 2.17: (1971 Question 68, 70%)

The force is going to vary as $\frac{1}{r^2}$, and the minimum separation has to be 11 cm. Since the spheres have touched, they have shared the charge from the smaller sphere, so they both have the same sign of charge, therefore they will repel each other

∴ **D (ANS)**

Example 2.18: (1972 Question 63, 50%)

The $F_{\text{on q due to \#Q}} = \frac{3}{4}$ F, because the charge is 3 times as great but the distance is twice as far. We now need to add these two forces as vectors.

Using Pythagoras we get $\frac{3}{4}$ F + $\frac{4}{4}$ F = $\frac{5}{4}$ F

∴ $\frac{3}{4}$ **F (ANS)**

Example 2.19: (1986 Question 51)

Use E = $\frac{\Delta V}{d}$

∴ E = $\frac{V}{0.080}$

∴**12. 5 V (ANS)**

Example 2.20: (1986 Question 53)

An electric field exists when there is a potential difference. The closer the equipotential lines are together the greater the electric field.

∴ **D (ANS)**

Example 2.21: (1986 Question 54)

The field is perpendicular to the equipotential lines.

∴ **D (ANS)**

Example 2.22: (1986 Question 55)

The electron will be attracted to the closest positive plate, therefore it will up to the top plate. It will go through a potential difference of 600 V. ∴ it will have an energy of 600 eV

∴ **B (ANS)**

Example 2.23: (1987 Question 57, 89%)

Use E = $\frac{\Delta V}{d}$

∴ E = $\frac{120}{2.5}$

∴**48 V m^{-1} (ANS)**

Example 2.24: (1987 Question 59, 75%)

The electric field is the direction of the force on a small unit positive charge.

∴ **G (ANS)**

Example 2.25: (1987 Question 60, 50%)

Use WD = qV

∴ 8.0 × 10^{-19} × 12

∴ **9.6 × 10^{-18} J (ANS)**

Example 2.26: (1988 Question 47)

The electric field is given by F = Eq, and

F = $k\frac{Q_1Q_2}{r^2}$

∴ E = $k\frac{Q_1}{r^2}$

∴ E = 9.0 × 10^9 × $\frac{8.0\times10^{-8}}{2^2}$

∴ **E = 18 V m^{-1} (ANS)**

Example 2.27: (1988 Question 48)

Use F = Eq

∴ F = 18 × 4 × 10^{-10}

∴ **F = 7.2 ×10^{-9} N in direction D (ANS)**

Example 2.28: (1989 Question 51)

Use F = $k\frac{Q_1Q_2}{r^2}$

∴ N = k × $\frac{C^2}{m^2}$

∴ k must have units of N C^{-2} m^2

∴ **D (ANS)**

Example 2.29: (1989 Question 52)

Use a cartesian axes system.
–Q will exert a force in – y and – x directions
+Q will exert a force in + y and – x directions.
The sum of these force will be in the – x direction.

∴ **E (ANS)**

Example 2.30: (1990 Question 46)

Since the charge of the neutron is zero, the electrostatic force between them must be zero

∴ **0 N (ANS)**

Example 2.31: (1990 Question 47)

Use F = Eq

∴ 118 = E × 1.6 × 10^{-19}

$\therefore$ **E = 7.38 × 10^{20} V m^{-1}**

Example 2.32: (1990 Question 48)

The electric field midway between the two protons must be zero, as the field due to each proton cancel out.

∴ **0 (ANS)**

Example 2.33: (1990 Question 49)

F = Eq, where E = $\frac{1.0\times10^6}{5.0\times10^{-4}}$

∴ E = 2 × 10^9 V m^{-1}

The ratio of the forces will be exactly the ratio of the fields.

∴ $\frac{5.0\times10^9}{7.38\times10^{20}}$ = 6.8 × 10^{-12}

∴ **A (ANS)**

Example 2.34: (1991 Question 42)

If the charge +q was a distance d from +Q, at Point X, then the force on it would be F = $k\frac{Qq}{d^2}$ as it is a distance of $\frac{d}{4}$ from +Q the force will be 16 × $k\frac{Qq}{d^2}$, to the right.

Using a similar argument the force on +q from the charge +Q at Y will be $\frac{16}{9}$ × $k\frac{Qq}{d^2}$, to the left. The net force is the vector sum of these

∴ (16 - $\frac{16}{9}$) × $k\frac{Qq}{d^2}$

∴ **F (ANS)**

Example 2.35: (1991 Question 43)

The two forces will cancel.

∴ **A (ANS)**

Example 2.36: (1988 Question 49)

Use E = $\frac{\Delta V}{d}$

∴ E = $\frac{500}{0.05}$

∴**10 000 V m^{-1} (ANS)**

Example 2.37: (1988 Question 50)

Use F = Eq

∴ F = 10 000 × 1.6 × 10^{-19}

∴ **F = 1.6 × 10^{-15} N (ANS)**

Example 2.38: (1988 Question 51)

The force due to the electric field is given by F = Eq, and the force due to the magnetic field is F = Bqv.

∴ E = Bv if the forces are to be of the same size, and in the opposite directions.

∴ 2.0 × 10^4 = B × 5.0 × 10^5

∴ **B = 0.04 (ANS)**

Example 2.39: (2009 Question 3, 80%)

Use F = Eq

∴ F = 200 × 10^3 × 1.6 × 10^{-19}

∴ F = 3.2 × 10^{-14}

∴ **C (ANS)**

Example 2.40: (2009 Question 4, 46%)

Use WD = ΔKE = F × d

0.5 × 9.1 × 10^{-31} × (8.4 × 10^7)^2 = 3.2 × 10^{-14} × d

∴ d = 0.1 m

∴ **B (ANS)**

Example 2.41: (NSW 2007 Question 11)

Use E = $\frac{\Delta V}{d}$

∴ E = $\frac{100}{0.001}$

∴100 000 V m^{-1}

∴ **D (ANS)**

Example 2.42: (NSW 2009 Question 15)

The electric field between parallel plates is modelled to be uniform.

∴ **A (ANS)**

Example 2.43: (NSW 2016 Question 3)

The electric field will exert a force, but the magnetic field only exerts a force on the charge when it is moving

∴**C (ANS)**

Example 2.44: (NSW 2013 Question 14)

Use E = $\frac{\Delta V}{d}$

If ΔV is kept constant, then as the plates move apart the field will get weaker. It will be an inverse variation.

∴ B (ANS)

Example 2.45: (NSW 2015 Question 24a)

The electron is deflected in the wrong direction because it should be attracted towards the positive plate (or repelled by the negative plate).
The electron does not suddenly get deflected at the midpoint as shown because the plate's field deflects the electron from the point it enters the region between the plates on the left.
The electron does not follow a straight path anywhere between the plates because its acceleration is uniform towards the positive plate.

Example 2.46: (NSW 2015 Question 24b)

Use F = Eq and E = $\frac{\Delta V}{d}$

∴ F = $\frac{\Delta V}{d}q$

∴ F = $\frac{5000 \times 1.6 \times 10^{-19}}{0.02}$

∴ F = 4 × 10^{-14} N (ANS)

Example 2.47: (NSW 2015 Question 24c)

Use F = ma

$4 \times 10^{-14} = 9.1 \times 10^{-31} \times a$

∴ $a = 4.4 \times 10^{16}$ m s^{-2}

Then use $v^2 = u^2 + 2 a x$

∴ $v^2 = 0 + 2 \times 4.4 \times 10^{16} \times 0.02$

∴ v = 4.19 × 10^{7} m s^{-1} (ANS)

Example 2.48: (NSW 2001 Question 2)

The field is out of the page, The current is in the direction of v,
Use your right hand rules to get force to the right.

∴ A (ANS)

Example 2.49: (2010 Question 1, 61%)

Use F = Eq and F = ma

∴ Eq = ma

∴ $E \times 1.6 \times 10^{-19} = 9.1 \times 10^{-31} \times 1.8 \times 10^{15}$

∴ E = 10 238

∴ B (ANS)

Example 2.50: (2010 Question 2, 68%)

Use $\Delta KE = Vq$
$0.5 \times 9.1 \times 10^{-31} \times (4.6 \times 10^{7})^{2} = V \times 1.6 \times 10^{-19}$
$\therefore V = 6017$
$\therefore$ C (ANS)

Example 2.51: (2010 Question 3, 78%)

Use $qvB = \frac{mv^2}{r}$
$\therefore 1.6 \times 10^{-19} \times 4.6 \times 10^{7} \times B = \frac{9.1\times10^{-31}\times(4.6\times10^{7})^2}{0.40}$
$\therefore 7.36 \times 10^{-12} \times B = 4.8139 \times 10^{-15}$
$\therefore B = 6.54 \times 10^{-4}$
$\therefore$ B (ANS)

Example 2.52: (2010 Question 4, 74%)

Use $F = Bqv$
$\therefore F = 5.0 \times 10^{-4} \times 1.6 \times 10^{-19} \times 4.6 \times 10^{7}$
$\therefore F = 3.68 \times 10^{-15}$
$\therefore$ B (ANS)

Example 2.53: (NSW 2006 Question 12)

Since F = Bqv, answers A and B cannot be correct. The force is perpendicular to the direction of motion, therefore D is not correct.
$\therefore$ C (ANS)

Example 2.54: (NSW 2010 Question 15)

Use $qvB = \frac{mv^2}{r}$
If B is doubled, then the force doubles, since the mass and the speed remain constant r must halve.
$\therefore$ B (ANS)

Example 2.55: (NSW 2014 Question 18)

The magnetic field will exert a force down the page on the negative charge. The electric field needs to exert a force up the page. Since it is a cathode ray, then the electric field will be down the page.
$\therefore$ D (ANS)

Example 2.56: (NSW 2016 Question 23b)

Use Bqv = Eq
∴ B × 5.2 × 10^4 = 10
∴ B = 1.85 × 10^{-4}
The electric field will exert of force out of the page on the electrons.
The magnetic field needs to exert a force into the page, therefore the magnetic field needs to be up the page.
∴ 0.0002 T up the page (ANS)

Example 2.57: (NSW 2007 Question 4)

Since $g = \frac{GM}{r^2}$, if the radius reduced to a quarter of its original then the acceleration would increase by a factor of 16.
∴ D (ANS)

Example 2.58: (2002 Question 1, 53%)

Area under graph is something like 11 to 13 squares
Each square has a value of
1000 × 3 × 10^6 = 3 × 10^9 J
∴ at least **3.3 × 10^{10} J (ANS)**

Allowing for a variation in the number of squares counted, a range of values **3.3 to 4.4 × 10^{10} J**, was accepted.

Example 2.59: (2004 P Sample Q 12, 80%))

The gravitational force, F, acting on the satellite (the only one) is directed from the satellite towards the centre of the earth.
This is F = mg, where $g = \frac{GM}{R^2}$, M is the mass of the earth, R the distance from the satellite to the centre of the earth, and G is the gravitational constant. We also know (given) that $g = \frac{4\pi^2 R}{T^2}$, where T is the period of the satellite orbit.
The value of
R = 3.8 ×10^5 m + 6.4 × 10^6 m = 6.78 × 10^6 m.

This gives $T = \sqrt{\frac{4\pi^2 R^3}{GM}}$

$$\therefore T = \sqrt{\frac{4\pi^2(6.78\times10^6)^3}{6.67\times10^{-11}\times6\times10^{24}}}$$

∴ T = 5.5 × 10^3 s.
∴ 5.5 × 10^3 s (ANS)

Example 2.60: (2004 P Sample Q 13, 27%)

This satellite is moving at constant speed as the altitude (given) implies a circular orbit. The only force acting is from the satellite towards the centre of the earth, and as R is constant this force is constant. This constant force implies a constant acceleration.
∴D (ANS)

Example 2.61: (2005 Question 14, 40%)

mg is the force that a mass *m* feels at the surface of Earth.
∴ g is the acceleration that a mass *m* feels at the surface of the Earth. Hence statement B is incorrect.
∴ B (ANS)

Example 2.62: (2007 Question 12, 47%)

Using $g_{Eris} = \frac{GM}{r^2_{Eris}}$ and $g_{Pluto} = \frac{GM}{r^2_{Pluto}}$

gives $\frac{g_{Eris}}{g_{Pluto}} = \frac{\frac{GM}{r^2_{Eris}}}{\frac{GM}{r^2_{Pluto}}} = \frac{r^2_{Pluto}}{r^2_{Eris}}$

On substitution $\frac{r^2_{Pluto}}{r^2_{Eris}} = \frac{(6.0\times10^{12})^2}{(10.5\times10^{12})^2}$

$= \frac{6.0^2}{10.5^2}$

= 0.33

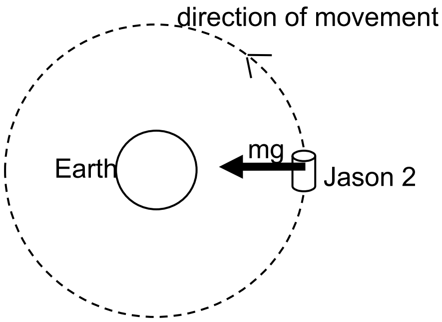
∴ A (ANS)

Example 2.63: (2008 Question 15, 50%)

The comet will basically have a constant energy as it orbits the Sun. (Even though it is losing a minute amount as it burns).
The total energy is the sum of the PE and KE. The comet will gain PE as it moves away from the sun, therefore it must lose KE. This means that it will travel faster at X than Y.
As the comet moves from X to Y, **the speed will decrease and the energy will remain constant (ANS)**

Example 2.64: (2009 Question 13, 40%)

There is only one force acting on Jason 2 as it orbits, that is its weight force and this acts towards the centre of the Earth.



Students were required to draw **and** label arrow(s) to represent any force(s) acting on the satellite orbiting the Earth.
The required answer was one arrow from the satellite and pointing towards the Earth, with a label *weight* or *gravitational force* or *mg* or *Fg*.
It was not acceptable to label it F_{net}.

Example 2.65: (2011 Question 21, 74%)

W = mg, if the visitor weighs the same then g must equal 10 on both the planet and the Earth.

$\therefore$ **10 N kg^{-1} (ANS)**

Example 2.66: (2011 Question 22, 50%)

Use F = mg

$= \frac{GMm}{r^2}$

$\therefore g_{Visitor} = \frac{GM_V}{r_V^2}$

also $g_{Earth} = \frac{GM_E}{r_E^2}$

$\therefore \frac{M_V}{r_V^2} = \frac{M_E}{r_E^2}$

$\therefore M_V = \frac{M_E r_V^2}{r_E^2}$

$= \frac{5.9\times10^{24}\times(3.4\times10^4)^2}{(6.37\times10^6)^2}$

$\therefore$ **M_V = 1.33 × 10^{20} kg (ANS)**

Example 2.67: (2011 Question 23, 50%)

Use $\frac{GMm}{r^2} = \frac{mv^2}{r}$

$\therefore \frac{GM}{r} = v^2$

Use $v = \frac{2\pi r}{T}$

$\therefore \frac{GM}{r} = \frac{4\pi^2 r^2}{T^2}$

$\therefore T^2 = \frac{4\pi^2 r^3}{GM}$

$\therefore T^2 = \frac{4\pi^2\times(1\times10^9)^3}{6.67\times10^{-11}\times5.7\times10^{25}}$

$\therefore T^2 = 1.04 \times 10^{13}$

$\therefore$ **T = 3.22 × 10^6 secs (ANS)**

Example 2.68: (2013 Question 7a, 41%)

Period = 24 hours
= 24 x 60 x 60
= 8.64 x 10^4 s (ANS)

Example 2.69: (1970 Question 23, 70%)

Use $F = \frac{GMm}{R^2}$ and F = mg to get

$g = \frac{GM}{R^2}$ (ANS)

Example 2.70: (1970 Question 24, 64%)

Use $\frac{GMm}{R^2} = \frac{mv^2}{R}$

$\therefore \frac{GM}{R} = v^2$

$\therefore v = \sqrt{\frac{GM}{R}}$

Since $g = \frac{GM}{R^2}$

$\therefore$ v can be written as $\sqrt{gR}$

$\therefore$ **D (ANS)**

Example 2.71: (1997 Question 1)

This is the standard manipulation of the formula obtained when equating the Gravitational field strength to the centripetal acceleration. I.e.

$$\frac{GM}{R^2} = \frac{4\pi^2 R}{T^2}$$

$$\therefore R^3 = \frac{GM}{4\pi^2} T^2$$

To get full marks you needed to:

- State Newton's law of universal gravitation
- State that the centripetal force for uniform circular motion.
- Make the two expressions to be equal.

Example 2.72: (1997 Question 2)

Substitute the data, into the formula and solve for R.

$$\therefore R^3 = \frac{GM}{4\pi^2} T^2$$

$$\therefore R^3 = \frac{6.67\times10^{-11}\times6.0\times10^{24}}{4\times\pi^2} \times (8.64 \times 10^4)^2$$

$$\therefore R^3 = 7.567 \times 10^{22}$$

$\therefore$ **R = 4.22 × 10^7 m (ANS)**

Example 2.73: (1997 Question 4)

Since the Voyager was moving closer to Jupiter, its Kinetic energy will have *increased* by 4.0 x 10^{11} J. This will have resulted from a *drop or decrease* in Gravitational Potential Energy of 4.0 x 10^{11} J.

Example 2.74: (1997 Question 5, %)

The area under the force vs separation graph has to equal this change of energy. Point C represents a separation of 4 on the horizontal axis. We need to have an area under the graph to equal 4.0 x 10^{11} J.

Example 2.75: (1995 Question 1, 52%)

Use $v = \frac{2\pi r}{T}$

$$\therefore v = \frac{2\times\pi\times6.76\times10^6}{5.52\times10^3}$$

$\therefore$ **v = 7.7 × 10^3 m s^{-1} (ANS)**

Example 2.76: (1995 Question 2, 50%)

Use $\frac{GMm}{r^2} = \frac{mv^2}{r}$

$$\therefore \frac{GM}{r} = v^2$$

Use $v = \frac{2\pi r}{T}$

$$\therefore \frac{GM}{r} = \frac{4\pi^2 r^2}{T^2}$$

$$\therefore M = \frac{4\pi^2 r^3}{GT^2}$$

$$\therefore M = \frac{4\pi^2\times(6.76\times10^6)^3}{6.67\times10^{-11}\times(5.52\times10^3)^2}$$

$\therefore$ **M = 6.0 × 10^{24} kg (ANS)**

Example 2.77: (1995 Question 5, 45%)

This is a force-distance graph. The area under this graph is the work done on the satellite to move it into the orbit further from the Earth. This is equal to the gain in gravitational potential energy of the satellite.

