Mechanics
ANSWERS

Introduction

Trigonometry
STOP AND CHECK (PAGE 7)

- The hypotenuse is the longest side, the adjacent side the side next to the angle (or adjacent to the angle) and the opposite side is the side opposite to the angle.
- $o = h \times \sin(\theta)$
- $a = h \times \cos(\theta)$
- $h = \frac{a}{\cos(\theta)}$ and $h = \frac{o}{\sin(\theta)}$

Vectors
STOP AND CHECK (PAGE 9)

- The length of a vector tells us the magnitude, or size, of the vector. For example, a long velocity vector means something is moving fast, while a short velocity vector means something is moving slowly.
- The angle the vector makes with the horizontal tells us the direction of the vector.

Units
STOP AND CHECK (PAGE 11)

Name	Scale	Value
Terra-	$\times 10^{12}$	1,000,000,000,000

Giga-	$\times10^{9}$	1,000,000,000
Mega-	$\times10^{6}$	1,000,000
Kilo-	$\times10^{3}$	1,000
	1	1
Mili-	$\times10^{-3}$	0.001
Micro-	$\times10^{-6}$	0.000001
Nano-	$\times10^{-9}$	0.000000001
Pico-	$\times10^{-12}$	0.000000000,001

Forces

Newton's Laws

STOP AND CHECK (PAGE 13)

- Newton's second law comes into play when there's a net force on an object and it says that the object will accelerate or decelerate depending on the direction of the force.
- $F_{net} = ma$
- Newton's third law tells us that for every force there is an equal and opposite force, which includes the reaction force.

Important Forces

STOP AND CHECK (PAGE 15)

- The weight of an object is really just the weight force in action. The weight force is given by F=mg, where g is the acceleration due to gravity.
- The direction of the reaction force for an object laying on the ground is always perpendicular to the ground, so on flat ground the force will be straight up and on a slope, the force will be diagonal.

- The friction force opposes an object's motion, which means that it applies a force in the opposite direction to the direction the object is moving. Because of this force, the object slows down according to Newton's second law since the force applies a deceleration (or negative acceleration) on the object.
- The tension force is the force that acts in strings or ropes to pull them together when they're stretched out. You can kind of think of the tension force as a force that tries to undo any stretching that you've done on a string or rope.

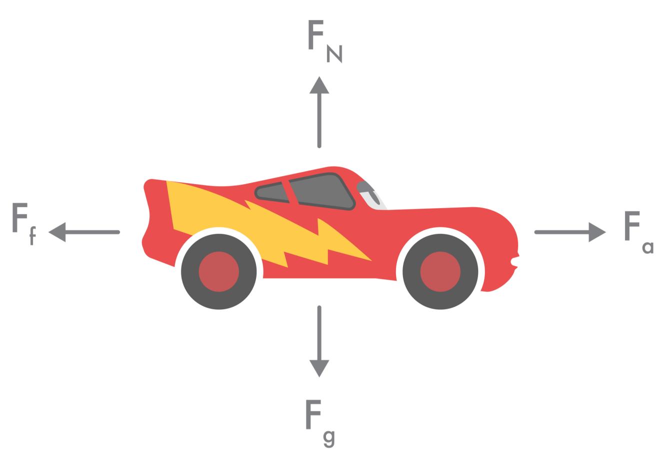
Equilibrium

STOP AND CHECK (PAGE 16)

- The term equilibrium describes situations where all the forces on an object cancel out to give no net force, or if there aren't any forces on an object in the first place. In this scenario, the object has no acceleration and we can say that the object is in equilibrium. Since the term "equilibrium" shows up in many areas of science, the kind of equilibrium we're talking about is sometimes referred to as mechanical equilibrium.
- The common misconception that people make when discussing objects that are in equilibrium is when people think that there are forces that cancel out, but aren't actually there. Just remember: don't write down forces you don't know are there.

Force Diagrams

STOP AND CHECK (PAGE 17)



- The forces are balanced, since the drag and thrust forces are equal and opposite they cancel out, and since the support and gravitational forces are equal and opposite they cancel out too. This means the car is in equilibrium, and by Newton's first law, the car is moving at a constant velocity.
- If the forward (thrust) force was any larger than the backward (drag) force, the object would accelerate in the direction of the forward force according to Newton's second law; which states that an object with a net force will accelerate in the direction of that force. This means that the car will speed up, as the net force is pointing in the forward (right) direction.

Kinematics

What do These Symbols Actually Mean?

STOP AND CHECK (PAGE 20)

- Distance is a scalar and displacement is a vector, meaning that displacement has a magnitude and direction, while distance just has a magnitude.
- Speed is a scalar and velocity is a vector, so speed has a magnitude, while velocity has a magnitude and direction.
- Acceleration is how much velocity changes every second, also known as the rate of change of velocity.
- A scalar unit only has a magnitude, while a vector unit has a magnitude and direction.

Positive and Negative Vectors

STOP AND CHECK (PAGE 20)

- Conventionally, right is the positive direction while left is the negative direction, and up is the positive direction while down is the negative direction. The same as on a graph!

The Kinematic Equations

STOP AND CHECK (PAGE 23)

- v_i is the initial speed, while v_f is the final speed.
- When an object "starts from rest" it means that v_i=0.
- An object that has been thrown into the air only has the force due to gravity acting upon it (if we ignore air resistance), and so since there are no other forces on the object, the force due to gravity must be the same as the net force on the object. Thus, the size of the acceleration on an object that has been thrown into the air is -9.8ms^{-2}.

Kinematics

STOP AND CHECK (PAGE 23)

- First, we write down everything we know and the thing we're trying to find out:
  - v_i = ?ms^{-1}
  - v_f = 90ms^{-1}
  - a = 5ms^{-2}
  - t = 15s

  Then, using our first kinematics equation $v_f = v_i + at$, we can substitute in our known values to get:
  - $90 = v_i + 5\times15$

  Then with a bit of rearranging magic:
  - $90 = v_i + 75$
  - $v_i = 15$

  Thus, the initial velocity of the speeding race car is 15ms^{-1}.
- Again, we write down everything we know and the thing we need to know;
  - v_i = 15ms^{-1}
  - a = 5ms^{-2}
  - t = 15s
  - d= ?m

  Then, using our second kinematics equation: $d = v_it + ½ at^2$, we can substitute in our known values to get:
  - d=15×15 + ½×5×152

  Then, we solve:
  - d = 225 + ½×5×225

- $d = 225 + 562.5$
- $d = 787.5m$

Thus, the speeding race car travelled 787.5m during those 15 seconds.

- Once again, we write down everything we know and everything we need to know:
  - $v_i = 0ms^{-1}$
  - $v_f = 10ms^{-1}$
  - $t = ?s$
  - $d = 50m$

  and we know that acceleration is constant. Remember: acceleration must be constant to use our kinematics equations.

  Then, using the third kinematics equation $d = \frac{(v_i + v_f)}{2t}$, we can substitute in our known values to get:
  - $50 = \frac{(0 + 10)}{2 \times t}$

  Then, with a bit of rearranging:
  - $50 = 5 \times t$
  - $\frac{50}{5} = t$
  - $t = 10s$

  Thus, it took the runner 10s to get up to their final velocity.
- The first thing to remember is that when the bullet gets as high as it can go, it will stop. Earlier on we talked about how when we throw something in the air it has a positive velocity when it's going up and a negative velocity when it's going down; this means that the velocity of the bullet must be zero at some point between when it's going up and coming down, which will be how far the bullet travels up before coming back down. This gives us the key to figuring out this sort of question: at the top of the bullet's arc, $v_f = 0ms^{-1}$. We also know that the bullet acts as a projectile, meaning that the only force on the bullet is gravity, so the acceleration on the bullet is $-9.8ms^{-2}$. Then, we proceed as normal. We write down everything we know and need to know:
  - $v_i = 762ms^{-1}$
  - $v_f = 0ms^{-1}$
  - $d = ?m$
  - $a = -9.8ms^{-2}$

  Next, we find the appropriate equation, which in this case is $v_f^2 = v_i^2 + 2ad$. Then we just substitute in our values:
  - $0^2 = 762^2 + 2 \times -9.8 \times d$
  - $0 = 580{,}644 - 19.6 \times d$

- $-580,644 = -19.6 \times d$
- $d = \frac{-580644}{-19.6}$
- d = 29,624.69m
- Which we then round to 29,600m (3 s.f.), and convert to standard form to get d = 29.6×103 m, which is 29.6km! Thus, the bullet will travel 29.6km upwards before coming back down again.