$\therefore$ **A (ANS)**

Example 2.78: (1978 Question 64, 80%)

The field is uniform, therefore use F = BiL

$\therefore$ F = 0.50 × 2.0 × 0.10

$\therefore$ **F = 0.1 N (ANS)**

Example 2.79: (1978 Question 65, 61%)

The current will flow from O to R, the field is from N to S, therefore the force on OR will be down.

$\therefore$ **B (ANS)**

Example 2.80: (1978 Question 66, 69%)

QR is parallel to the field, therefore the force on it is zero.

$\therefore$ **0 N (ANS)**

Example 2.81: (1996 Question 7)

Use F = nBiL

$\therefore$ F = 20 × 3.0 × 10^{-2} × 2.0 × 0.05

$\therefore$ **F = 6.0 × 10^{-2} N (ANS)**

Example 2.82: (1996 Question 8)

KL is parallel to the field, therefore the force on it is zero.

∴ 0 N (ANS)

Example 2.83: (2004 Pilot Question 3, 35%)

Rearranging F = nBil, (with n = 1) gives B = $\frac{F}{iL}$

$= \frac{0.01}{1 \times 0.01}$

∴ B = 1.0 T (ANS)

Be careful with the measurements of the wire (10 mm = 0.01 m)

Examiner's comment

It was disappointing how many students were unable to convert 10 mm to metres. The simple transposition required to obtain B also caused difficulty for a surprising number of students.

Example 2.84: (2004 Pilot Question 4, 57%)

The wire will vibrate up and down at 100 Hz.

Example 2.85: (2000 Question 9)

The right hand slap rule give that the fingers are pointing form N to S (ie. from right to left), the current is pointing to the top of the page, so the palm is facing upwards. Therefore the force is out of the page.

∴ H (ANS)

Example 2.86: (2000 Question 10)

The force at the point y is zero, because the direction of the current is parallel to the field here. Therefore the component of the current perpendicular to the field is zero.

∴ I (ANS)

Example 2.87: (2000 Question 11)

The right hand slap rule give that the fingers are pointing form N to S (ie. from right to left), the current is pointing to the bottom of the page (in general), so the palm is facing downwards. Therefore the force is into the page.

∴ G (ANS)

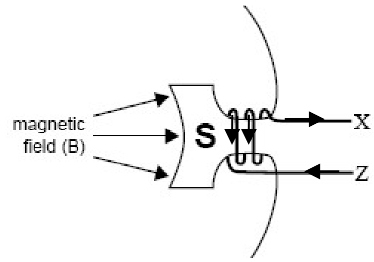
Example 2.88: (2000 Question 12)

The right hand slap rule give that the fingers are pointing from N to S (ie. from right to left), the current is pointing to the top of the page, so the palm is facing upwards. Therefore the force is out of the page.

∴ H (ANS)

Example 2.89: (2001 Question 9, 54%)

To produce a field to the right, the current in the wire loops on the 'front' of the electromagnet must be going down, from the right hand grip rule.



∴ B (ANS)

Example 2.90: (2001 Question 10, 68%)

Use F = nBil

F = 50 × 0.10 × 1.5 × 0.12

F = 0.9 N (ANS)

Example 2.91: (2002 Question 11, 58%)

F = nBil

= 50 × 0.005 × 3.0 × 0.05

= 0.038 N (ANS)

(Remember to convert cm to m)

Example 2.92: (2002 Question 12, 73%)

The direction of the force is always perpendicular to both P and the magnetic field. As the field is to the right, and the current is to the rear of the page, the right hand rule gives the force as downwards.

∴ B (ANS)

Example 2.93: (2002 Question 13, 32%)

The commutator needs to be free to rotate since this is the way that the connection is made between the external current source and the coil itself via the brushes rubbing on the commutator.

The motor rotates because the force on the sides of the coil that are perpendicular to the magnetic applies a torque to the coil. This torque is down on the side nearest the south pole and up on the side nearest the north pole, given the direction of current flow shown on the diagram.
However, when the coil rotates into the vertical position, the force on side P at the bottom needs to reverse in order for the torque to be applied in the clockwise direction.
For this to happen, the direction of the current needs to reverse and it is the role of the split-ring commutator to do this. The split in the ring is such that as the coil gets to the vertical position, the direction of the current flow through the coil reverses and the direction of the torque applied to the coil remains in the same direction.

Example 2.94: (2014 Question 17c, 50%)

The force on WX is down and ZY is up. Both these forces have the same magnitude, but act in opposite directions. As they act at different points this pair of forces produce a torque to rotate the coil.

How are fields used to move electricity solutions

Example 3.1: (1970 Question 90, 20%)

A This will cause the flux in coil 1 to change, this will lead to an induced current in coil 1

B This will not induce a change in flux through coil 1

C This will create a change in flux through coil 1, therefore there will be an induced current in coil 1

D This will change the current flowing in oil 2. This will change the field produced by coil 2. This will change the flux through coil1, inducing a current.

∴ A, C, D (ANS)

Example 3.2: (1972 Question 91, 84%)

The face is parallel to the field.

∴ Flux = 0 (ANS)

Example 3.3: (1972 Question 92, 76%)

Flux = BA (ANS)

Example 3.4: (1972 Question 93, 47%)

$$\text{EMF} = \frac{\Delta\Phi}{\Delta t}$$

$$= \frac{BA}{t}$$

Use V = iR

$$\therefore i = \frac{BA}{tR} \text{ (ANS)}$$

Example 3.5: (1981 Question 70, 22%)

If the rate of rotation is doubled, two things will happen. The induced EMF will be doubled and the period will be halved.

∴ B (ANS)

Example 3.6: (2000 Question 3)

It must be the negative gradient of the B vs t graph. Initially the graph had a constant positive gradient, (which will be shown as a negative straight line) followed by zero gradient (shown as zero) and then a constant negative gradient (shown as a constant positive line).

∴ D (ANS)

Example 3.7: (2002 Question 9, 24%)

From Lenz's Law the induced field produced by the coil must oppose the increasing external magnetic field caused by the magnet moving closer. The induced field must therefore be to the right, towards the magnet.
From the RH grip rule, to get a magnetic field that points out of the centre of the coil to the right will require the current to flow anti-clockwise when viewed from the magnet towards the end of the coil.
The current through the external resistor will thus flow from left to right.

Example 3.8: (2002 Question 10, 45%)

As the magnet approaches the induced current will increase to a maximum as the magnet enters the coil, it will then be zero while the magnet moves through the coil (it is assumed that 'small' magnet will not change the flux in the coil). As the magnet exits the coil and moves away this will result in a reduction of the field within the coil and the induced current will flow in the direction needed to try and maintain the field, i.e. it will reverse.

∴ Diagram A (ANS)

Example 3.9: (2003 Question 8, 75%)

$$\varphi = BA$$
$$= 0.25 \times 0.30 \times 0.40$$
$$\mathbf{= 0.030\ Wb\ (ANS)}$$

Example 3.10: (2003 Question 9, 35%)

$$T = \frac{1}{f}$$
$$= \frac{1}{50}$$
$$= 0.020\ \text{s}$$

A rotation through 90^0 is $\frac{1}{4}$ of a revolution, which will take 0.005 s.

$$EMF_{AVE} = -n\frac{\Delta\varphi}{\Delta t}$$

$$|EMF_{AVE}| = n\frac{\Delta\varphi}{\Delta t}$$

$$= 20 \times \frac{0.030}{0.0050}$$

= 120 V (ANS)

Example 3.11: (2003 Question 10, 62%)

The flux starts as a positive maximum, and then decreases to zero. It will then vary sinusoidally.

∴ B (ANS)

Example 3.12: (2003 Question 11, 28%)

$$EMF = -n\frac{\Delta\varphi}{\Delta t}$$

The flux starts at a maximum, and then decreases, so, according to Lenz's law, the induced EMF (current) will oppose this change. This means that the induced current would flow from V to U to increase the flux.

The V vs t graph is the negative of the gradient of the ϕ vs t graph. The graph starts with a zero gradient, and then the gradient becomes a negative maximum. So the Induced EMF should start from zero and go to a positive maximum.

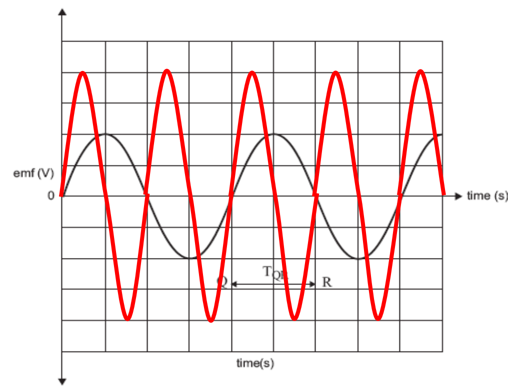
But this current flows from V to U initially, unfortunately the question asks for current in the direction from U to V, so it starts at zero and goes to a negative maximum.

∴ D (ANS)

Example 3.13: (2005 Question 5, 57%)

When the rotation speed of the coil is increased to 20 revolutions per second, the output signal will change in two ways. The period will halve **and** the amplitude will double.

The doubling of the amplitude is because the emf is given by $\xi = -n\frac{\Delta\Phi_B}{\Delta t}$ and since Δt has halved, the ξ must double.



Examiner's comment

Although most students realised the period had to be halved, a significant number did not realise the amplitude would be doubled.

Example 3.14: (2005 Question 15, 53%)

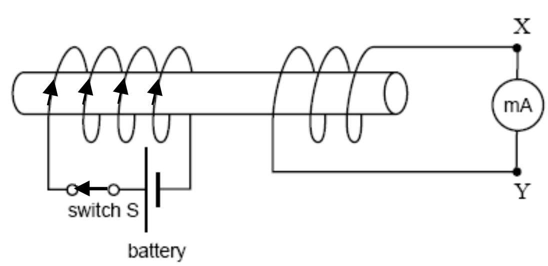
Faraday's law gives the size of the induced EMF, while Lenz's law gives the direction of the induced EMF and the direction of the induced current.

Faraday's law states that "The magnitude of the induced emf is directly proportional to the rate of change of magnetic flux".

Faraday's law is summarised as

$$\xi = -n\frac{\Delta\Phi_B}{\Delta t}$$

Lenz's Law states that "the direction of the induced EMF is the same as that of a current whose magnetic action would <u>oppose</u> the flux change". This is the 'minus' sign in the equation.



Examiner's comment

Explanations of Lenz's Law were often unclear. Even when students knew that it had something to do with the direction of the *induced EMF, their explanations were often incorrect. A large number of students referred to induced current rather than induced voltage.*

Example 3.15: (2006 Question 8, 43%)

Using $\xi = -n\dfrac{\Delta\Phi_B}{\Delta t}$, here the flux changes from zero to a maximum in $\frac{1}{2}$ sec.

(The loop is travelling at 4 cm s^{-1} and it is 2 cm wide, so it takes $\frac{1}{2}$ sec to enter the field completely.)

The field strength is 3.7×10^{-3} T

The area is 2 cm × 2 cm = 4×10^{-4} m^2

$$\therefore \xi = -n\frac{\Delta\Phi_B}{\Delta t},$$

$$= 1 \times \frac{3.7\times10^{-3}\times4\times10^{-4}}{0.5}$$

$$= 2.96 \times 10^{-7} \text{ V}$$

= 3 × 10^{-7} V (ANS)

Examiner's comment

This was a challenging question. Calculating the area of the loop in square metres proved to be difficult for many students, but determining the time interval was the real stumbling block. Instead of calculating the time for the loop to enter (or exit) the field, many used the time for it to pass through the entire field.

Example 3.16: (2007 Question 14, 45%)

When the switch is closed, there will be a current in the primary coil circuit. The current will change from zero to a constant value.

When the current is changing from zero to this constant value, it will create a changing magnetic field in the iron core.

This changing magnetic field will induce a momentary current in the secondary coil and hence in the milliammeter.

In the primary coil, the current is from right to left through the switch.

This will create a North pole at the left hand end of the iron core. To oppose this, the induced current will create a North pole at the extreme right hand end of the iron core. This will lead to a current as shown below.

Therefore the momentarily induced current will be from Y to X.

∴ B (ANS)

Examiner's comment

This question was not well done. Students clearly had difficulty applying Lenz's law.

Example 3.17: (2007 Question 15, 40%)

This question required you to state Lenz's law and then apply it to this context.

Lenz's Law states that "the direction of the induced EMF is the same as that of a current whose magnetic action would oppose the flux change"

This means that the current in the secondary coil must be opposite to the current in the primary coil.

When the current in the primary coil is changing from zero to a constant value, it will create a changing magnetic flux to the left.

This will be opposed by the induced current in the secondary coil producing a changing magnetic flux to the right.

To do this the current in the secondary coil must be in the direction Y to X.

Examiner's comment

Very few students were able to explain the application of Lenz's law.

Example 3.18: (2008 Question 8, 55%)

The emf graph will be produced from the change in flux that the loop experiences. This change only occurs as the loop enters the magnetic field and as it exits the field. The emf will be in the opposite direction as the loop exits the magnetic field compared to when it entered.

∴ C (ANS)

Example 3.19: (2008 Question 9, 60%)

First you need to calculate how much flux is in the coil:

$$\Phi = BA$$

$$\Phi = 4.0\times10^{-3}\times0.02\times0.02$$

$$\Phi = 1.6\times10^{-6}\text{ Wb}$$

Now calculate the amount of time taken to exit the magnetic field.

The loop is 2.0 cm wide and travelling at a speed of 2.0 cm/s. So it will take the loop 1.0 seconds to exit the magnetic field.

To find the emf you now use:

$$\varepsilon = \frac{\Delta\Phi}{\Delta t}$$

$$\varepsilon = \frac{1.6\times10^{-6}}{1.0}$$

$$\varepsilon = 1.6\times10^{-6}\,V$$

$\therefore$ **1.6×10^{-6} V (ANS)**

Examiner's comments

The most common error made by students was not converting (or incorrectly converting) centimetre to metre. Other students incorrectly worked out the time for the loop to exit the field.

Example 3.20: (2008 Question 10, 43%)

The direction of the current can be found by applying Lenz's law. The induced current in a loop will be in the direction that will create a flux that is in the opposite direction to the change in flux that created the current. Applying Lenz's law to the square loop, the change in flux the loop experiences is having the flux into the page being reduced. To oppose that change the loop will generate a current that puts some magnetic field back into the page. For the loop to generate a field into the page the current must flow from Q to P through the square loop.

Examiner's comments

Most students were able to quote Lenz's law but many were unable to apply it to the specific situation. Some quoted Lenz's law as opposing the flux instead of the change in flux. Few referred to the direction of the initial flux or its change and others had the change in flux going to the left or right. Another approach to Lenz's law had an induced electromagnetic force opposing the motion which caused it. Students who employed this approach tried to use the 'right hand slap' rule to deduce the direction of the current, but generally could not successfully do so. It is possible that some students did not read the question carefully and gave the current direction through the external ammeter instead of through the square loop.

Example 3.21: (2010 Question 2, 45%)

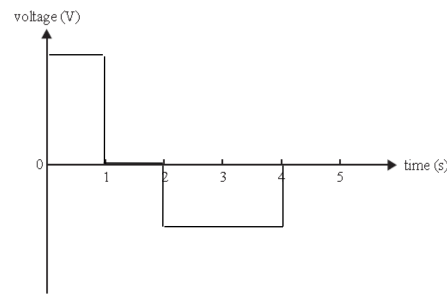
Inside the loop the magnetic field is parallel to the loop. Therefore there is not any flux threading the loop.

$\therefore$ **0 (ANS)**

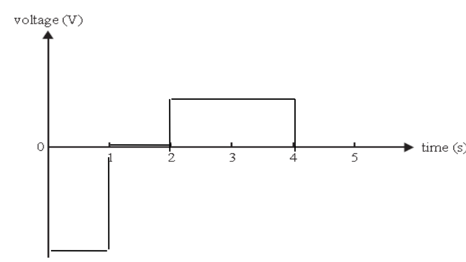
Example 3.22: (2010 Question 8, 40%)

Using the graph as setting the direction, the gradient between 0 - 1 sec is a positive constant, therefore the induced EMF will be a negative constant. Between 1 - 2 sec, the gradient is zero, therefore the induced EMF is zero. Between 2 - 4 sec, the gradient is negative and half the original, therefore the induced EMF will be half the size and positive.

Therefore, you get



As the direction of positive is not defined the graph could also look like the one below.



Examiner's comments

It was important that the first voltage was about twice that of the second; however, many students missed this point.

Example 3.23: (2010 Question 9, 44%)

Faraday's Law was used to determine the size of the relative voltages, and Lenz's law to give the relative directions.

Example 3.24: (2010 Question 11, 50%)

The original flux was from left to right. This flux was decreasing. To oppose this change in flux, the induced flux needed to try to reinforce the changing flux, by adding to it. A current was required from Q $\rightarrow$ P to do this.

Examiner's comment
Many students wrote about the induced flux opposing the original flux rather than the change in the original flux.

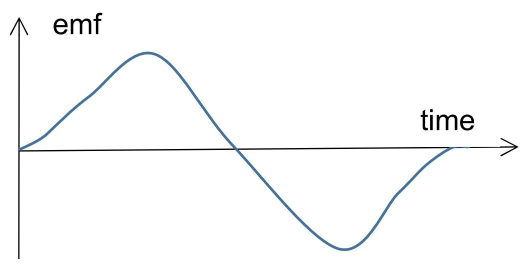
Example 3.25: (2011 Question 6, 63%)
The device was now acting as a DC generator.
∴ A (ANS)

Example 3.26: (2011 Question 7, 35%)

As the coil rotates, the changing flux induces an AC voltage. The commutator reverses the connection every half cycle, converting this AC to (varying) DC.

Examiner's comments
Common errors included neglecting the commutator.

Example 3.27: (2011 Question 11, 50%)



The graph needed to show an increase to a maximum over time, then a decrease to zero. Followed by a mirror image in the negative demonstrating what happened on the way out. It was also possible to have a small flat section in the middle (at zero).
The graph starts at zero, as the magnet moves towards the loop, the number of south field lines going through the loop increase, the induced emf opposes this increase in flux. As the loop feels the south field increasing, so it will produce a north field to oppose this increase. This north field is produced by a positive emf.
When the magnet gets close to the loop, the field lines going through the loop become almost parallel, so there is not a significant change in flux, so the opposing emf decreases to zero.
The reverse happens on the way out.
(You did not need to include any explanation, and I wouldn't as it is very hard to put into words).

Examiner's comment
Most students realised that the polarity would change after passing through the loop. However, many drew square graphs above and below the axis. If the flux was changing at a constant rate, it would not suddenly commence at an arbitrary distance from the loop.

Example 3.28: (2011 Question 12, 43%)

The N-pole of the magnet is on the left. As the magnet moves away from the loop, the magnetic flux to the left decreases. The loop feels the north field going through it, decreasing.
Lenz's law says that the induced current will oppose the change in flux.
Therefore an induced current flows anticlockwise in the loop to produce magnetic field to the left

Examiner's comments
This question was very poorly done. Many students wrote generalities about Lenz's law instead of showing that they could apply their understanding to this particular situation. It should be noted that Lenz's law refers to the change in flux, not just the flux. The EMF induced results from a change in flux, not simply a change in the magnetic field.

Example 3.29: (2012 Question 8c, 33%)

As the loop moves from position 2 to position 3, the flux through it is decreasing. Therefore the induced EMF is going to try to reinforce the flux.
As viewed from the South pole, the current will go from X to Y in the square loop, so that the induced EMF is adding to the decreasing flux from the North pole.

Example 3.30: (2013 Question 17b, 45%)

The EMF will be zero when the gradient of the flux vs time graph is zero.

After t = 0, and before t = 2.0 gives

0.5, 1.0, 1.5 secs (ANS)

Example 3.31: (2013 Question 17c, 27%)

The current will be clockwise when viewed from above.
The induced current will oppose the changing flux that is creating it. The ring has increasing flux, therefore the current will be clockwise, to create a field downwards to oppose this increase in flux.
This is an application of Lenz's law.

Example 3.32: (2013 Question 17d, 27%)

At point A: (0), 2.0
At point B: 1.0
At point C: 0.5, 1.5, (2.5)

Example 3.33: (2014 Question 13a, 33%)

For a current to flow, the flux needs to change,. Therefore either the field strength needs to alter or the area within the field needs to alter. With both **A, B** there is no change in flux through the loop, therefore no induced current. **C** will decrease the flux, Therefore an induced current. **D** will change the flux, therefore an induced current.

$\therefore$ **C, D (ANS)**

Example 3.34: (2014 Question 13c, 37%)

The initial flux is downwards, and decreases to zero. The direction of the induced magnetic field will try to oppose this change in flux.
The induced field will try to strengthen the downwards field (hence flux).
To get a field pointing down, from the right hand grip rule, the direction of the current must be clockwise.

Example 3.35: (2015 Question 12c, 43%)

One quarter of a revolution will take 0.125 sec.

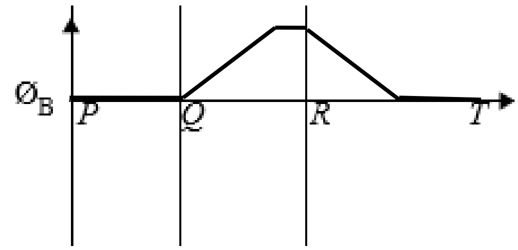
$$\varepsilon = n\frac{\Delta\Phi}{\Delta t}$$

$$\varepsilon = 10 \times \frac{2.0\times10^{-3}\times(16\times10^{-4}-0)}{0.125}$$

$$\varepsilon = 2560\times10^{-7}\,\text{V}$$

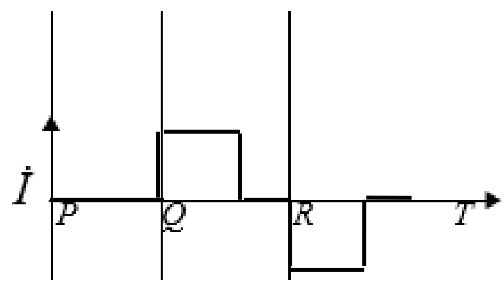
$\therefore$ **256 mV (ANS)**

Example 3.36: (2015 Question 13a,20%)



The flux is zero before the loop enters the field between the magnets. Therefore the flux is zero until the front edge reaches Q. The flux then increases linearly to a maximum (When the loop is completely between the magnet ends) then remains constant until the loop starts to leave the field (R). The flux will decrease linearly to zero. The rate of increase of flux will be the same as the rate of decrease of the flux on leaving the field. Once out of the field the flux will remain zero.

Example 3.37: (2015 Question 13b, 35%)



The induced emf is the gradient of the flux vs time graph. The sign of the induced emf depends on the external connections to the voltmeter. The negative of the graph above is also correct.

Example 3.38: (2015 Question 13c, 45%)

The field from the magnets is down, so as the loop enters the field the flux increases. From Lenz's law, the induced current will oppose this change in flux. Therefore the induced current will create its own field upwards. This means that the current must flow anticlockwise around the loop.

$\therefore$ **From X to Y (ANS)**

Example 3.39: (1993 Question 1)

The maximum flux will occur when the coil is perpendicular to the field.

∴ B, F (ANS)

Example 3.40: (1993 Question 2)

The galvanometer is connected to the coil via slip rings. Therefore the output will be sinusoidal.

∴ E (ANS)

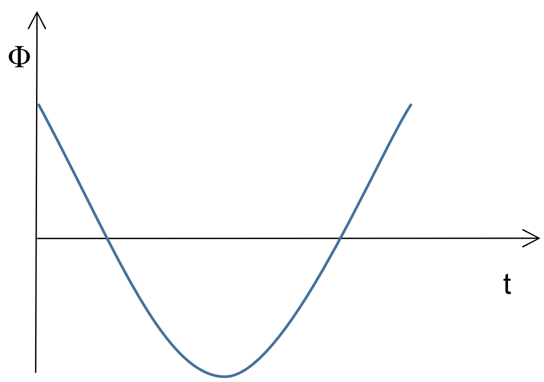
Example 3.41: (1993 Question 3)

The split ring will reverse the direction of the output every half cycle.

∴ D (ANS)

Example 242: (2012 Question 7a, 45%)

The magnetic flux will vary sinusoidally as the loop rotates.



It will start at a maximum value and drop to zero (a quarter of a cycle later) and then to an identical negative maximum value (half a cycle later). It will then return to zero and then back to its original maximum value. (One complete cycle)

Example 3.43: (2014 Question 18a, 37%)

As the loop rotates, the magnetic flux through the loop increases from zero to a maximum, (when the wire forming the loop is perpendicular), then decreases back to zero, when it is horizontal. As the loop continues the magnetic flux comes through from the other side, increasing to a maximum, then decreasing to zero. This variation in flux is sinusoidal, and so the induced voltage is also sinusoidal. The slip rings provide a constant connection so the output is AC.

Example 3.44: (2015 Question 12d, 47%)

The students need to replace the split ring commutator with a slip rings. This will ensure that the output doesn't reverse every half cycle. The slip rings maintain constant connection, hence as the direction of the flux changes, the output will reflect this change. Therefore AC output.

Example 3.45: (2000 Question 6 Electronics)

The period of this waveform is T = $\frac{1}{f}$

= $\frac{1}{50}$

= 0.02s

= 20 ms.

The time from t_0 to t_1 is $\frac{1}{2}$ a cycle, therefore they are 10 ms apart.

∴ 10 ms (ANS)

Example 3.46: (2000 Question 7 Electronics)

This graph shows the peak voltage to be one division high. Therefore each vertical division must be 240 $\sqrt{2}$.

∴ **339 V** (ANS)

The question has 3 sig. figs. so it is appropriate to use this many in your answer.

Example 3.47: (2011 Question 17, 20%)

Using F = BiL,
we get B = 1.0×10^{-4},

i = 30 × $\sqrt{2}$ we need to use the peak value to calculate the magnitude of the maximum force.

L = 1.0 m. this comes from the graph where the vertical axis is "force on one metre of wire".

∴ F = $1.0 \times 10^{-4} \times 30 \times \sqrt{2}$ x 1

= 4×10^{-3} N

The force will be sinusoidal, because it varies as the current.

∴ B (ANS)

Examiners comment

Students found this question very difficult. They had little concept of how the AC current related to the question. It should be noted that the question required students to show evidence for their choice of answer. Without *the relevant information they did not obtain full marks.*

Example 3.48: (1983 Question 70, 68%)

The peak voltage is $V_{RMS} \times \sqrt{2}$

$\therefore$ 12 × $\sqrt{2}$ = 16.97

$\therefore$ **V_{PEAK} = 17 V (ANS)**

Example 3.49: (1983 Question 71, 60%)

This is a step up transformer, with a turns ratio of ×20.

$\therefore V_{OUT\ RMS}$ = 12 × 20

$\therefore$ **$V_{OUT\ RMS}$ = 240 V (ANS)**

Example 3.50: (1983 Question 72, 58%)

Use P = VI

$\therefore$ P = 12 × 1

= 12 W (ANS)

Example 3.51: (1994 Question 10)

When the input of the transformer is DC, there is not a changing flux in the primary coils of the transformer, so there will not be an induced EMF produced in the secondary coils.

Example 3.52: (2006 Question 14, 50%)

A changing current at the primary coil produces an alternating *B* inside the soft iron core. The secondary coil is linked to the primary through the soft iron core. The changing *B* in the soft iron core results in a changing flux in the secondary coil. This changing flux induces an EMF in the secondary coil.

The magnitude of the induced EMF is given by Faraday's Law

$$EMF_{AVE} = -n\frac{\Delta BA}{\Delta t}$$

Examiner's comment

The main error was students not referring to the changing current, field or flux. Some wrote about the purpose of the transformer being to increase or decrease voltage without explaining how this was achieved.

Example 3.53: (2006 Question 15, 50%)

The transformers in the transmission system require AC. The alternator provides the AC, changing the magnetic flux to induce an EMF in the secondary. If the voltage produced is constant (from a DC generator), then the output of the transformer would be zero.

Therefore an alternator should be used rather than a DC generator.

Example 3.54: (2006 Question 16, 25%)

The power demand has increased but the voltage at the alternator (P) remained the same. Since $P_{supplied}$ = VI, the current supplied had to increase.

This would lead to an increased current in the power lines.

This would mean an increased voltage drop along the lines, (V_{drop} = IR).

Therefore a slightly lower voltage at the primary of transformer 2.

Since the transformer has not changed, with a lower voltage across the primary there will be a lower voltage across the secondary.

$\therefore$ **B (ANS)**

Example 3.55: (2006 Question 17, 55%)

The alternator produces $250V_{RMS}$ at 50 Hz.

The peak voltage will be $250\sqrt{2}$ = 354 V. The 50 Hz means that the period is 0.02 sec.

$\therefore$ **B (ANS)**

Examiner's comment

The most common incorrect response was D; presumably these students had assumed the output of the alternator to be the peak value

Example 3.56: (2007 Question 11, 57%)

This circuit can be considered as a 12 V_{RMS} AC supply in series with three elements. Element 1 is a 2 Ω resistor, element 2 is the transformer, and element 3 is the second 2 Ω resistor.

With a current of 0.50 A, each of the resistors will lose 2 × 0.5 = 1 V across them.

The circuit will have a 12 V drop along it, so the potential difference across the transformer needs to be 10 V.

The transformer ratio is 5:1, so the secondary voltage will be $\frac{10}{5}$ = 2 V

The transformer is ideal, so

$Power_{IN} = Power_{OUT}$

$\therefore (VI)_{IN} = (VI)_{OUT}$

$\therefore 10 \times 0.5 = 2 \times I_{secondary}$

$\therefore I_{secondary}$ = 2.5 A

$\therefore$ **A_2 = 2.5 A**

V_1 = 10 V

V_2 = 2 V (ANS)

= 20 (20:1) (ANS)

Examiner's comment
A considerable number of students had difficulty with part ii., which involved voltage in a series circuit.

Example 3.57: (2012 Question 6a, 85%)

$$\frac{V_{out}}{V_{in}} = \frac{n_{secondary}}{n_{primary}}$$

Use

$$\frac{V_{out}}{20} = \frac{150}{600}$$

∴ **Vout = 5 V (ANS)**

Example 3.58: (2012 Question 6b, 35%)

The constant voltage of the 20 V volt battery will supply a constant current. Therefore there will not be any change the flux. Therefore from Faraday's law there will not be an induced EMF.

Example 3.59: (2013 Question 15d, 37%)

As the switch closes, the current changes from 0 to a maximum value.
This change in current creates a changing flux in the iron core of the transformer. This change in flux induces and EMF across the secondary coil. As the circuit is complete this will lead to a brief current through the resistor. This is an application of Faraday's law.
Once the switch is closed, there won't be any change in the current, therefore no change in the flux, therefore no induced current.

Example 3.60: (2014 Question 14a, 30%)

This questions comes up fairly routinely on the exam. With a DC input, there isn't a changing flux in the primary of the transformer, so there will not be any induced voltage.
∴ **0 V (ANS)**

Example 3.61: (2000 Question 4)

$$\frac{V_1}{V_2} = \frac{N_1}{N_2}$$

$$= \frac{240}{12}$$

Example 3.62: (2000 Question 5)

$P = VI$

$= \frac{V^2}{R}$

$= \frac{12^2}{18}$

= 8.0 V (ANS)

Example 3.63: (2000 Question 6, 14%)

The resistance of the wire is given by

$16.0 \times 2 \times 0.050 = 1.6\ \Omega$

(You need to include both wires, hence the length is 16.0×2)

$\therefore R_{total} = 18.0 + 1.6$

$= 19.6\ \Omega$.

$I = \frac{V}{R}$

$= \frac{12}{19.6}$

$= 0.6122$

Using $V = I \times R$

$= 0.6122 \times 18$

= 11.0 V (ANS)

Example 3.64: (2000 Question 7, 16%)

Light 1: $I_1 = 0.6122$ A (as per question 6)

Light 2: $I_2 = \frac{12}{18}$

$= 0.6667$ A

$\therefore$ current in light 2 > current in light 1

$\therefore$ **Light 2 brighter (ANS)**

Example 3.65: (2001 Question 3, 58%)

$P = VI$

$120 = 240 \times I$

$\therefore$ **I = 0.5 A (ANS)**

Example 3.66: (2001 Question 4, 58%)

This system would only have worked if there was no power loss in the wires. The voltage is dropped down at the first transformer; this increases the current in the wires.

The more current in the wires the more the power loss there will be.

The relationship between power loss and current is $P_{loss} = I^2R$, so if the current increase by a factor of 2 the power loss increases by 4.

There is also the effect on the voltage loss in the wires $V_{loss} = IR$ this means that at the second transformer there is not a full 12 V. The value will be lower so that after it is transformed back then it will not be as high as 240 volts.

If the voltage supplied to the light globe is not 240 volts then the power dissipated in the light globe will not be 120 Watts, it will be lower, thus the light is not putting out as much light energy per second, it will not work effectively.

Example 3.67: (2001 Question 5, 58%)

$$\frac{V_2}{V_1} = \frac{N_2}{N_1}$$

$$V_2 = \frac{240}{12} \times 10$$

$\therefore$ **V_2 = 200 V (ANS)**

Example 3.68: (2001 Question 6, 45%)

As the transformers are ideal we know that

$P_{in} = P_{out}$

If the voltage increases by a factor of 20, to maintain the same power the current must decrease by a factor of 20.

$\therefore V_{out} = 10 \times \frac{240}{12}$.

$\therefore$ current$_{out}$ must be $8.3 \times \frac{12}{240}$

= 0.415 A (ANS)

Example 292: (2001 Question 7, 19%)

Determine the voltage loss because of the wires.

The step down transformer supplies 12 V but there is 10 volts at the step up transformer.

Therefore there is 2 volts lost across the wires.

Using $V_{loss} = IR$, the current through the wires was 8.3 A.

Using $R = \frac{V_{loss}}{I}$

$\therefore R = \frac{2}{8.3}$

$\therefore$ **R = 0.24 Ω (ANS)**

Example 3.69: (2001 Question 8, 48%)

If the resistance of the wires was lower, then the voltage drop across them would decrease, so the voltage across the globe would increase.
If the transformer was 240:24, then the voltage on the output side of the step down transformer would be 24 volts.
To supply the power needed the current would be smaller than if the transformer was 240:6.
∴ the smaller current means less power loss due to i^2r in the wires, a higher voltage at the second transformer.

∴B and C (ANS)

Example 3.70: (2008 Question 11, 90%)

Use:

$$P = \frac{V^2}{R}$$

$$P = \frac{12^2}{3.0}$$

∴ P = 48 W (ANS)

Examiner's comments
A significant number of students converted the 12 V_{RMS} to V_{PEAK} before substituting.

Example 3.71: (2008 Question 12, 40%)

Combine the resistance of the wires to be 1.0 Ω. The total resistance of the circuit would be 4.0 Ω.
Use:

$$V_1 = V_s \frac{R_1}{R_T}$$

$$V_1 = 12 \times \frac{3}{4}$$

∴V_1 = 9.0 V (ANS)

Examiner's comments
It was apparent that basic circuit theory was poorly understood by students.

Example 3.72: (2008 Question 13, 33%)

First find the effective resistance of the two light globes.

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{R_T} = \frac{1}{3} + \frac{1}{3}$$

$$R_T = 1.5\Omega$$

Those light globes are connected in series with the 1.0 Ω of the wires. So the effective resistance of the circuit is 2.5 Ω.
The current at point A will be found by using:

$$I = \frac{V}{R}$$

$$I = \frac{12}{2.5}$$

∴I = 4.8 A (ANS)

Example 3.73: (2009 Question 11, 50%)

The output voltage of the generator is 500 V.
The potential drop across each line is given by V = iR

∴ V = 20 × 5

∴ V = 100 V across each line.