- This is something we will discuss in more detail in the next section, but for now, we just need to know that it takes the same amount of time for the bullet to travel from the ground to the topmost point as it takes the bullet to travel from the topmost point back down to the ground. So, all we need to do is find the time it takes the bullet to get to the top of its arc, then double it.
  After this hurdle, our weird bonus question becomes just another kinematics question!
  First, we write down everything we know and everything we need to know:
  - $v_i = 762ms^{-1}$
  - $v_f = 0ms^{-1}$
  - d = 29.6km
  - $a = -9.8ms^{-2}$
  - t=?s, where the time we'll get is half of our final result (since we're only using data for half of the arc!).

  Then, since we like to play it safe, we'll use our first kinematics equation: $v_f = v_i + at$ since we could be wrong about our previous answer for the distance travelled. Hopefully, we're right (or my boss will have a word or two with me), but in case we're not, we'll play it safe and not use our value for d whenever we can avoid it. Next, we just substitute in our known values:
  - $0 = 762 + -9.8 \times t$
  - $-762 = -9.8 \times t$
  - $t = \frac{-762}{-9.8}$
  - t = 77.755s

  Since this is half of our final value, we'll double it to get t = 155.5s, which we round to give our final answer t = 156s. Thus, it takes the bullet 156 seconds to reach the ground after it is shot upwards.

Projectile Motion

Understanding the Motion

STOP AND CHECK (PAGE 25)

- Gravity is the only force that acts on a projectile; that's what makes it a projectile.
- In projectile motion, since gravity only acts in the vertical direction (straight down), the vertical component of the velocity goes from positive to zero to negative, while the horizontal component of the velocity stays the same at every point.
- At the start of the flight, the direction of the total velocity is diagonally upwards and to the right. At the top of the flight, the total velocity vector is pointing directly to the right, and at the end of the flight, the total velocity vector is directed diagonally downwards and to the right.

Doing the Calculations

STOP AND CHECK (PAGE 26)

- The acceleration is the acceleration due to gravity, which is $-9.8ms^{-1}$.
- Only the vertical component changes, gravity acts straight downwards, so the horizontal component experiences no acceleration from gravity.

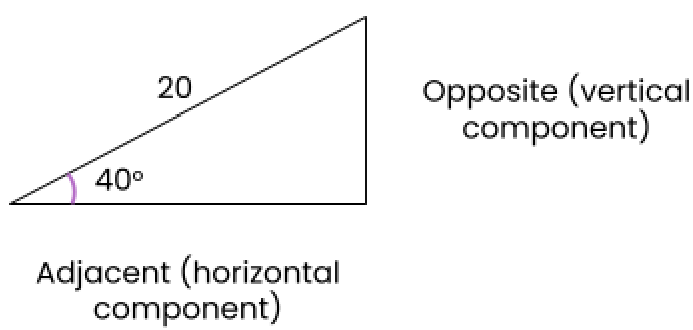
Projectile Motion

QUICK QUESTIONS (PAGE 27)

- This is an example of projectile motion because the only force acting on the golf ball when it is in the air is gravity, this is our requirement for projectile motion.
- As the golf ball flies, its horizontal velocity remains constant, while its vertical velocity experiences an acceleration of $-9.8ms^{-1}$. Since its initial velocity would be at an angle above the horizontal, initially the vertical velocity would be positive, then as the ball flies the vertical component becomes smaller until it

reaches 0; this is the point where the ball reaches the top of its arc, as with no vertical velocity the ball cannot move upwards any further. After this point, the vertical component keeps decreasing and becomes more negative, and the golf ball falls back down to the ground.

- At the ball's maximum height, the horizontal velocity of the ball is the same as it was at the beginning of the ball's flight, but the vertical component has reduced to 0. Therefore, at this point, the only contribution to the ball's velocity comes from the horizontal component of the ball's velocity.
- Throughout the ball's journey, the only force it experiences is a force due to gravity (since we always ignore air resistance) which acts straight downwards. Since gravity only acts straight downwards it can only create an acceleration on the ball which goes straight downwards, which affects the vertical component of the ball's velocity and does not affect the horizontal component of the ball's velocity.
- To figure this one out, we'll need to use a bit of our good friend trigonometry. We know that the ball's initial velocity is 20m/s with an angle of 40° with the horizontal, so when looking for our vertical and horizontal velocities we can draw up the following triangle:



Now, using SOH CAH TOA, we see that:

- $\sin(\theta) = \frac{opposite}{hypotenuse}$
- $\cos(\theta) = \frac{adjacent}{hypotenuse}$

Since we know that the opposite side is our vertical component and the adjacent side is our horizontal component, we can do a little bit of rearranging to get:

- $\sin(\theta) \times$hypotenuse = vertical velocity component
- $\cos(\theta) \times$hypotenuse = horizontal velocity component

Now to make the math a little clearer, let's use the naming convention that most of your textbooks will use and name the horizontal component v_x and the vertical component v_y. This just means the velocity in the x (horizontal) direction and the velocity in the y (vertical) direction, the same directions as on a graph. Then we can substitute in our numbers and get our result:

  - $v_y = \sin(40)\times 20 = 12.86ms^{-1}$
  - $v_x = \cos(40)\times 20 = 15.32ms^{-1}$

Which we then round to get a vertical velocity component of $12.9ms^{-1}$ and a horizontal velocity component of $15.3ms^{-1}$.

- For this question, we'll need to use our kinematic equations twice, but only in the vertical direction. We only care about what the ball is doing in the vertical direction for this question, so we'll be using the (unrounded) vertical velocity we got in the last question. Since the rugby ball is moving in projectile motion, we also know that the acceleration is $-9.8ms^{-1}$. Now we can write down all our information a bit more clearly:

  - $v_i = 12.8557ms^{-1}$
  - $v_f = 0ms^{-1}$
  - $a = -9.8ms^{-1}$
  - t=?s,
  - d=?s

  Here we've written both t and d as unknowns, but we'll have to use two equations to find them both. First, we'll find t using $v_f = v_i + at$.

  - $0 = 12.8557 + -9.8\times t$
  - $9.8t = 12.8557$
  - $t = 1.31s$

  So it takes the ball 1.31s to reach its maximum height, we've just done half the question! Now we can add t (unrounded) to our list of known variables.

  - $v_i = 12.8557ms^{-1}$
  - $v_f = 0ms^{-1}$
  - $a = -9.8ms^{-1}$
  - $t = 1.3118s$
  - $d = ?s$

  Then using this information we can use the equation $d = v_it + ½at^2$ to find d:

  - $d = 12.8557\times 1.3118 + ½\times -9.8\times 1.31182$
  - $d = 8.432$

  So, the ball travels 8.43m upwards to its highest point and takes 1.31s to get there.

- From the previous question, we know that the ball travels 1.31s to its highest point, and so we know that the ball takes another 1.31s to hit the ground from its highest point. We then know that the ball has a total flight time of 2.62s, and the rest of the question is easy! If we remember that the horizontal velocity of the ball remains constant, then the ball is travelling horizontally at v_x = cos(40) ×20 = 15.32ms^{-1} for 2.62 seconds. So to find the distance travelled horizontally, we just use our v = $\frac{\Delta d}{\Delta t}$ equation, multiplying both sides by t to get d = vt. Thus, d= 15.32×2.62 = 40.1384.
  So the ball travels 40.1m horizontally before hitting the ground.

Circular Motion

Understanding the Motion

STOP AND CHECK (PAGE 28)

- 4 situations of circular motion are; roller coasters going through loop-the-loops, buckets full of water you swing around, a car turning a corner, and swinging a mass around your head. Any other situation where the object is going in a circle, or through part of a circle, is also circular motion.

Constant Speed but Centripetal Acceleration?

STOP AND CHECK (PAGE 29)

- Speed is a scalar and velocity is a vector, so the difference between speed and velocity is that velocity has a direction, while speed does not.
- The acceleration on the object changes the object’s direction but doesn’t change its speed, so while the object is travelling at a constant speed it is not travelling with a constant velocity.
- The acceleration acts towards the centre of the circle and it is called centripetal acceleration.

The Centripetal Force

STOP AND CHECK (PAGE 30)

- The centripetal force and centripetal acceleration are directed towards the centre.
- The object's velocity is directed tangent to the circle.
- Some examples are; a reaction or friction force from the ground, the tension force from a rope or wire, or gravity if an object is in orbit.
- The friction force of the tires on the ground causes the centripetal force to occur on the car. However, when it goes over ice or oil, that friction is gone, so the car will go in a straight line in the direction of its velocity at that point.