The total of the potential drops of the circuit is 200 V
Therefore the voltage supplied to the lights is 500 – 200

= 300 V (ANS)

Example 3.74: (2009 Question 14, 65%)

The step-up transformer increases the voltage by a factor of 10. To deliver the same power (P = VI) the current decreases by a factor of 10.
Therefore the new current is
20 ÷ 10 = 2 A
The power loss in the lines is given by
$P_{loss} = i^2R$

∴ $P_{loss} = 2^2 \times 10$

(Use the total resistance of the wires)

∴ $P_{loss} = 40$

∴ P_{loss} = 40 W (ANS)

Example 3.75: (2009 Question 15, 47%)

With the step-up transformer in place the current in the cables is 2.0 A.
The output voltage of the step-up transformer is 5000 V.
The potential drop across each line is given by V = iR

∴ V = 2 × 5

∴ V = 10 V across each line.

Total of the potential drops of the circuit is 20 V
Therefore the voltage supplied to the step-down transformer is

5000 – 20 = 4980 V
The transformer steps this voltage down by a factor of 10, so the output voltage of the step-down transformer is

$\frac{4980}{10}$ **= 498 V (ANS)**

Example 3.76: (2014 Question 15d, 47%)

If the light globe is designed to operate at 6 V, with a resistance of 1.5 Ω, then from V = iR we get that it will allow a 4 A current to flow through it.
∴ the maximum current in the circuit is 4 A.
The total resistance of the circuit is (5 + 1.5) Ω.
Therefore from V = iR (for the circuit)

$V = 4 \times 6.5$

$\therefore$ **V = 26 V (ANS)**

Example 3.77: (2014 Question 16, 43%)

The amount of power being transmitted is fixed. The power being transmitted is given by P = VI. To minimise power losses in the transmission lines, current needs to be decreased, as the power loss is given by

$P_{loss} = i^2R$.

A step up transformer at the start of the transmission lines is used to increase the voltage, and decrease the current but still deliver the power. This decrease in the transmission current means that power loss in the lines is minimised.
A step down transformer is needed at the other end to reduce the voltage to a useable level (typically 240 V).

How can waves explain the behaviour of light solutions.

Example 4.1: (QLD 2016 Question 7)

In a wave there is no net transfer of material, only the energy is transferred.

∴ **B (ANS)**

Example 4.2: (1971 Question 53, 80%)

Pick any point on the diagram, then find out how far it has moved in the +x direction in the next 0.10 sec.
Choose the crest, initially at 3 cm.
This crest moves 2 cm (to a position of 5cm).

∴ $v = \frac{2}{0.1}$

∴ **v = 20 cm/s (ANS)**

Example 4.3: (1971 Question 54, 71%)

Use v = fλ.
From the diagram, the wavelength is 8 cm.

∴ 20 = f × 8

∴ **f = 2.5 Hz (ANS)**

Example 4.4: (1971 Question 55, 43%)

It might also be possible that instead of the wave crest moving 2 cm, it might have moved 10 cm.

∴ $v = \frac{10}{0.1}$

∴ **v = 100 cm/s (ANS)**

Example 4.5: (1971 Question 56, 52%)

This is a travelling wave, so the point P is about to move down, because in the next instant, when the wave has moved to the right a little bit, the point P will have moved down a little bit.

∴ **E (ANS)**

Example 4.6: (1971 Question 57, 23%)

The velocity of the point Q is initially a maximum positive value. A quarter of a period later, the point Q is at the top of the wave disturbance, hence its velocity will be zero. It will then move downwards so its velocity will be negative. The velocity function will be sinusoidal.

∴ **B (ANS)**

Example 4.7: (1974 Question 52, 70%)

This is a wave travelling to the right, so the point P will be moving downwards.

∴ **E (ANS)**

Example 4.8: (1974 Question 53, 58%)

The first graph is when t = 0, so the point P starts midway up, it then travels downwards to the extremity and then back up again in a cyclic manner.

∴ **C (ANS)**

Example 4.9: (1978 Question 33, 71%)

For the slowest possible velocity, the left hand crest has moved from 10 cm to 25 cm, in 0.15 seconds.

∴ $v = \frac{15}{0.15}$

∴ **100 cm s^{-1} (ANS)**

Example 4.10: (1978 Question 34, 69%)

Use v = f λ

∴ 100 = f × 40

∴ **2.5 Hz (ANS)**

Example 4.11: (1978 Question 35, 75%)

The wave is a transverse wave. Therefore there isn't any movement of medium in the direction of the wave.

∴ **0 cm s^{-1} (ANS)**

Example 4.12: (1980 Question 35, 67%)

This is a travelling pulse. The point Y is moving downwards to become the bottom point of the trough.

∴ **B (ANS)**

Example 4.13: (1980 Question 36, 42%)

The point T is moving up to become the top point of the crest

∴ **A (ANS)**

Example 4.14: (1980 Question 37, 76%)

The pulse has passed the point P, so it will now remain undisturbed.

∴ **P (ANS)**

Example 4.15: (1989 Question 36)

Find two identical parts of the wave and find he distance between them. Use 0.5 and 1.5.

$\therefore$ **1.0 m (ANS)**

Example 4.16: (1989 Question 37, %)

This is a longitudinal wave, so all parts vibrate in the direction OX about their mean position

$\therefore$ **A (ANS)**

Example 4.17: (1999 Question 1, 85%)

For this wave, which is a longitudinal representation, it is best to try and find the distance between adjacent compressions. Ignore the end of the wave train near the hand and work with the rest. It looks like there were 4 compressions between 28 and 88 cm. These 4 compressions correspond to 3 wavelengths, (count them on the diagram). Be careful with this diagram, the horizontal axis does not have zero where the wave begins.

$$\therefore \lambda = \frac{88 - 28}{3}$$

$$= \frac{60}{3}$$

$\therefore$ **λ = 20 cm (ANS)**

(19 - 21 cm was acceptable)

Example 4.18: (1999 Question 2, 85%)

Make sure that you read this question carefully; they want non-MKS units for the answer. This was actually designed to make it easier for you.

So $v = f\lambda = 4 \times 20$

v = 80 cm/s (ANS)

Example 4.19: (2006 Question 2, 80%)

Sound is a longitudinal wave

$\therefore$ **D (ANS)**

Example 4.20: (2009 Question 4, 53%)

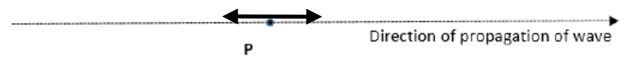
In a quarter of a period, the wave will travel one quarter of a wavelength to the right.

Therefore the initial pressure maximum will have moved to 0.5 m.

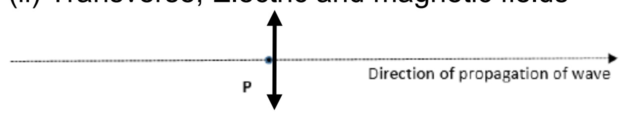
$\therefore$ **B (ANS)**

Example 4.21: (TAS 2015 Question 13a, %)

(i) Longitudinal, air molecules



(ii) Transverse, Electric and magnetic fields



Example 4.22: (1969 Question 60, 43%)

The speed of the waves will not change because of the movement of the source. Only the wavelength and frequency of the waves in front of the source will change

$\therefore$ **C (ANS)**

Example 4.23: (1969 Question 61, 39%)

Since the wavelength is now half the original, and the speed has remained constant, use

$v = H \times \lambda$

$\therefore v = H_{new} \times \lambda_{new}$

$\therefore v = H_{new} \times \frac{\lambda}{2}$

$\therefore f = 2H$

$\therefore$ **B (ANS)**

Example 4.24: (1969 Question 62, 58%)

The average wavelength will remain the same. So if the waves in front are 0.5 λ, then the waves behind need to be 1.5 λ

$\therefore$ **B (ANS)**

Example 4.25: (1973 Question 49, 87%)

We need to assume that it is a fixed end. Therefore the reflected pulse will be inverted.

$\therefore$ **D (ANS)**

Example 4.26: (1983 Question 33, 27%)

The distance between adjacent maxima (or nodes) for a standing wave is ½λ.

$\therefore \lambda = 1.57 - 1.27$

$\therefore$ **λ = 0.30 m (ANS)**

Example 4.27: (1983 Question 34, 89%)

Use $v = f\lambda$

$\therefore v = 1000 \times 0.3$

$\therefore$ **v = 300 m s^{-1} (ANS)**

(Check that this is a reasonable answer.)

Example 4.28: (1988 Question 35)

The maximum position of the pulse hasn't reached P yet, so P is moving up.

∴ **C (ANS)**

Example 4.29: (1988 Question 36)

Since it is a standing wave at its maximum displacement, everywhere on the spring is momentarily stationary.

∴ **E (ANS)**

Example 4.30: (1988 Question 37)

In a standing wave, the nodes remain stationary. Therefore G, H, J could all exist

∴ **G, H, J (ANS)**

Example 4.31: (1998 Question 10)

From the formula $v = f \times \lambda$, the lowest frequency will occur when the wavelength is longest. $340 = f \times 0.864$

∴ **f = 394 Hz (ANS)**

Example 4.32: (1998 Question 11)

The wavelengths must be the same, because the nodes and antinodes need to be in the same positions for resonance to occur.
Because the velocity has increased by 10% then the frequencies will also increase to compensate and to keep the equation $v = f\lambda$ correct.
The other way to think about this is that the wavelengths are given by the relationship $\lambda = 4L, 4L/3, 4L/5$ etc. they do not depend on velocity.

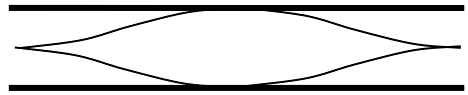
The frequencies are given by ∴ $f = \frac{nv}{4L}$, which does depend on the velocity, so the frequencies will vary if you vary the velocity.

Example 4.33: (2007 Question 4, 60%)

Constructive interference (from the waves reflected from both ends of the pipe) will produce a standing wave. This standing wave will be louder.
As the driving frequency gets closer to the natural frequency of the pipe, the sound produced by the pipe will get louder.

Example 4.34: (2009 Question 11, 45%)

The resonance will look like:



With an antinode in the middle.
This means that the point P will fluctuate between a pressure maximum to a pressure minimum.
If the fundamental frequency is 385 Hz, then the period will be 2.6 ms.

∴ **A (ANS)**

Example 4.35: (2014 Question 8, 30%)

A standing wave is set up inside the tube. A pressure node is where the pressure is constant. It remains at atmospheric pressure, therefore this will be zero on their sensor.

∴ **D (ANS)**

Example 4.36: (1985 Question 38)

The string is fixed to the wall, so the pulse will invert on reflection from the fixed end. The leading edge remains as the leading edge.

∴ **E (ANS)**

Example 4.37: (1985 Question 39The)

Example 4.38: (1986 Question 41)

The nodes must remain where they are, and the antinodes will move from where they currently are through to a reflected position below the axis.

∴ **B, C, D (ANS)**

Example 4.39: (1986 Question 42)

The point P is a node, it will remain stationary.

∴ **C (ANS)**

Example 4.40: (1986 Question 43)

If this is a travelling wave then the crest is moving to the right. To achieve this the point P needs to move upwards.

∴ **A (ANS)**

Example 4.41: (1987 Question 41, 71%)

The standing wave moves from one extremity to the other in 1 sec, therefore the period is 2

∴ **2.0 s (ANS)**

It may have completed multiple cycles in the 1.0 sec, so this is the longest possible period

Example 4.42: (1987 Question 42, 35%)

Since this is the extremity of the standing wave, the point R is momentarily at rest, but it is about to move downwards.

∴ **E (ANS)**

Example 4.43: (1987 Question 43, 74%)

If this is a travelling wave then the crest is moving to the right. To achieve this the point R needs to move upwards.

∴**A (ANS)**

Example 4.44: (1989 Question 34)

This is a standing wave, at its maximum displacement, so all points on the wave are momentarily stationary. The point Q is also a node, so it will remain stationary.

∴ **C (ANS)**

Example 4.45: (1989 Question 35)

The point R will oscillate between its current maximum positive displacement form the line OX to an equivalent position below the line OX. It will perform simple harmonic motion. (SHM is not on the course, but the motion of point R is)

∴ **B (ANS)**

Example 4.46: (1990 Question 27)

Since the point P is at the extremity of the pulse, it is about to move down. The point P does not have any component of its velocity in the horizontal direction,

∴**C (ANS)**

Example 4.47: (1990 Question 28)

In two seconds the crest of the pulse on the left (above the string) has moved 8 m to be 15 m from the left hand wall, and the crest from the pulse below the string has move to a position 13 m from the left hand wall. The two waves will combine as vectors.

∴ **E (ANS)**

Example 4.48: (1990 Question 29)

In 7 seconds the crest above the string will have moved 28 m. Therefore it will have reflected from the fixed end, inverted, and be heading in the opposite direction. It will have moved to the position where the other pulse is (in the diagram). The pulse below the string has also travelled 28 m to be where the left hand pulse started.

∴ **A (ANS)**

Example 4.49: (1991 Question 39)

The crest has moved from 15 cm to 25 cm in 1 sec.

∴ **10 cm s^{-1} (ANS)**

Example 4.50: (1991 Question 40)

Point P is moving down, so that in 0.5 seconds time it will be the trough.

∴ **E (ANS)**

Example 4.51: (1991 Question 41)

Point P s a node, hence it is stationary

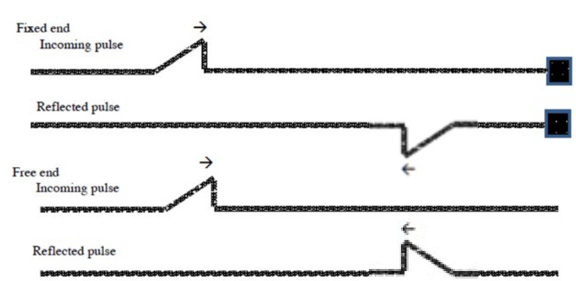
∴ **A (ANS)**

Example 4.52: (QLD 2015 Question 7)

Waves cannot propagate energy.

∴ **A (ANS)**

Example 4.53: (TAS 2012 Question 12a)



Example 4.54: (1978 Question 40, 86%)

When light passes through small holes, diffraction effects occur.

∴ **B (ANS)**

Example 4.55: (1990 Question 30)

The amount of diffraction varies as $\frac{\lambda}{w}$.
Therefore if a smaller hole is used there will be more diffraction. This means that the angle, α, will increase.

$\therefore$ **B (ANS)**

Example 4.56: (1990 Question 31)

The red light will diffract more than the other colours. So you would expect white light in the middle of the cone with a red fringe around the extremities.

$\therefore$ **C (ANS)**

Example 4.57: (1999 Question 13, 80%)

The bending (spreading) of sound is called diffraction. Make sure that when you do this question your technique is right. (Did you look at the options before you thought about the answer? You shouldn't have, if you did, you just made the question more difficult by introducing some doubt).

$\therefore$ **D (ANS)**

Example 4.58: (2000 Question 11, 47%)

You need to use the equation $v = f\lambda$, to determine v for sound in this situation. You then use this information in the same equation to find the wavelength of the
10 000 Hz sound.

$v = f\lambda$

$\therefore v = 200 \times 1.65$ m

$= 330$ m/s.

You need to make sure that your answer makes sense. You would expect that the speed of sound is 330 m/s.
Use $v = f\lambda$, again, to find the wavelength.

$\therefore 330 = 10\,000 \times \lambda$

$\therefore \lambda = \frac{330}{10000}$

$= 0.033$ m

You should be careful with sig. figs here, so the answer is best written as

3.3×10^{-2} m (ANS)

Example 4.59: (2000 Question 12, 57%)

To gain full marks you had to show some calculations, if you only spoke in general terms then you lost at least one mark.

Speaker sizes	Frequency	Wavelengths
P 35 cm	200 Hz	165 cm
Q 5 cm	10 000 Hz	3.3 cm

The reason that Michelle hears the 10 000 Hz sound much softer is due to diffraction. Diffraction is the spreading out of sound and the amount of diffraction is given by the ratio of $\frac{\lambda}{w}$. When the ratio $\frac{\lambda}{w}$ = 1, then the diffraction is said to be complete, and the sound spreads out through an angle of 180^0.

For speaker P the ratio of $\frac{\lambda}{w}$ for 200 Hz =

$\frac{165}{35}$ = 4.7 which is >> 1

$\therefore$ the sound spreads out.

For speaker P ratio of $\frac{\lambda}{w}$ for 10 000 Hz = $\frac{3.3}{35}$ = 0.09 which is << 1

$\therefore$ the sound does not spread out.

For speaker Q the ratio of $\frac{\lambda}{w}$ for 200 Hz =

$\frac{165}{5}$ = 33 which is >> 1

$\therefore$ the sound spreads out.

For speaker Q ratio of $\frac{\lambda}{w}$ for 10 000 Hz =

$\frac{3.3}{5}$ = 0.66 which is < 1

$\therefore$ the sound only spreads out a little.

You also need to link this theory with the practical, so:
Because Michelle is not in front of the speaker, she will not hear the high frequency sound from the larger speaker, because it doesn't diffract very much and so will be soft if you are not in front of the speaker.
So for the 200 Hz signal, the sound is evenly distributed, but for the 10 000 Hz signal the sound is very directional from the larger speaker.

Example 4.60: (2007 Question 6, 50%)

A wider slit produces a narrower pattern. Since the spacing between the fringes is inversely proportional to the width of the gap.

∴ **B (ANS)**

Examiner's comment

It was disappointing that fewer than half of the students were able to apply the simple relationship required to determine the answer.

Example 4.61: (1989 Question 27)

Both colours will have the same speed in a vacuum, but both the frequency and wavelength will depend on colour

∴ **A, C (ANS)**

Example 4.62: (SA 2009 Question 13a, 67%)

The oscillating magnetic and electric fields are perpendicular to each other and mutually perpendicular to direction of travel.

Example 4.63: (QLD 2012 Question 9a)

Both will travel at the speed of light in air.

∴ $c = f \times \lambda$

The longer the wavelength the smaller the frequency.

Therefore violet will have the higher frequency.

Example 4.64: (QLD 2013 Question 7a)

The maximum intensity occurs for a wavelength of 5 cm. Therefore microwaves.

∴ **microwaves (ANS)**

Example 4.65: (QLD 2013 Question 7b)

From the graph, maximum for 5000 K is 0.5 eV

This corresponds to 8×10^{-20} J

Use $E = hf$

∴ $8 \times 10^{-20} = 6.63 \times 10^{-34} \times f$

∴ $f = 1.2 \times 10^{14}$ Hz

∴ **Infrared (ANS)**

Example 4.66: (1977 Question 74, 72%)

The components of the electric fields in both vertical and horizontal directions will be blocked.