Doing Those Calculations

STOP AND CHECK (PAGE 31)

- One period of circular motion is the time it takes the object to move in a full circle.
- The distance travelled is the circumference of the circle the object travels, which is $2\pi r$.
- Decreasing the radius, but keeping a constant time period would decrease the speed of the object.

Circular Motion

QUICK QUESTIONS (PAGE 32)

- This is considered circular motion because the car is travelling around the circular track, so it must be moving in a circle.
- The centripetal force is the force that turns the car around the track, and in this case, it's the friction of the wheels on the track.
- The car is accelerating because its direction is changing, which causes a change in velocity even though the speed of the car remains constant.
- If the car suddenly drove over an ice patch and had no friction force pulling it inwards, the car would no longer be able to move in a circle and would simply drive off in a straight line, tangent to the circle it was previously travelling in.

- First, we know that the time taken for the car to travel the circumference of the track is 7 seconds and the circumference of the track is 2πr metres. Since the radius of the track is 50m, the circumference is 2π×50=314m. Now we use our good ol' equation $v = \frac{\Delta d}{\Delta t}$:
  - $v = \frac{314}{7}$
  - $v = 44.9ms^{-1}$
- For this question we use $a_c = \frac{v^2}{r}$
  - $a_c = \frac{44.92^2}{50}$
  - $a_c = 40.36ms^{-2}$
- Here we can either use $F_c = ma_c$ or $F_c = \frac{mv^2}{r}$, since they're both the same. Either way, we wind up with:
  - $F_c = 1000 \times 40.3$
  - $F_c = 40300N$

Torque

Defining Torque

STOP AND CHECK (PAGE 34)

- Torque is a force acting at a distance from the centre of mass.
- Torque depends on the size of the force as well as how far out the force is applied from the pivot.
- No, there wouldn't be a torque because the distance from the pivot point is 0.

Torque and Equilibrium

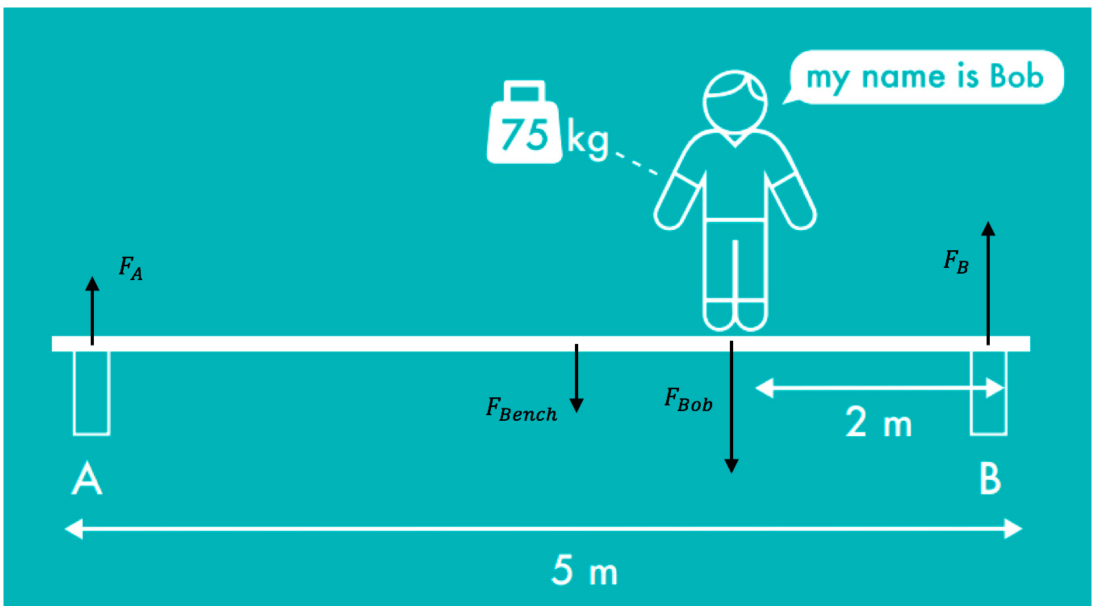
STOP AND CHECK (PAGE 36)

- A force doesn't cause a torque when it acts directly on top of a pivot.
- You can put the pivot point anywhere, but it's useful to choose your pivot to be on top of a force, so you don't have to worry about that force.
- In equilibrium, the clockwise and anticlockwise torques have the same size but opposite directions, so they cancel out leaving no net torque.