∴ **B (ANS)**

Example 4.67: (SA 2012 Question 13a)

The plane of polarisation is defined as the plane of the electric field. The plane of the magnetic field is perpendicular to the plane of the electric field. The variation of the field in the transmitter is in the vertical

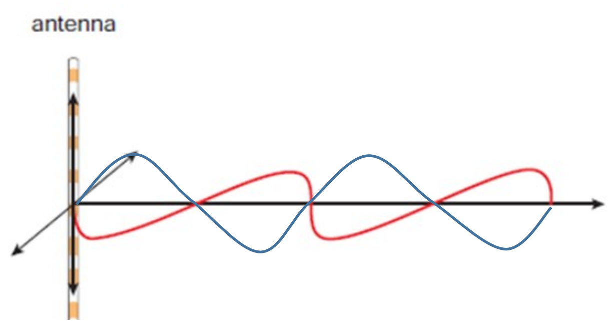
∴ **Vertical (ANS)**

Example 4.68: (SA 2014 Question 13a)

The plane of polarisation is defined as the plane of the electric field. The plane of the magnetic field is perpendicular to the plane of the electric field.

∴ **Horizontal (ANS)**

Example 4.69: (SA 2016 Question 10a)



The wave needed to be in a perpendicular plane to the original with the same period.

Example 4.70: (SA 2016 Question 10b)

Vertical (ANS)

Example 4.71: (1968 Question 77, 85%)

The refractive index is related to the wavelength of the waves in both media.

∴ $\frac{6.0}{5.0} = 1.2$

∴ **1.2 (ANS)**

Example 4.72: (1968 Question 78, 81%)

The frequency of the waves does not alter as they go from one media to another. (If the frequency did alter, then there would be either more or less waves coming into the boundary than leaving the boundary every second. This cannot happen.

∴ **1 (ANS)**

Example 4.73: (1968 Question 79, 82%)

The speed is given by the distance travelled over the time taken. You are shown two wave fronts, and the wave front in medium X has travelled 6.0 cm in the time it took for the wavefront in medium Y to travel 5.0 cm

$\therefore \frac{6.0}{5.0} = 1.2$

∴ 1.2 (ANS)

Example 4.74: (1974 Question 48, 79%)

The refractive index is related to the wavelength of the waves in both media.

$\therefore \frac{5.0}{4.0} = 1.25$

∴ 1.3 (ANS)

Example 4.75: (1974 Question 49, 79%)

The frequency of the waves does not alter as they go from one media to another. (If the frequency did alter, then there would be either more or less waves coming into the boundary than leaving the boundary every second. This cannot happen.

∴ 1 (ANS)

Example 4.76: (1974 Question 50, 83%)

The speed is given by the distance travelled over the time taken. You are shown two wave fronts, and the wave front in medium X has travelled 6.0 cm in the time it took for the wavefront in medium Y to travel 5.0 cm

$\therefore \frac{5.0}{4.0} = 1.25$

∴ 1.3 (ANS)

Example 4.77: (1974 Question 51, 50%)

For TIR to occur, the waves need to travel from high refractive index to low refractive index. This occurs when the waves speed up.

∴ B (ANS)

Example 4.78: (1971 Question 60, 80%)

The frequency of the light does change. As light goes from air to water, it will slow down. Since $v = f \times \lambda$, if the speed slows down then the wavelength must also shorten.

∴ (i) S (ii) D (iii) D (ANS)

Example 4.79: (1971 Question 61, 45%)

The light is travelling in a vacuum, therefore it is travelling at the speed c. The white light has dispersed in the glass block, so Path 1 and Path 2 represent different colours. Therefore both the frequency and wavelength are different.

∴ (i) D (ii) D (iii) S (ANS)

Example 4.80: (1972 Question 46, 24%)

The diagram is a little deceptive in that the angle of incidence is 60^0

Use $n_1 \sin \theta_{ic} = n_2 \sin 90$ for critical angle.

$\therefore 1.48 \sin 60 = n_2$

$\therefore n_2 = 1.28$

Total internal reflection occurs when light is going from a high refractive index to a low refractive index, so values below 1.28 will give TIR

∴ A, B, C (ANS)

Example 4.81: (1975 Question 44, 46%)

To deviate all the light, means we want total internal reflection.

Use $n_1 \sin \theta_{ic} = n_2 \sin 90$ for critical angle.

$\therefore n_1 \sin 45 = 1 \times 1$

Since $n_2 = n_{air} = 1$

∴ 1.4 (ANS)

Example 4.82: (1976 Question 46, 64%)

Use $n_1 \sin \theta_{ic} = n_2 \sin 90$ for critical angle.

$\therefore 1.5 \sin \theta_{ic} = 1.33 \times 1$

$\therefore \sin \theta_{ic} = \frac{1.33}{1.5}$

∴ $\theta_{ic} = 62.5^0$ (ANS)

Example 4.83: (1976 Question 47, 63%)

The angle of incidence is 45^0, this is below the critical angle so the light will not totally internally reflect

∴ D (ANS)

Example 4.84: (1976 Question 48, 55%)

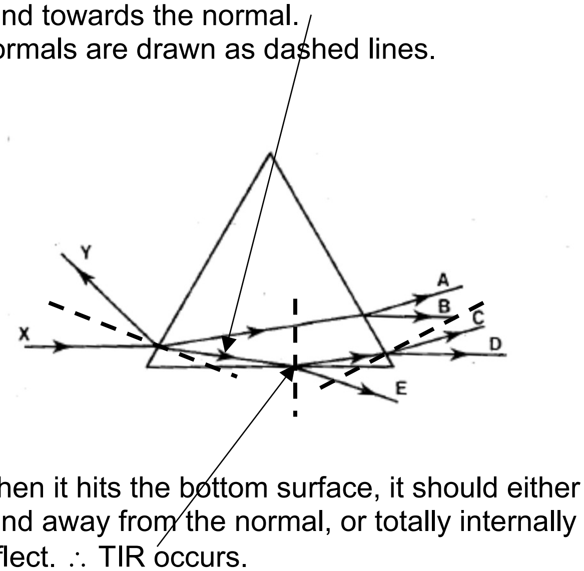
Use $n_w v_w = n_g v_g$

$\frac{v_g}{v_w} = \frac{1.5}{1.33}$

∴ 1.13 (ANS)

Example 4.85: (1979 Question 35, 35%)

As the light travels into the prism it is going to bend towards the normal.
Normals are drawn as dashed lines.



When it hits the bottom surface, it should either bend away from the normal, or totally internally reflect. ∴ TIR occurs.

When it gets to the next surface it needs to bend away from the normal, as it is going from high refractive index to lower refractive index.

∴ **D (ANS)**

Example 4.86: (1979 Question 33, 47%)

Use $n_1 \sin i = n_2 \sin r$
This example requires you to remember your Pythagorean triads. WV = 13 cm, VU = 10 cm.

∴ $\sin i = \frac{12}{13}$, and $\sin r = \frac{6}{10}$

∴ $1 \times \frac{12}{13} = n_2 \times \frac{6}{10}$

∴ $n_2 = \frac{120}{78}$

∴ **1.54 (ANS)**

Example 4.87: (1979 Question 34, 36%)

The light will always reach the observer as it is bending towards the normal as it goes from a low refractive index to a higher refractive index

∴ **A (ANS)**

Example 4.88: (1981 Question 44)

Use $n_1 \sin i = n_2 \sin r$

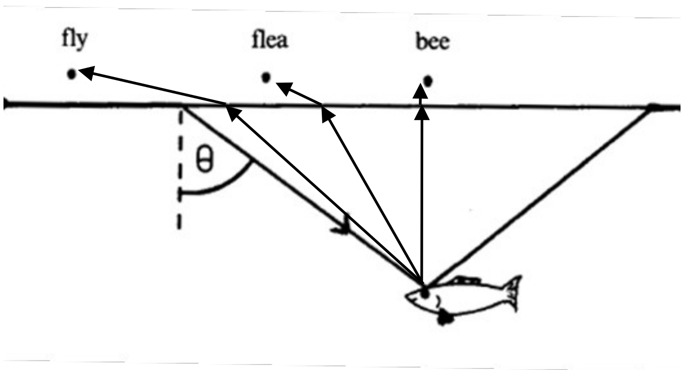
∴ $1.33 \times \sin\theta = 1.00 \sin 90$

∴ $\sin\theta = 0.7519$

∴ **49^0 (ANS)**

Example 4.89: (1981 Question 45, %)

The fish could see all three insects. It is possible to draw rays from the fish's eye to the surface and then refract them to reach each insect.



∴ **D (ANS)**

Example 4.90: (1982 Question 46, 57%)

TIR can only occur when the light is going from high refractive index to lower refractive index.

∴ **C (ANS)**

Example 4.91: (1982 Question 47, 84%)

Use $n_1 \sin i_C = n_2 \sin 90^0$

$\therefore 1.63 \times \sin i_C = 1.33$

$\therefore \sin i_C = \frac{1.33}{1.63}$

∴ **54.7^0 (ANS)**

Example 4.92: (1983 Question 43, 66%)

Use $n_1 \sin i = n_2 \sin r$

This example requires you to remember your Pythagorean triads. RQ = 100 mm, QP = 125 mm.

$\therefore \sin i = \frac{80}{100}$, and $\sin r = \frac{75}{125}$

$\therefore 1 \times \frac{80}{100} = n_2 \times \frac{75}{125}$

$\therefore n_2 = \frac{80 \times 125}{100 \times 75}$

$\therefore n_2 = \frac{4 \times 5}{5 \times 3}$

∴ **1.3 (ANS)**

Example 4.93: (1983 Question 44, 32%)

As the blue light is going from a high refractive index to a lower refractive index, TIR will occur at some point. When TIR occurs some light will be reflected back into the liquid.

∴ **B, D (ANS)**

Example 4.94: (1984 Question 34)

Use $n_{air} \sin 90 = n_{water} \sin \alpha$

∴ $1.0 = 1.33 \times \sin \alpha$

∴ $\sin \alpha = 0.7519$

∴ **49^0 (ANS)**

Example 4.95: (1984 Question 35)

Wavelength will be shorter, as the speed of light in water is slower than in air, and $v = f \times \lambda$, where f is constant.

∴ $\lambda_{water} = \lambda_{air} \div 1.33$

∴ $\lambda_{water} = 5.4 \times 10^{-7} \div 1.33$

∴ **4.1×10^{-7} m (ANS)**

Example 4.96: (1986 Question 33)

Use $n_1 \sin i = n_2 \sin r$

∴ $1.0 \times \sin 45 = n_2 \sin 40$

∴ **$n_2 = 1.10$ (ANS)**

Example 4.97: (1986 Question 34)

Use $n_1 v_1 = n_2 v_2$

∴ $\frac{v_{water}}{v_{air}} = \frac{n_{air}}{n_{water}}$

∴ $\frac{1}{1.33} = 0.75$

∴ **0.75 (ANS)**

Example 4.98: (1986 Question 35)

The frequency does not change.

∴ **1 (ANS)**

Example 4.99: (1986 Question 36)

Using $v = f \times \lambda$, The wavelengths will change in the same ratio as the velocities.

∴ $660 \times 10^{-9} \times 0.75 = 495 \times 10^{-9}$

∴ **495 nm (ANS)**

Example 4.100: (1987 Question 44, 71%)

Use $n_1 \sin i = n_2 \sin r$

∴ $1.0 \times \sin 40 = 1.33 \sin r$

∴ **$r = 28.9^0$ (ANS)**

You do not need to consider the oil, as this just translates the ray sideways, but won't affect the angle.

Example 4.101: (1988 Question 31)

Use $n_{plastic} \sin i = n_{glass} \sin r$

∴ $1.8 \times \sin 30 = 1.2 \times \sin r$

∴ $0.9 = 1.2 \times \sin r$

∴ $\sin r = 0.75$

∴ **48.6^0 (ANS)**

Example 4.102: (1988 Question 32)

Use $n_{plastic} \sin i = n_{glass} \sin 90$

∴ $1.8 \times \sin i = 1.2$

∴ $\sin i = 0.667$

∴ **$i = 41.8^0$ (ANS)**

Example 4.103: (1988 Question 33)

Use $n_{plastic} v_{plastic} = n_{glass} v_{glass}$

∴ $\frac{v_{glass}}{v_{plastic}} = \frac{n_{plastic}}{n_{glass}}$

∴ $\frac{v_{glass}}{v_{plastic}} = \frac{1.8}{1.2}$

∴ **1.5 (ANS)**

Example 4.104: (1990 Question 34)

Use $\theta = 90 - i$, and $n_1 \sin i_c = n_2 \sin 90$

∴ $1.650 \times \sin i = 1 \times 1$

∴ $\sin i = \frac{1}{1.650}$

∴ $\sin i = 0.6061$

∴ $i = 37.3^0$

∴ **$\theta = 52.7^0$ (ANS)**

Example 4.105: (1990 Question 35)

Use $\theta = 90 - i$, and $n_1 \sin i_c = n_2 \sin 90$

∴ $1.650 \times \sin i = 1.333 \times 1$

∴ $\sin i = \frac{1.333}{1.650}$

∴ $\sin i = 0.8079$

∴ $i = 53.9^0$

∴ **$\theta = 36.1^0$ (ANS)**

Example 4.106: (1976 Question 54, 44%)

The amount of diffraction is given by the ratio of $\frac{\lambda}{w}$. In this case w is the same, so the longer the wavelength (red has a longer λ), the more diffraction, hence the more bending of the light ray.

∴ **D (ANS)**

Example 4.107: (1976 Question 55, 28%)

The speed of light differs when it is in a medium other than a vacuum (or air). If it is at an angle to the interface, then the paths the colours take will also be different. Diffraction is the bending of light as it goes through a narrow slit, but remains in the same medium.

∴ **A (ANS)**

Example 4.108: (1980 Question 41, 52%)

The speed of light in a vacuum is constant. Light travels fastest in a vacuum.

∴ **E (ANS)**

Example 4.109: (1982 Question 40, 67%)

Dispersion is the separation of white light into different colours due to the differing refractive indices for the colours.

∴ **C (ANS)**

Example 4.110: (1987 Question 35, 70%)

Use $n_1 \sin i = n_2 \sin r$

∴ $n_1 \times \sin 45 = 1.00 \sin 90$

∴ $\mathbf{n_1 = 1.4}$ **(ANS)**

Example 4.111: (1987 Question 36, 33%)

If the blue light totally internally reflects at the glass/air interface, then red light will also. Therefore the red light will follow exactly the same path. The angle of incidence at the first air/glass interface is zero, so there will not be any bending of the light here.

Example 4.112: (TAS 2016 Question 13a)

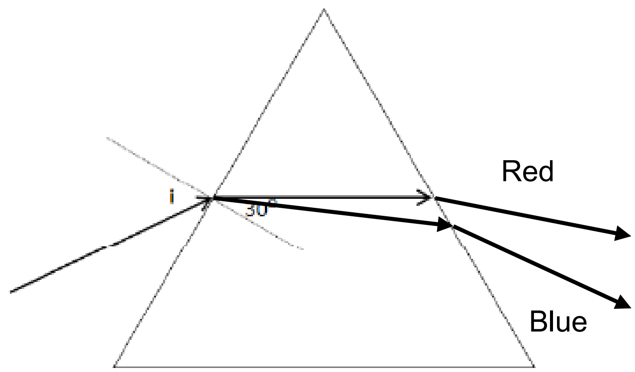
Use $n_1 \sin i = n_2 \sin r$

∴ $1.0 \times \sin i = 1.55 \sin 30$

∴ $\sin i = 0.775$

∴ $\mathbf{i = 50.8^0}$ **(ANS)**

Example 4.113: (TAS 2016 Question 13b)



n for blue light (1.59 is larger than for red light (1.55), so there is a larger change in direction of the ray.

Example 4.114: (1967 Question 57, 79%)

The first minimum wilL occur when destructive interference occurs when the path difference is $\frac{1}{2}\lambda$.

∴ **B (ANS)**

Example 4.115: (1967 Question 58, 77%)

Minima will occur at $\frac{1}{2}\lambda$, $\frac{3}{2}\lambda$, $\frac{5}{2}\lambda$ etc, so if the occur every 30 cm then λ = 60 cm.
For hydrogen λ = 240 cm.
If the frequency remains constant the speed will increase ×4.

∴ $340 \times 4 = 1360$ m s^{-1}

∴ **D (ANS)**

Example 4.116: (1970 Question 57, 40%)

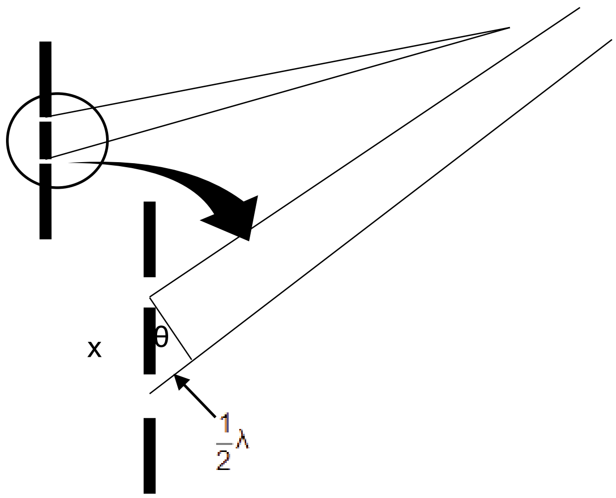
If M is on the first nodal line, then the path difference, MQ – MP, is $\frac{1}{2}\lambda$.
In this situation MQ = d, and MP = c

∴ $d - c = \frac{1}{2}\lambda$

∴ **λ = 2(d – c) (ANS)**

Example 4.117: (1970 Question 58, 51%)

We draw it as shown below and model θ as being the same in both triangles, even though one triangle has two right angles (but c and d are >>> λ) and so θ is very small.



$\therefore \sin\theta = \dfrac{\frac{1}{2}\lambda}{x}$

$\therefore$ **$\theta = \sin^{-1} \dfrac{\lambda}{2x}$ (ANS)**

Example 4.118: (1972 Question 59, 57%)

For a nodal point at X the path difference needs to be $\frac{1}{2}\lambda$. Since λ = 1.00, $\frac{1}{2}\lambda$ = 0.5 m. This means that L_1X is 3.5 + 0.5 m

∴ **4.00 (ANS)**

Example 4.119: (1971 Question 57, 50%)

If the signal strength West and East of the antennae is zero, then the path difference in these directions must be $\frac{1}{2}\lambda$.

∴ **50 m (ANS)**

Example 4.120: (1972 Question 53, 53%)

This question is not relevant. The sources are out of phase.

∴ **E (ANS)**

Example 4.121: (1972 Question 54, 81%)

This question is not relevant. The sources are out of phase.

∴ **A (ANS)**

Example 4.122: (1972 Question 55, 33%)

This question is not relevant. The sources are out of phase.

∴ **0.25 T (ANS)**

Example 4.123: (1972 Question 56, 56%)

This question is not relevant. The sources are out of phase.

∴ **A, C (ANS)**

Example 4.124: (1973 Question 52, 81%)

This question is not relevant. The sources are out of phase.

∴ **3λ (ANS)**

Example 4.125: (1973 Question 53, 49%)

This question is not relevant. The sources are out of phase.

∴ **λ (ANS)**

Example 4.126: (1973 Question 54, 40%)

This question is not relevant. The sources are out of phase.

∴ **0.5 λ (ANS)**

Example 4.127: (1979 Question 36, 42%)

The point P is on the second nodal line.

∴ **1.5 λ (ANS)**

Example 4.128: (1979 Question 37, 55%)

The point Q is on the central anti-nodal line. It starts as a dark point, therefore it is a trough initially. It will vary from a trough to a crest to a trough etc.

∴ **B (ANS)**

Example 4.129: (1979 Question 38, 68%)

The point R is on a nodal line. It will not change.

∴ **E (ANS)**

Example 4.130: (1982 Question 33, 68%)

If the first minima occurs when the path difference is 0.25, then $\frac{1}{2}\lambda$ = 0.25 m

∴ λ = 0.5 m

Use v = f × λ

∴ v = 660 × 0.5

∴ 330 m s^{-1} (ANS)

Example 4.131: (1987 Question 33, 92%)

Use c = f × λ

∴ 3.0 × 10^8 = f × 0.30

∴ f = 10 × 10^8

∴ f = 1.0 × 10^9 Hz (ANS)

Example 4.132: (1987 Question 34, 66%)

For destructive interference the path difference needs to be 0.5 λ, 1.5 λ, 2.5 λ etc

Therefore the distance needs to be

2210.15

2210.45

2210.75

2211.35

∴ C (ANS)

Example 4.133: (1988 Question 38)

Use v = f × λ

∴ 330 = f × 2

∴ f = 165 Hz (ANS)

Example 4.134: (1988 Question 39)

Use Pythagoras to find the distance from speaker Y to John. Distance = 15 m. This means that the path difference (15 – 12) = 3 m. This is a PD of $\frac{3}{2}\lambda$. Therefore there will be destructive interference and a local minimum.

∴ B (ANS)

Example 4.135: (1991 Question 33)

Use $x \approx \frac{n\lambda L}{d}$, (x is the distance to next local maximum from the central maximum)

where x = 1.0, n = 1, L = 10, and d = 1.5

∴ 1.0 = $\frac{1 \times \lambda \times 10}{1.5}$

∴ λ = 0.15 m

∴ A (ANS)

Example 4.136: (1984 Question 38)

The distance from the central maximum to the next local maximum is given by $x \approx \frac{n\lambda L}{d}$

Therefore increasing L will increase spacing between the bands. Increasing λ will increase spacing between the bands.

∴ B, C (ANS)

Example 4.137: (1984 Question 39)

The distance from the central maximum to the next local maximum is given by $x \approx \frac{n\lambda L}{d}$

∴B, E (ANS)

Example 4.138: (2004 Pilot Question 10)

For a bright spot P2 - P1 = nλ

∴ P2 - P1 = 6 × 632 ×10^{-9}

= 3.8 × 10^{-6} m. (ANS)

Examiner's comment

Some students misunderstood the prefix nano in the unit for wavelength. Others were confused about whether it was a node or antinode and whether the path difference was 5λ, 6λ, 7λ, 5½ λ or 6½ λ.

Example 4.139: (2006 Question 7, 59%)

For the second maximum the path difference needs to be 2λ.

∴ 2 × 2.8

∴ 5.6 cm (ANS)

Example 4.140: (2006 Question 8, 59%)

The interference pattern, (the bright and dark bands) is evidence that light exhibits wave like properties.

Example 4.141: (2008 Question 3, 45%)

Position Z is the second minimum, so the path difference is 1.5λ.

So: PD = 1.5λ

PD = 1.5 × 3.0

∴ PD = 4.5 cm (ANS)

Examiner's comments
A common difficulty was the correct application of the relationship (n – ½) λ.

Example 4.142: (2008 Question 4, 50%)

The path difference at point Y is 1 wavelength, this means that the peaks from source 1 meet peaks from source 2, and troughs from sources 1 meet troughs from source 2. This means the light will always constructively interfere at point Y, so point Y will then be a point of maximum intensity.

Examiner's comments
Many students simply referred to the path difference as being an integral number of wavelengths, instead of applying their understanding to the specifics of the question. Others incorrectly referred to the path difference in terms of the distance measured along PQ from point W.

Example 4.143: (2008 Question 5, 65%)

Reducing the separation of the slits will result in the distance between adjacent maxima and minima increasing. The width of the maxima and minima will increase. The distance between the maxima and minima points along PQ will increase.

Example 4.144: (2009 Question 3, 67%)

The path length from both slits is the same. Therefore the path difference is zero. This results in constructive interference, hence a bright central region.

Thelma is correct (ANS)

Example 4.145: (2009 Question 4, 50%)

Let us assume that the bright central maximum is in the middle of the diagram.

This means that the path difference to 'B' is $\frac{3}{2}\lambda$ and the path difference to 'A' is $\frac{5}{2}\lambda$.

$\therefore \frac{5}{2}\lambda - \frac{3}{2}\lambda = \lambda$

$= 496$ nm

$\therefore$ **λ = 496 nm (ANS)**

Example 4.146: (2012 Question 2b, 60%)

The laser provides a coherent light source. Therefore the path difference for the two beams reaching the central point is zero. They will interfere constructively, so there will be a local maximum, which is seen as a bright band.

Example 4.147: (2012 Question 2d, 40%)

With the new wavelength, 2λ must be the same as 1½λ in the original wavelength.

$\therefore 2\lambda_{new} = 1.5 \times 612$

$\therefore \boldsymbol{\lambda_{new}}$ **= 459 nm (ANS)**

Example 4.148: (2013 Question 22c, 33%)

Determine the wavelength of the light, (in metres).
Use:
The second bright band has a path difference of 2λ

$\therefore 2\lambda = 1.4 \times 10^{3}$ nm

$= 1.4 \times 10^{-6}$ m

So λ was 7×10^{-7} m.
The PD to the first dark band is λ/2,

$\therefore$ **3.5×10^{-7} m (ANS)**

Example 4.149: (2014 Question 19b, 45%)

If the point P is now on the second dark band, this means that the path difference is now 1.5λ.

$\therefore 840 = 1.5\lambda_{new}$

$\therefore \lambda_{new} = \frac{840}{1.5}$

$\therefore \boldsymbol{\lambda_{new}}$ **= 560 nm (ANS)**

How are light and matter similar solutions

Example 5.1: (1981 Question 47)

The light intensity is constant. Therefore once the collector is positive in relation to the emitter, all the electrons will travel across. Increasing the potential, won't impact on this current, as the current is dependent on the intensity of the light (constant).

∴ B (ANS)

Example 5.2: (1981 Question 48)

The incident energy of the photon is dependent on its frequency. The higher the frequency the greater the energy of the photon, so the more energy if has to give to the electron. Therefore the electron will be able to do more work against the voltage. It will always take some energy to release an electron.

∴D (ANS)

Example 5.3: (1981 Question 49)

It is the work function, which is also the y-intercept. It is a property of the metal.

∴ A (ANS)

Example 5.4: (1997 Question 2, 42%)

The stopping potential (from the graph) is 1.5 V.
This means that the maximum KE of the ejected electrons is $1.5 \times 1.6 \times 10^{-19}$

∴ 2.4×10^{-19}J (ANS)

Example 5.5: (1997 Question 3, 9%)

The intensity of the light source does not change the energy of the incident photons. It only increases the number of photons hitting the surface. So the energy of the ejected electrons will not change. The electron absorbs the energy from a single photon. The energy of the incident photon is given by E = hf. For a single colour the energy remains constant, it is independent of the intensity.
The energy of the ejected photon is given by KE = hf – W. Since this all stays the same, this means that they will still be able to do the same amount of work against the potential difference. Hence the voltage that stops them will remain the same.

Example 5.6: (1979 Question 66, 86%)

From your definitions, the gradient of this graph is Planck's constant

∴ C (ANS)

Example 5.7: (1979 Question 67, 54%)

The minimum amount of energy required to remove an electron is the work function. i.e. the y-intercept.

∴ 6×10^{-19} J (ANS)

Example 5.8: (1979 Question 68, 85%)

'k' is Planck's constant. Therefore it doesn't change. The slope of graph for the different metals will have the same gradient but different y-intercepts.

∴ C (ANS)

Example 5.9: (1979 Question 69, 56%)

You need to read the axis on this graph very carefully.
From the graph at the beginning of this set of questions, if the frequency is 12×10^{14} Hz, then magnesium will emit electrons.
If the intensity starts from zero and increases, then electrons will be emitted as soon as the intensity is above zero. Increasing the intensity will only increase the number of photons, not the energy of the individual photon. Therefore the ejected photoelectron will have the same maximum KE.

∴ C (ANS)

Example 5.10: (1982 Question 48, 63%)

The gradients should all be the same.

∴ D (ANS)

Example 5.11: (1982 Question 49, 52%)

To produce photoelectric emission, you need light with more energy for the platinum. More energy implies higher frequency hence shorter wavelength.

∴ B (ANS)

Example 5.12: (1982 Question 50, 89%)

The platinum has a larger work function, therefore it takes more energy to release an electron.

∴ C (ANS)

Example 5.13: (1985 Question 46, 71%)

If the intensity of the light is doubled, the number of incoming photons is doubled, so the number of collisions will double. This means that the number of electrons ejected, hence the current, will double.
The energy of the photon has not changed so the cut-off voltage $-V_0$ will remain the same.

$\therefore$ **B (ANS)**

Example 5.14: (1985 Question 47, 59%)

The higher frequency will give the ejected electrons more energy, therefore the negative cut-off voltage will become more negative.
As the same number of photons are coming in, the number of collisions hence the current will remain constant.

$\therefore$ **D (ANS)**

Example 5.15: (1986 Question 47)

Doubling the intensity of the light, will increase the current, but this graph is showing the KE vs f. This will not alter when the intensity is doubled. Therefore the graph will be identical.

$\therefore$ **A (ANS)**

Example 5.16: (1986 Question 48)

Replacing the potassium with another metal will alter the work function only. The gradient of the lines must remain the same.

$\therefore$ **C and E (ANS)**

Example 5.17: (1988 Question 29)

The work function is also given by $E = hf_0$.
$\therefore E = 4.1 \times 10^{-15} \times 5.0 \times 10^{14}$

$\therefore$ **E = 2.05 eV (ANS)**

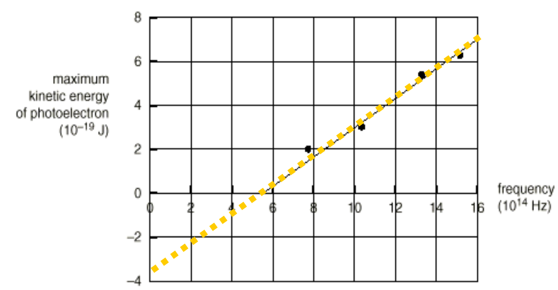
Example 5.18: (1988 Question 30)

The energy of the incoming photon is given by $E = hf$,
$\therefore E_{photon} = 4.1 \times 10^{-15} \times 7.0 \times 10^{14}$
$\therefore E_{photon} = 2.87$ eV
The electron loses 2.05 eV escaping from the surface, therefore the
KE = 2.87 – 2.05
= 0.82 eV (ANS)

Example 5.19: (2001 Question 4, 66%)

The work function is given by either
$W = hf_0$ or by extrapolating the graph back to the vertical axis.
Using $W = hf_0$ gives
$W = 6.63 \times 10^{-34} \times 5.5 \times 10^{14}$
$= 3.65 \times 10^{-19}$
= 3.7 × 10⁻¹⁹J (ANS)

Extrapolating the graph, gives an answer of –3.7 or –3.8.



This would give a work function of either 3.7×10^{-19}J or 3.8×10^{-19}J. As long as you had shown your working, by drawing the extrapolation on the graph, either would have been correct. But you do need to be careful when doing this.
The examiners accepted values in the range of $(3.5 - 3.9) \times 10^{-19}$J.

Example 5.20: (2001 Question 5, 60%)

The cut-off frequency, from graph, was 5.5×10^{14} Hz. The wavelength is given by $c = f\lambda$.
Where $c = 3.0 \times 10^8$.

So $\lambda = \dfrac{c}{f}$

$= \dfrac{3 \times 10^8}{5.5 \times 10^{14}}$

$= 5.45 \times 10^{-7}$

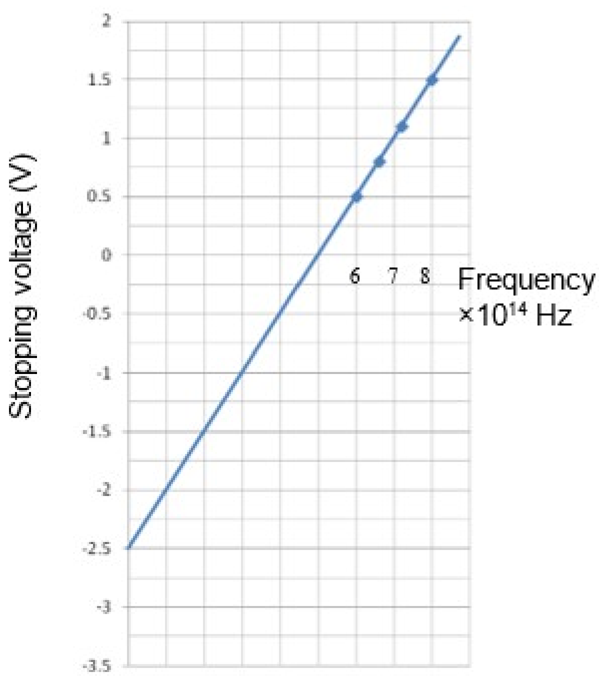
$\therefore$ 545 nm

$\therefore$ **Sodium (ANS)**

Example 5.21: (2006 Question 2, 70%

Wave model	Particle model
Y	**Y**
Y	N
Y	**N**
Y	**N**

Example 5.22: (2008 Question 6, 63%)



Examiner's comments
Common mistakes made by students included failing to label the axes with the physical quantity and unit, not clearly identifying the plotted points and poor selection of scales on axes. Many students did not recognise which were the dependent and independent variables and had the axes interchanged from the normal convention. Students who did not commence the frequency axis at zero or had a break in the scale of the frequency axis had problems determining the work function from the vertical intercept. It was surprising how many students managed to draw four different lines that were sometimes parallel or crisscrossing.

Example 5.23: (2008 Question 7, 50%)

From the gradient of the graph will give you Planck's constant in eVs. The gradient is:

$$h = \frac{\text{rise}}{\text{run}}$$

$$h = \frac{1.5 - 0}{(8-5) \times 10^{14}}$$

$\therefore$ h = 5.0 × 10^{-15} eV s (ANS)

Examiner's comments
Students were able to determine Planck's constant either from the gradient of the graph or by substitution into the equation EK = hf – W.
Taking the value of 4.1 × 10^{-15} from the data sheet was not awarded any marks.

Example 5.24: (2008 Question 8, 45%)

Use the graph again and find the y – intercept, this was around -2.5 Volts. This means the work function of the metal is:

2.5 eV (ANS)

Examiner's comments
*Students who had not correctly graphed the data in Question 6 struggled with this question. Students are reminded that when the question specifically states the unit in which the answer is to be given, **alternatives are not acceptable**.*

Example 5.25: (2011 Question 5, 20%)

Due to the photoelectric effect photoelectrons are ejected from the metal. They exit the metal with a range of kinetic energies.
The collector electrode is connected to the negative side of the battery, this negative bias means that the photoelectrons need to do work to reach it.
The photoelectrons lose kinetic energy as they travel from the metal plate (emitter) to the collector electrode.
As the voltage increases the number of photoelectrons with enough kinetic energy to reach the collector electrode decrease, therefore the current decreases.
Eventually the increased voltage is such that not even the photoelectron with the maximum kinetic energy can reach the

collector electrode. So the current becomes zero.
This is the point X on the graph.

Example 5.26: (2012 Question 1b, 45%)

The particle model predicts that increasing the intensity, will increase the number of incident photons, but the photons will still have the same energy. Therefore the photons will not have sufficient energy to release an electron from the metal surface. Therefore the will not be any current.
The wave model predicts that increasing the intensity will increase the energy to a level to eject photoelectrons.

Example 5.27: (2012 Question 1c, 80%)

$KE_{max} = hf – W$
$\therefore$ KE = $4.14 \times 10^{-15} \times 7.50 \times 10^{14} – 2.28$
$\therefore$ **KE = 0.825 eV (ANS)**

Example 5.28: (2012 Question 1d, 41%)

If the photoelectrons have a KE of 0.825 eV, then it will take 0.825 V to stop them.
$\therefore$ **0.825 V (ANS)**

Example 5.29: (2013 Question 21a, 42%)

The voltage that stops all photoelectrons is 1.85 V (i.e. when the current is zero). Therefore the maximum kinetic energy that a photoelectron can have is 1.85 eV.
To convert to joule, multiply be 1.6×10^{-19}
$\therefore$ **2.96×10^{-19} J (ANS)**

Example 5.30: (2013 Question 21b, 35%)

Using KE = hf – W,
We get that the maximum KE of the ejected photoelectrons is 1.85 eV.
If the energy of the incident photon is given by E = hf, then the difference between these is the work function.
$\therefore$W = $4.14 \times 10^{-15} \times 1.00 \times 10^{15} – 1.85$
$\therefore$ W = 4.14 – 1.85
$\therefore$ **2.29 eV (ANS)**

Example 5.31: (2013 Question 21d, 25%)

If the photocurrent remains zero, even when the collector voltage is positive, then this means that there are no photoelectrons being ejected. This means that the incident photons do not have enough energy to release a photoelectron.
Therefore the energy of the incident photons, given by E = hf, must be less than the work function of sodium.
Therefore the frequency of the light is less than the cut –off frequency.