Torque and Equilibrium

QUICK QUESTIONS (PAGE 36)

- Bob's weight creates a force downward on the bench at a distance to the right from support A, so naturally, the weight force he exerts on the bench will create a clockwise torque.
- Equilibrium is when the clockwise and anticlockwise torques around a pivot are equal and cancel out, causing the stuff rotating about the pivot to either stay still or rotate at a constant speed.
- First off let's draw up a diagram and label all the forces to help us visualise what's going on here:



Notice how we put F_{Bench} in the middle of the bench; this is because the weight force acts through the centre of mass of the object, which in this case will probably be the middle of the bench. I also put F_{Bob} on the bench but directly under Bob to help visualise the torques.

Now the question is asking us to find the forces F_A and F_B, which are the support forces from the supports A and B, by considering the torques around A, which is essentially telling us to choose our pivot to be A. With that information, we can start finding our torques. Notice that Bob is 3m away from support A and the weight force from the bench acts 2.5m away from support A.

- $\tau_{Bench} = F_{Bench} \times d$
- $\tau_{Bench} = 25 \times 9.8 \times 2.5$
- $\tau_{Bench} = 612.5$Nm, clockwise
- $\tau_{Bob} = F_{Bob} \times d$
- $\tau_{Bob} = 75 \times 9.8 \times 3$
- $\tau_{Bob} = 2205$Nm, clockwise

Here we've just turned the weights of Bob and the bench to torques. Now, to find F_B, we know that the anticlockwise torque created by the support must be equal to the clockwise torques created by Bob and the bench since the bench is in equilibrium. Thus,

- $\tau_B = \tau_{Bench} + \tau_{Bob}$
- $\tau_B = 612.5 + 2205$
- $\tau_B = 2817.5$Nm, anticlockwise

Then with a bit of rearranging, we can use our torque equation to find F_B!

- $\tau_B = F_B \times d$
- $F_B = \frac{\tau_B}{d}$
- $F_B = \frac{2817.5}{5}$
- $F_B = 563.5$N

Now we have F_B! Then we just need to use the little hint at the end of the question to see that all the forces downwards (F_{Bob} and F_{Bench}) have the same size as all the forces upwards (F_A and F_B), so we can just throw them all into an equation and find F_A:

- $F_A + F_B = F_{Bob} + F_{Bench}$
- $F_A = F_{Bob} + F_{Bench} - F_B$
- $F_A = 75 \times 9.8 + 25 \times 9.8 - 563.5$
- $F_A = 416.5$N

Therefore, the support force from support A is 416.5N and the support force from support B is 563.5N.

Momentum

Defining and Calculating Momentum

STOP AND CHECK (PAGE 39)

- Momentum is measured in $kgms^{-1}$.
- Momentum is a vector property.
- You can find the change in momentum using the equation: $\Delta p = p_f = p_i$

Conservation of Momentum

STOP AND CHECK (PAGE 41)

- Total momentum is conserved when no external forces act on the system.
- We can calculate the initial and final momentum of the balls, along with their speeds.

Chance in Momentum: Impulse

STOP AND CHECK (PAGE 43)

- External forces lead to a change in momentum.
- Impulse is the change in momentum of a system.
- Crumple zones on cars increase the time of the collision between the car and whatever it is hitting. The total change in momentum of the car stays the same whether or not the car has the crumple zone (assuming it weighs the same and travels the same speed before and after), but by increasing the time of the collision, the force the car experiences is reduced. This is shown in the formula $\Delta p = F\Delta t$. If Δt was increased and Δp stayed the same, then F will decrease.

Momentum

QUICK QUESTIONS (PAGE 43)

- The total momentum is:
  - $p_w + p_b = 0.1 \times 10 + 0.1 \times 0 = 1 kgms^{-1}$
- Since the total momentum will be the same after the collision (assuming no external forces), we can think of the two stuck together balls being a new third ball, with a weight of 0.2kg and a momentum of $1 kgms^{-1}$, and so:
  - $p = mv$
  - $1 = 0.2 \times v$
  - $v = \frac{1}{0.2}$
  - $v = 5 ms^{-1}$
- If we consider the equation for impulse ($\Delta p = F\Delta t$), we see that for a constant Δp, increasing Δt (the contact time) decreases F. Now if we consider that crumple zones in cars extend the duration of the crash (the contact time), then we see they increase Δt, therefore decreasing F. This decrease in F represents a decrease in the force the passengers of a car experience during a car crash. Without a crumple zone, the passengers would experience a greater force during the crash, and so the crumple zones in cars protect passengers by reducing the force they experience during a crash.

Kinetic Energy

Kinetic Energy

STOP AND CHECK (PAGE 45)

- Kinetic energy and potential energy.
- Kinetic energy depends on the velocity squared (v^2), not just the velocity and the mass of the object.

Potential Energy

STOP AND CHECK (PAGE 47)

- An object gains gravitational potential energy by being raised off the ground.
- An object gains elastic potential energy by being stretched or squished.
- The spring constant, k, tells us how stiff or soft a spring is. A spring with a high k value will be stiff and difficult to compress, while a spring with a low value for k will be soft and easily compressible.
- The force of resistance is directly proportional to the compression or stretch of the spring.

Conservation of Energy

STOP AND CHECK (PAGE 47)

- Energy is measured in Joules (J).
- $E_pi + E_ki = E_pf + E_kf$

Work

STOP AND CHECK (PAGE 49)

- Work has the symbol W and is measured in Joules (J).
- Work is the change in energy of a system caused by a force being exerted over some distance.
- Work depends on the force being exerted on the object and how far the object moves because of that force.
- If you provide a horizontal force, kinetic energy is increased because the ball is moving quicker. If you provide a vertical force, potential energy is increased because you are increasing the height of the ball.

Power

STOP AND CHECK (PAGE 49)

- Power (P) is measured in Joules per second (Js^{-1}).
- Power is the rate at which the energy of a system changes and since work is the change in energy of the system, power is therefore how much work is done per second.

Kinetic Energy

QUICK QUESTIONS (PAGE 50)

- The potential energy stored in the spring is:
  - $E_p = \frac{1}{2}kx^2$
  - $E_p = 0.5 \times 100 \times 1^2$
  - $E_p = 50J$

  The ball has 0J of potential energy since it cannot fall any further, and therefore has no gravitational potential energy.
- When the spring is released, the potential energy of the spring will be converted into kinetic energy in the ball, which will fire off with 50J of kinetic energy, due to conservation of energy. Since the ball has a mass of 0.5kg we can easily work out the velocity:
  - $E_k = \frac{1}{2}mv^2$
  - $v^2 = \frac{2 \times 50}{0.5}$
  - $v^2 = 200$
  - $v = 14.14ms^{-1}$

  So, the ball will fire off at $14.1ms^{-1}$.
- After the ball is fired, all the kinetic energy the ball has when it is fired is converted into gravitational potential energy, so at the ball's highest point it will have 50J of gravitational potential energy. From here, we can just use a bit of rearranging magic:
  - $E_P = mg\Delta h$
  - $50 = 0.5 \times 9.8 \times h$
  - $h = \frac{50}{0.5 \times 9.8}$
  - $h = 10.2m$

  So, the ball will reach 10.2m at the highest point.

- The energy will likely be lost as thermal energy as the ball flies through the air and experiences air resistance; the friction between the ball and the air will cause the kinetic energy of the ball to be converted to thermal energy.
- First, we have to think of the box as starting off at 0m and then being raised two metres. Use the equation W = ΔE to find the work done on the box. Since all of the box's energy is potential (since it's stationary at the beginning and end), we'll just use E rather than E_P.
    - $E_i = mgh_i$
    - $E_i = 10 \times 9.8 \times 0$
    - $E_i = 0J$
    - $E_f = mgh_f = 10 \times 9.8 \times 2 = 196J$

  Now, to find the work done:
    - $W = \Delta E = E_f - E_i$
    - $W = 196 - 0$
    - $W = 196J$

  So 196J of work is done to raise the box.

  The power used is given by:
    - $P = \frac{W}{t}$
    - $P = \frac{196}{10}$
    - $P = 19.6Js^{-1}$

  So the power used in raising the box is $19.6Js^{-1}$
- Since the box is still being raised to the same height with no change in the mass, taking longer to raise the box causes no change to the work done. However, if it takes more time to raise the box, we would be increasing t in the equation $P = \frac{W}{t}$ while keeping W the same. This would decrease P, therefore decreasing the power used in lifting the box.