Example 5.32: (2014 Question 20b, 38%)

According to the particle model of light increasing the intensity of the light increases the number of photons, but doesn't change the energy of the photon. The energy of the photon is given by E = hf, therefore if the frequency is unchanged, then the energy of the photons is unchanged. Each photon interacts with only one electron, therefore the maximum kinetic energy of ejected photoelectrons will be unchanged. The increase in intensity means that there will be more photoelectrons ejected. This is evidence of the particle-like nature of light.

Example 5.33: (1971 Question 58, 40%)

A The particle model gives the angle of incidence = angle of reflection.
B Explains the inverse square law.
C True
D The particle model predicts that light will travel faster in a refracting material.
$\therefore$ **A, B, C (ANS)**

Example 5.34: (1971 Question 59, 60%)

A True
B The wave model predicts that light will travel slower in a refracting material.
C False
D True
$\therefore$ **A, D (ANS)**

Example 5.35: (1973 Question 48, 68%)

The particle model predicts that it will pass straight through, whereas the wave model suggests that the slit will act as a new point source for the wave.
$\therefore$ **B (ANS)**

Example 5.36: (1976 Question 58, 56%)

Particles can explain B and C. A, E and F are not relevant in this case.
Therefore the only wave property that can't be explained by a particle, is diffraction. Sound will diffract.

∴ **D (ANS)**

Example 5.37: (1976 Question 59, 53%)

The fact that sound travels at 300 m/s in air, means that it can't be an EM radiation. All EM radiations travel at the speed of light.

∴ **F (ANS)**

Example 5.38: (1997 Question 4, 60%)

This interference pattern is best explained from the wave model. Waves from the two point sources (the slits) will interfere with each other at the screen. You will get bands of constructive and destructive interference. A path difference of $\frac{\lambda}{2}$, $\frac{3\lambda}{2}$, $\frac{5\lambda}{2}$ etc. will produce nodal lines. (A dark band is due to destructive interference). The bright central band will always be a region where constructive interference occurs

Example 5.39: (1998 Question 8, 39%)

The de Bröglie wavelength is given by

$p = \frac{h}{\lambda}$ $\quad\quad \therefore \lambda = \frac{h}{mv}$

The momentum of the electrons is given by p = mv

$= 9.1 \times 10^{-31} \times 1.0 \times 10^{7}$

$= 9.1 \times 10^{-24}$ Ns

$\therefore \lambda = \frac{6.63 \times 10^{-34}}{9.1 \times 10^{-24}}$

$= 7.3 \times 10^{-11}$ m (ANS)

Example 5.40: (2001 Question 2, 45%)

Use the equations for particles here, not those associated with photons. This is because the electron has mass, and cannot travel at the speed of light.
The work done, or change in KE is given by

$\Delta KE = qV$

$= 1.6 \times 10^{-19} \times 10 \times 10^{3}$

$= 1.6 \times 10^{-15}$ J

$\therefore 1.6 \times 10^{-15} = \frac{1}{2} mv^2$

$\therefore \frac{1}{2} \times 9.1 \times 10^{-31} \times v^2 = 1.6 \times 10^{-15}$

$\therefore v = 5.93 \times 10^{7}$ m s^{-1}

$\lambda = \frac{h}{mv}$

$= \frac{6.63 \times 10^{-34}}{9.1 \times 10^{-31} \times 5.93 \times 10^{7}}$

$\therefore \lambda = 1.2 \times 10^{-11}$ m (ANS)

Example 5.41: (2003 Question 4, 45%)

The deBröglie wavelength is given by

$\lambda = \frac{h}{mv}$

$= \frac{6.6 \times 10^{-34}}{0.2 \times 30}$

$= 1.1 \times 10^{-34}$ m.

The amount of diffraction is given by the ratio of $\frac{\lambda}{d}$. Using d ~ 8cm, the amount of diffraction is negligible.

To actually answer the question, you need to say that you could not see the wave nature of the ball because the wavelength was too small to observe and that the diffraction was so negligible that it also couldn't be observed.

Example 5.42: (2001 Question 3, 17%)

The most difficult part to this question is identifying what it is asking. This is a question on diffraction comparing the effects of light and electrons.
The poorer quality of the optical image when compared with the image from the electron microscope is caused by the greater diffraction of the photons than the electrons. I.e. the sharper the image, the less the diffraction, as the rays are travelling in straight lines, so we get a sharp image.
Assume that the electrons are moving quite fast, giving them their longest wavelength, then typically the wavelength would be of the order of 10^{-11} m.
The wavelength of light is typically 10^{-7} m.

$\lambda_{electrons} << \lambda_{photons}$.

The scale of the diagram, shown in the bottom right hand corner is 25μm. This means that

the wavelength of the light is similar to the width of sections of organism.
The amount of diffraction is given by the ratio of $\frac{\lambda}{d}$, so the electrons are much less likely to diffract, therefore this image will be clearer.

Example 5.43: (1998 Question 6, 47%)

This is a standard interference pattern, and this can best be explained if we treat the source as a wave. The photons bend as they go through the slit. The photons do not continue to travel in the original straight line.
The amount of spreading depends on the ratio $\frac{\lambda}{w}$. If $\frac{\lambda}{w} \geq 1$, then the diffraction pattern spreads through 180^0. This pattern occurs when there is only one photon at a time (Taylor proved this) or when there are many photons. It is a property of individual photons.

Example 5.44: (2005 Question 6, 71%)

The momentum of the electron
$m \times v = 9.1 \times 10^{-31} \times 2.0 \times 10^{7}$
$= 1.82 \times 10^{-23}$
Using $p = \frac{h}{\lambda}$
$\therefore \lambda = \frac{6.63 \times 10^{-34}}{1.82 \times 10^{-23}}$
$= 3.64 \times 10^{-11}$ m (ANS)

Examiner's comment
Some students made arithmetical or calculator errors. Others used the wrong Planck's constant. A number of students used 3×10^{8} as the speed of the electron.

Example 5.45: (2006 Question 11, 59%)

The wavelength of the electrons is 250 pm.
Using $p = \frac{h}{\lambda}$
$\therefore p = \frac{6.63 \times 10^{-34}}{250 \times 10^{-12}}$
$= 2.65 \times 10^{-24}$ kg m/s (ANS)

Examiner's comment
A common error was using the wrong value for Planck's constant. Other students assumed that the energy of the electrons must equal that of the X-rays.
Still others used p = mv, assuming the speed of the electron was 3×10^{8} m s^{-1}.

Example 5.46: (2007 Question 5, 60%)

The amount of diffraction is given by the ratio of $\frac{\lambda}{w}$.

There is diffraction when $\frac{\lambda}{w} \sim 1$.
In this case $\frac{\lambda}{w} = \frac{2.0 \times 10^{-10}}{3.0 \times 10^{-10}}$
$= 0.67$
$\therefore$ There will be significant diffraction

Example 5.47: (2011 Question 11, 25%)

Since the two patterns are the same, both the X-rays and the electrons must have the same momentum.
Find the momentum of the X-rays and then use $E_k = \frac{p^2}{2m}$ to convert to energy.
<u>Momentum of X-rays.</u>
de Broglie wavelength
$\lambda = \frac{h}{p}$
$p = \frac{h}{\lambda}$
$= \frac{6.63 \times 10^{-34}}{0.20 \times 10^{-9}}$
$= 3.315 \times 10^{-24}$ Ns
$E_k = \frac{p^2}{2m}$
$= \frac{(3.315 \times 10^{-24})^2}{2 \times 9.1 \times 10^{-31}}$
$= 6.04 \times 10^{-18}$ J
$= \frac{6.04 \times 10^{-18}}{1.6 \times 10^{-19}}$ eV
$= 37.7$ eV
So energy is 37.7 eV (ANS)

Example 5.48: (2012 Question 3b, 40%)

As the pattern remains the same, the momentum of the photon must be the same as the momentum of the electron.

$p_{electron} = mv$

$= 9.1 \times 10^{-31} \times 1.5 \times 10^{5}$

$= 1.365 \times 10^{-25}$.

For the photon, E = pc

$\therefore E = 4.095 \times 10^{-17}$ J

Convert to eV by dividing by 1.6×10^{-19}

∴ E = 256 eV (ANS)

Example 5.49: (2013 Question 23a, 35%)

The simplest way to solve this is to use

E = pc, where E is the energy (Joules) and c is the speed of light.

$$\therefore p = \frac{E}{c}$$

$$\therefore p = \frac{80\,000 \times 1.6 \times 10^{-19}}{3 \times 10^{8}}$$

∴ p = 4.3×10^{-23} kg m s^{-1} (ANS)

The alternative method is to use $E = \frac{hc}{\lambda}$, to find λ and then $p = \frac{h}{\lambda}$.

Example 5.50: (2013 Question 23b, 40%)

Student A is correct.

The fringe pattern is controlled by the wavelength, which is directly related to the momentum as $p = \frac{h}{\lambda}$

Example 5.51: (2014 Question 21b, 35%)

Smaller than (ANS)

Example 5.52: (2014 Question 21c, 35%)

The amount of diffraction is given by $\frac{\lambda}{d}$, so it will increase as λ increases and decrease as the gap decreases. In this instance the aperture width has increased, therefore the spreading is decreased.

Example 5.53: (2014 Question 21d, 30%)

The spacing of the diffraction pattern depends on the wavelength. The electrons and the photons do not have the same diffraction pattern, therefore they cannot have the same wavelength. The fact that they have the same energy does not mean that they have the same wavelength.

Example 5.54: (2015 Question 20b, 30%)

The diffraction of electrons is evidence of the wavelike nature of electrons. When fired at a crystal, electrons create an interference pattern, as a result of constructive and destructive interference.

Example 5.55: (1998 Question 4, 38%)

The energy of a photon is given by

$E = \frac{hc}{\lambda}$.

∴ the energy of each photon

$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{640 \times 10^{-9}}$$

= 3.1×10^{-19} J (ANS)

Example 5.56: (1998 Question 5, 25%)

The energy of a photon is given by

$E = \frac{hc}{\lambda}$.

∴ the energy of each photon

$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{640 \times 10^{-9}}$$

$= 3.1 \times 10^{-19}$J

∴ To make a beam of 1.0 mW, you need 1.0×10^{-3} Joules every second.

∴ 1.0×10^{-3} = ‘n’ × 3.1×10^{-19}J

∴ n = $1.0 \times 10^{-3} \div 3.1 \times 10^{-19}$J

= 3.2×10^{15} photons per second. (ANS)

Example 5.57: (1997 Question 6, 70%)

The momentum of a photon with wavelength 2.0×10^{-7} m is:

$$p = \frac{h}{\lambda}$$

$$= \frac{6.63 \times 10^{-34}}{2.0 \times 10^{-7}}$$

= 3.3×10^{-27} Ns (ANS)

Example 5.58: (2009 Question 9, 60%)

Use p = $\frac{h}{\lambda}$

= $\frac{6.63 \times 10^{-34}}{1.4 \times 10^{-10}}$

∴4.7 × 10^{-24} Ns (ANS)

Example 5.59: (1973 Question 103, 37%)

The photoelectron has 30.4 eV, it took 10.4 eV to ionise (release the electron), so the photon must have had 40.8 eV

∴ 40.8 eV (ANS)

Example 5.60: (1978 Question 77, 78%)

This graph is a little different to the common one, here the ground state has been assigned a negative value.

∴ n = 1 (ANS)

Example 5.61: (1978 Question 78, 78%)

It needs to reach 0 eV

∴ 13.6 eV (ANS)

Example 5.62: (1989 Question 65)

It is easiest to draw them on the diagram.
The paths to ground state are
3^{rd} to 2^{nd} to 1^{st} to ground
3^{rd} to 2^{nd} to ground
3^{rd} to ground
3^{rd} to 1^{st} to ground

∴ D (ANS)

Example 5.63: (1989 Question 66)

Since E = hf, the highest frequency will occur when the change in E is greatest. Therefore from the 3^{rd} to ground

∴ 12.7 = 4.135 × 10^{-15} × f

∴ f = 3.07 × 10^{15} Hz (ANS)

Example 5.64: (2001 Question 6, 60%)

Use: $E_{photon} = \frac{hc}{\lambda}$

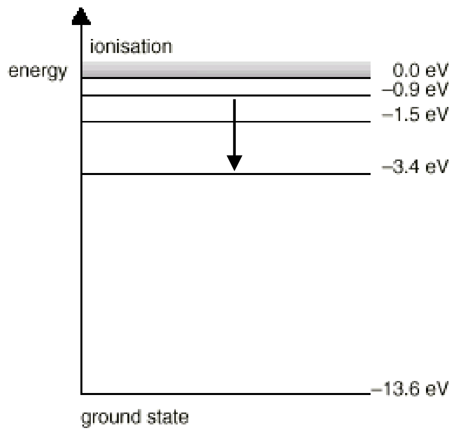
Where λ is given as 497 nm.

∴ $E_{photon} = \frac{4.14 \times 10^{-15} \times 3.0 \times 10^{8}}{497 \times 10^{-9}}$.

∴ 2.5 eV (ANS)

Example 5.65: (2001 Question 7, 40%)

The difference between two energy levels needs to be 2.5eV.
Difference between
–0.9 and –3.4 = 2.5 eV.
To get full marks the arrow had to be pointing down. The emission is a result of a change from a higher energy level to a lower energy level, i.e. heading back to ground state.



Example 5.66: (2005 Question 10, 50%)

The energy difference from the first excited state to ground state is 3.4 eV

Using $E = \frac{hc}{\lambda}$, so

$$\lambda = \frac{hc}{E}$$

$$= \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{3.4}$$

$= 3.65 \times 10^{-7}$

$= 3.7 \times 10^{-7}$ m (ANS)

Example 5.67: (2007 Question 9, 51%)

Hydrogen exists in the atmosphere of the sun and the earth.
As light travels from the sun to the earth, this hydrogen can absorb light.
The frequencies of the absorbed light are related to the difference between any two energy levels of the hydrogen atoms.
These photons are re-emitted in all directions, so they don't all make it to Earth.
Thus the light reaching the earth will have a reduced amount of those absorbed frequencies and dark lines appear in the spectrum of light from the sun.

Examiner's comment
It was very common for students to attempt to explain the dark lines in terms of destructive interference.

Example 5.68: (2008 Question 12, 45%)

Use $\lambda = \frac{hc}{E}$

$$\lambda = \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{12.8}$$

$\therefore$ **$\lambda = 97\text{nm}$ (ANS)**

Example 5.69: (2012 Question 4b, 40%)
Electrons exhibit wavelike properties. As they orbit the nucleus they must form standing waves. This means that only whole numbers of wavelengths can exist. i.e the wavelength is quantised.

The energy of the electron is given by $E = \frac{hc}{\lambda}$, therefore the energy levels are also quantised, hence only certain energy levels are stable.

Example 5.70: (2013 Question 20a, 40%)

Since the energy is given by $E = \frac{hc}{\lambda}$, the longest wavelength will occur when the energy level difference is the smallest.

$\therefore$ 3.19 – 2.11 = 1.08 eV.

$$\therefore 1.08 = \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{\lambda}$$

$\therefore$ **$\lambda = 1.15 \times 10^{-6}$ m (ANS)**

Example 5.71: (2013 Question 20b, 43%)

Using $E = \frac{hc}{\lambda}$

We get $E = \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{588.63 \times 10^{-9}}$

$\therefore$ E = 2.11 eV.
This energy difference corresponds to a transition from the first excited state (2.11) to the ground level. Therefore a photon with this energy can be given off.

Example 5.72: 2004 Sample Question 11

Each dotted line has 3 wavelengths around the circumference and hence it is the n = 3 level.

Example 5.73: (2005 Question 11, 50%)

Electrons have a de Bröglie wavelength.
When the atom has stable energy levels, these electrons only exist in states where a 'standing wave' is formed around the nucleus.
This only allows specific wavelengths, as the path needs to be multiples of the de Bröglie wavelength.
This means that only specific energies (associated with the wavelength) exist.

Examiner's comment
A diagram could have been used to explain most of this question. While not an easy concept, students' understanding of the meaning of the standing wave for electrons in stable states within atoms was weak.

Example 5.74: (2009 Question 12, 35%)

Electrons orbit the nucleus of the atom in circular paths. For this path to continue to exist, it must be exactly the length to allow a circular standing wave to exist.
The circumference of these standing waves must be an exact multiple of an electron's wavelength. Therefore only particular wavelengths can exist, this means that the wavelengths are quantised.

The energy level of the electron is given by $\frac{hc}{\lambda}$
This means that the energy levels (which are dependent on the wavelength) are also quantised.

Example 5.75: (2014 Question 23b, 37%)

Since an electron can exhibit wave-like behaviour, then the electron can form a standing wave as it orbits the nucleus.
Only certain de Broglie wavelengths will resonate and set up a standing wave. The electron's momentum is related to its wavelength and the energy of the electron is related to its momentum. Therefore only specific value of electron energy are allowed. This the quantisation of electron energy.

Example 5.76: (2015 Question 21a, 37%)

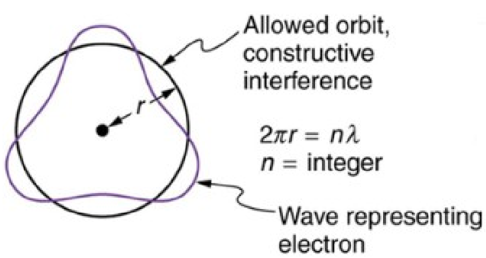
Electrons have a De Broglie wavelength. Electrons will only exist in stated where a standing wave can be formed around the nucleus when the circumference of orbit is a whole number of wavelengths, from $n\lambda = 2\pi r$. Accordingly only specific wavelengths and their associated energies are allowed.

Examiner's comments

Students were required to identify the wave nature of electrons. They were then required to explain the standing wave theory, where $n\lambda = 2\pi r$. Finally, they were required to identify that the different allowed orbits had different whole values of n.

While most students knew that 'standing waves' was a key term, they could not apply it in a coherent way. Of further concern was the number of students who seemed to believe that the electrons wobble or follow a sinusoidal path around the nucleus. It should be understood that the Bohr model of the atom is a simplistic model and the electrons do not orbit at all. Even if they did, they would not follow a sinusoidal path. Students should familiarise themselves with de Broglie's work.

Example 5.77: (2015 Question 21b, 45%)



Examiner's comments

Students who tried to draw a strip of paper joined end to end with a sinusoidal wave pattern on it generally had difficulty identifying the standing wave nature of the wave function in the orbit.

Example 5.78: (1969 Question 107, 52%)

The edge will create some interference effects.

∴C (ANS)

Example 5.79: (1969 Question 108, 78%)

Photons are random.

∴C (ANS)

Example 5.80: (1969 Question 109, 40%)

You expect the same pattern.

∴C (ANS)

Example 5.81: (1969 Question 110, 34%)

You expect the same pattern as electrons can exhibit wavelike properties.

∴C (ANS)

Example 5.82: (1971 Question 107, 92%)

The greater the probability the greater the intensity.

∴C (ANS)

Example 5.83: (1971 Question 108, 64%)

You expect the same pattern

∴D (ANS)

Example 5.84: (2007 Question 1, 57%)

The three correct statements were 'population inversion', 'photons' and 'the same'.

Example 5.85: (2007 Question 2, 46%)

The LED requires sufficient voltage across the diode to raise the electrons to the higher allowable energy state. Electrons then return to the lower state emitting photons.

Example 5.86: (2007 Question 3, 46%)

Use $E = \frac{hc}{\lambda}$.

$\therefore \lambda = \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{2.64}$

$\therefore \lambda = 4.7 \times 10^{-7}$ m (ANS)

Example 5.87: (2007 Question 4, 55%)

The red light requires less energy to emit light, it will turn on at a lower voltage. As the supply voltage is left the same the voltage drop across the resistor will increase, this will increase the current in the circuit.

∴ A (ANS)

Example 5.88: (2008 Question 1, 71%)

The Laser has a very small spectrum (monochromatic) so it is graph 1.
The Mercury vapour lamp has discrete wavelengths so it is graph 2.
The LED has a small range of wavelengths emitted with a peak value in the middle so it is graph 3.

∴ D (ANS)

Example 5.89: (2008 Question 2, 72%)

Use $\lambda = \dfrac{hc}{E}$

∴ $\lambda = \dfrac{4.14 \times 10^{-34} \times 3 \times 10^{8}}{1.8}$

∴ $\lambda = 6.90 \times 10^{-7}$

∴ $\lambda = 690$ nm

∴ B (ANS)

Example 5.90: (2008 Question 3, 80%)

The Laser has a very small spectrum (Monochromatic).
The LED has a small range of wavelengths emitted.

∴ C (ANS)

Example 5.91: (2008 Question 4, 67%)

The important part to this question was the stimulated emissions. For stimulated emission to occur the atom must be in the excited metastable state, then the photon hits that atom and stimulates it to emit a photon.

∴ C (ANS)

Practical Investigation solutions

Example 6.1: (NSW 2011 Question 10)

The independent variable is the one that the student can control

∴ **D (ANS)**

Example 6.2: (1981 Question 34, 66%)

As *d* increases *I* decreases, therefore an inverse relationship.
Doubling *d*, from 10 to 20, decreases *I* from 127 to 38, a factor of 0.30.
Doubling *d*, from 20 to 40, decreases *I* from 38 to 10.5, a factor of 0.28.
Doubling *d*, from 30 to 60, decreases *I* from 17.4 to 4.7, a factor of 0.27.
Doubling *d*, from 50 to 100, decreases *I* from 6.9 to 1.65, a factor of 0.24.
These approximate an inverse square relationship.

∴ **C (ANS)**

Example 6.3: (1981 Question 35, 44%)

See previous answer for calculations to support B

∴ **B (ANS)**

Example 6.4: (1968 Question 27, 79%)

If this equation is in the form of y = mx + c, it becomes

$\therefore S = S_0 kt + S_0$

Hence it is a straight line of gradient S_0k.

∴ **D (ANS)**

Example 6.5: (WA 2013 Question 14b)

The reading is **24 mA**
The uncertainty is half of one division, therefore **±0.5 mA**

The relative uncertainty is $\frac{0.5}{24} \times 100\%$

∴ **2% (ANS)**

Example 6.6: (1967 Question 68, 71%)

To make better predictions, it is preferable to have a graph that is a straight line. As *r* decreases *t* decreases, so an inverse relation exists. As *r* is quartered, *t* increases by a factor of 16, so an inverse linear relationship exists.

$t \propto \frac{1}{r^2}$

∴ **D (ANS)**

Example 6.7: (1967 Question 69, 49%)

As the density increases the time decreases, so an inverse relationship exists. Increasing the density by a factor of 2.5 decreases the time by a factor of 3. Therefore an inverse relationship occurs.
To make better predictions, it is preferable to have a graph that is a straight line.
If we use 4 gm/cm^3 and 7 gm/cm^3, and we subtract ρ_o, we get (4 – 1) = 3, and this doubles to (7 -1) = 6, when the times halve from 144 to 72.

$t \propto \frac{1}{\rho_s - \rho_o}$

∴ **E (ANS)**

Example 6.8: (1967 Question 70, 42%)

Use the two previous answers to get

$t \propto \frac{1}{r^2(\rho_s - \rho_o)}$

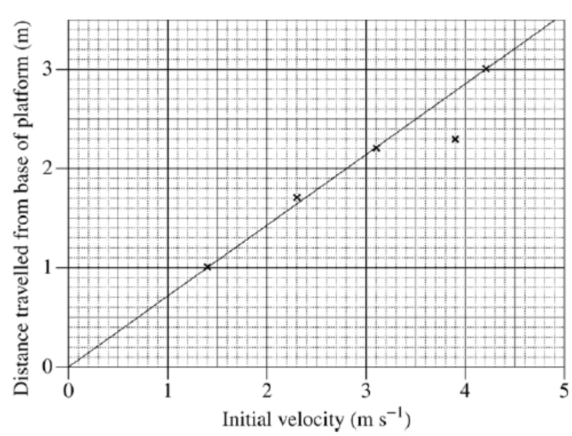
∴ **F (ANS)**

Example 6.9

A systemic error will not increase the range of the results, it will just affect the accuracy.

∴ **A (ANS)**

Example 6.10: (NSW 2015 Question 21a)



Example 6.11: (NSW 2015 Question 21b)

Since $\Delta x = u_x \times t$
Slope of graph = t

$\therefore t = \frac{3.0 - 0}{4.2 - 0}$

$\therefore$ t = 0.714

Then use $\Delta y = ut + \frac{1}{2} at^2$

$\therefore \Delta y = 0 + 0.5 \times 9.8 \times (0.714)^2$

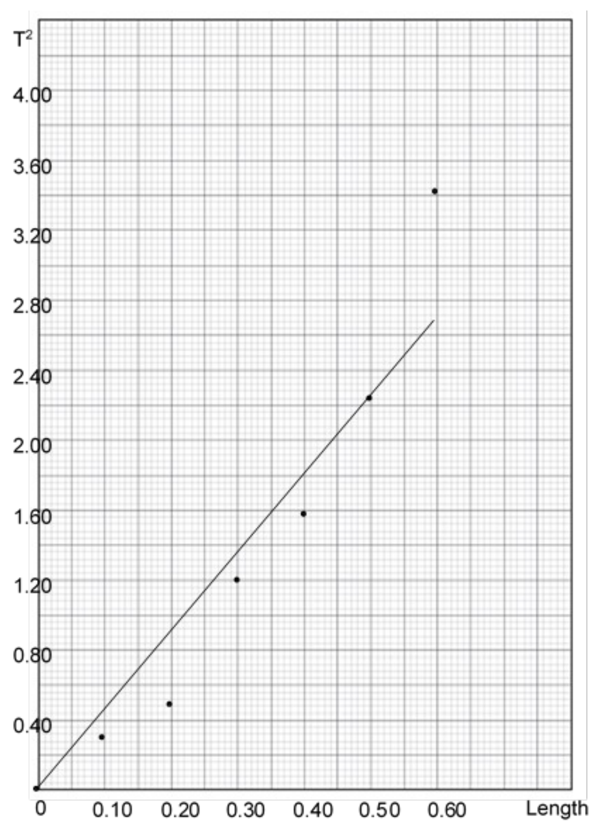
$= 2.5$

$\therefore$ **Height = 2.5 m (ANS)**

Example 6.12: (WA 2013 Question 15b (i))

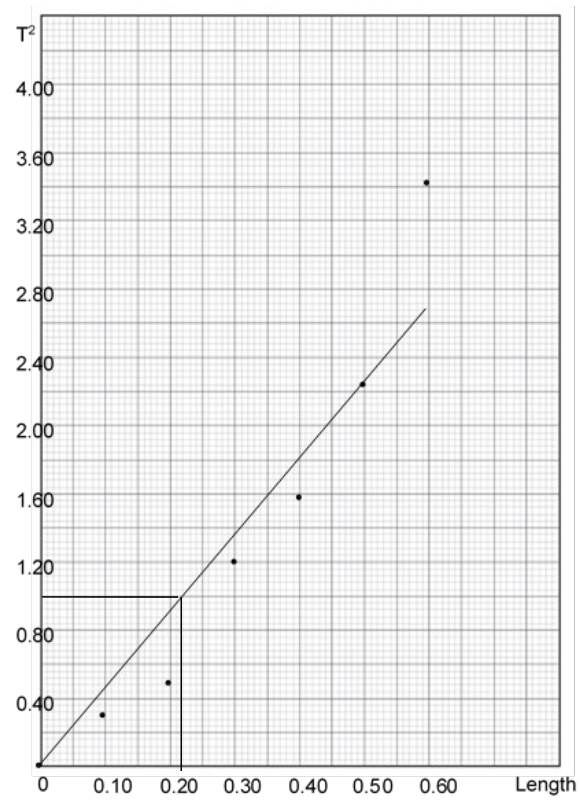
Length of pendulum ℓ (m)	Time for ten swings (s)	Time for one swing T (s)	Period squared T^2 (s^2)
0.10	5.5	0.55	0.303
0.20	6.9	0.69	0.476
0.30	10.9	1.09	1.188
0.40	12.5	1.25	1.563
0.50	15.0	1.50	2.25
0.60	18.5	1.85	3.423

Example 6.13: (WA 2013 Question 15b (ii))



It is reasonable to use the origin, and to try to have the distance of the points above the line to be the same as the distance of the points below the line of best fit.

Example 6.14: (WA 2013 Question 15b (iii))



From the graph, when t= 1.0, t^2 = 1.0 and the length = **0.22 m.** **(ANS)**

Example 6.15: (WA 2013 Question 15b (iv))

The gradient is given by the $\frac{\text{rise}}{\text{run}}$

$\therefore$ gradient = $\frac{2.25 - 0}{0.50 - 0}$

$\therefore$ **gradient = 4.50 s^2 m^{-1}** **(ANS)**

Example 6.16: (WA 2013 Question 15b (iv))

From $T = 2\pi \sqrt{\frac{\ell}{g}}$, we get

$T^2 = 4\pi^2 \times \frac{\ell}{g}$

$\therefore T^2 = \frac{4\pi^2}{g} \times \ell$

Therefore the gradient of the graph is $\frac{4\pi^2}{g}$.

$\therefore g = \frac{4\pi^2}{\text{gradient}}$

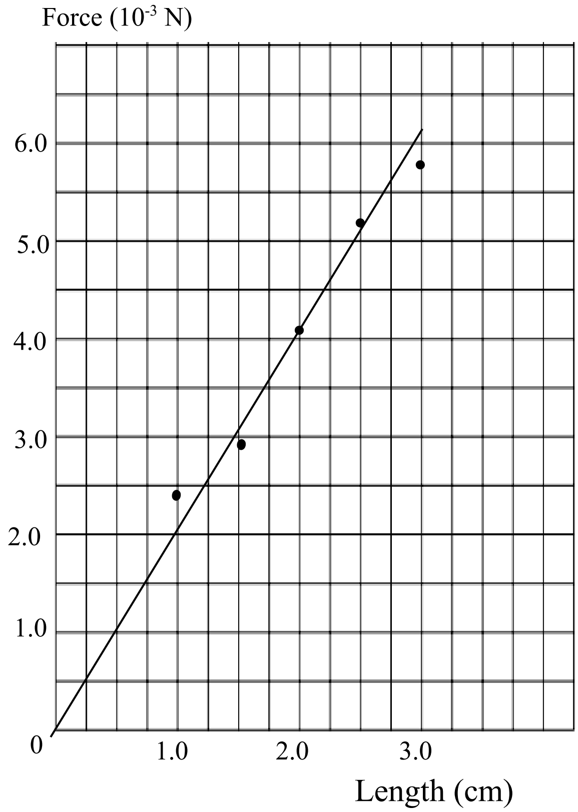
$\therefore g = \frac{4\pi^2}{4.50}$

∴ g = 8.77 m s^{-2} (ANS)

Example 6.17: (SA 2015 Question 26a)

Length of Wire L (cm)	Mass Measurement Shown on Scales m ($\times 10^{-4}$ kg)	Force F (N)
1.0	2.4	2.4×10^{-3}
1.5	3.0	2.9×10^{-3}
2.0	4.2	4.1×10^{-3}
2.5	5.3	5.2×10^{-3}
3.0	5.9	5.8×10^{-3}

Example 6.18: (SA 2015 Question 26b)



Example 6.19: (SA 2015 Question 26c)

The gradient is given by the $\frac{\text{rise}}{\text{run}}$

$\therefore$ gradient = $\frac{6.2 - 0}{3.0 - 0}$

∴ gradient = 0.21 × N m^{-1} (ANS)

Example 6.20: (SA 2015 Question 26d)

Use F = nBil.

Therefore the gradient = n × B × i.

n = 1, I = 1.5

∴ 0.21 = 1.5 × B

∴ B = 1.4 T (ANS)

Example 6.21: (SA 2015 Question 26e)

The calculated value of 1.38 T compares well with the actual value of 1.3 T.

Example 6.22: (1976 Question 26, 23%)

The net force is always being exerted by the washers

∴ D (ANS)

Example 6.23: (1976 Question 27, 78%)

Use $F = \frac{mv^2}{r}$

If 'm' and 'r' are kept constant then

$F \propto v^2$

$\therefore F \propto \frac{1}{T^2}$

∴ D (ANS)

Example 6.24: (1976 Question 28, 53%)

The frequency f is given by $\frac{1}{t}$ and $v = \frac{2\pi r}{t}$

$\therefore F = \frac{mv^2}{r}$ can be written as $F = m4\pi^2rf^2$

Therefore the plot of F vs f^2 is a straight line with gradient $m4\pi^2r$.

If the radius is doubled, the gradient of the line will double.

∴B (ANS)

Example 6.25: (1976 Question 29, 94%)

As $F = m4\pi^2rf^2$

∴A (ANS)

Example 6.26: (QLD 2015 Question 1)

a. Unsupported

b. Supported

c. Supported

d. Unsupported

Example 6.27: (1973 Question 78, 70%)

The deflection θ is proportional to the strength of the field. As R increases, θ decreases

∴ **A (ANS)**

Example 6.28: (1973 Question 79, 10%)

The deflection is due to two magnetic fields, the Earth's and the field due to the current in the wire. The earth's field is constant, but the field in the wire will vary according to the distance from the wire.
The length of the field at right angles to the earth's field is what is creating the variation in the angle.
If we calculate tan θ we get

θ	tan θ	r	r tan θ
45	1	5	5.0
27	0.51	10	5.1
14	0.25	20	5.0

Therefore when r = 3, tan θ = 1.67

∴ **59^0 (ANS)**

Example 6.29: (1973 Question 80, 42%)

The only possible answer is

∴ **D (ANS)**

Example 6.30: (1973 Question 81, 18%)

The component of the field due to the wire will be pointing SE here. So it will deviate the needle a bit more than when it was east in the initial experiment

∴ **D (ANS)**

Example 6.31: (NSW 2009 Question 24a)

With a 0.25kg mass attached, Band E extends by a length of 0.30m while the others extend much less.

∴ **Band E (ANS)**

Example 6.32: (NSW 2009 Question 24b)

Directly proportionally from 0 to 1.25kg

∴ **Band F (ANS)**

Example 6.33: (QLD 2014 Question 1)

The value for u = 3.57, has three sig figs. Therefore the answer can only be quoted to 3 sig figs.

∴ **C (ANS)**

Example 6.34: (QLD 2015 Question 1)

The value for t = 0.05 s, has one sig fig. Therefore the answer can only be quoted to 1 sig fig.

∴ **A (ANS)**

Example 6.35: (QLD 2013 Question 1)

i	4
ii	4
iii	2
iv	4

Example 6.36: (QLD 2013 Question 2)

i $45.6 \pm 1.4\% = 45.6 + 45.6 \times \frac{1.4}{100}$

$= 45.6 \pm 0.6384$

∴ **45.6 ± 0.7 cm (ANS)**

(To include all possible values, this is not rounding it is error control)

ii $7.45 \pm 12\% = 7.45 + 7.45 \times \frac{12}{100}$

$= 7.45 \pm 0.894$

∴ **7.45 ± 0.9 kg (ANS)**

(To include all possible values, this is not rounding it is error control)

Example 6.37: (QLD 2014 Question 1)

i	4
ii	2

Example 6.38: (QLD 2014 Question 2)

$423.6 \pm 2.0\% = 423.6 + 423.6 \times \frac{2.0}{100}$

$= 423.6 \pm 8.472$

∴ **423.6 ± 8.5 m (ANS)**

(To include all possible values, this is not rounding it is error control)

Example 6.39: (QLD 2015 Question 1)

i 5
ii 1

Example 6.40: (QLD 2015 Question 2)

$1050 \pm 3.0\% = 1050 + 1050 \times \frac{3.0}{100}$
$= 1050 \pm 31.50$
$\therefore$ **1050 ± 32 m** **(ANS)**
(To include all possible values, this is not rounding it is error control)

Example 6.41: (QLD 2016 Question 1)

a 3

b 1

Example 6.42: (QLD 2016 Question 2)

$235 \pm 5.0\% = 235 + 235 \times \frac{5.0}{100}$
$= 235 \pm 11.75$
$\therefore$ **235 ± 12 m** **(ANS)**
(To include all possible values, this is not rounding it is error control)