Higher Physics – Our Dynamic Universe

Summary Notes

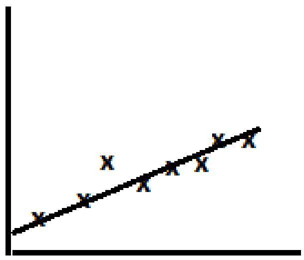
Contents

In the next few pages there will be tables with knowledge that **must** be learned before the Higher Physics exam. The wording used is what is acceptable when answering questions in the exam, although at times there will be alternative answers. In the 1st box put a ✓ or ✗ to show your understanding. You can use the 2nd box to check your understanding at a later date.

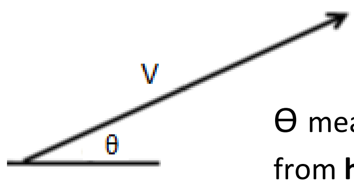
Using this sheet **will** help you become more prepared for your final exam, however it is down to you to put in the hard work to learn as much as possible to achieve your best.

Use the extra space sections to include any additional information that you find when doing past paper questions/reading your notes etc…

Section 1 – Uncertainties etc…

Units - The correct unit must be written beside every final answer (even if there is no calculation) or full marks cannot be given.		
Prefixes include; Terra (T = x 10^{12}), Giga (G = x 10^{9}), Mega (M = x 10^{6}), Kilo (k = x 10^{3}), milli (m = x 10^{-3}), micro (µ = x 10^{-6}) and nano (n = x 10^{-9}). If the prefixes are not converted before doing a calculation full marks cannot be given.		
Significant figures – All **FINAL** answers must be given to the correct number of significant figures. An easy way round this is to give all final answers to **3** significant figures. Answers not rounded up will not be awarded full marks. The answer to a calculation that is **not** a final answer should **NEVER** be rounded up.		
Reading uncertainty – Every measurement will have some uncertainty in the value recorded. Any apparatus used will have a scale reading uncertainty. The rules are; for a digital device = ± 1 in least significant digit, e.g. t = (1.54 ± 0.01) s. For an analogue device = ± half in the smallest division on the scale of the apparatus, e.g. d = (12.1 ± 0.05) cm, if the ruler has divisions of millimetres.		
Systematic uncertainties – These are uncertainties caused by the apparatus or the experimenter where the same mistake is made each time a measurement is taken. If a graph with a line of best fit through the origin is expected and this does not happen, this is usually down to a systematic uncertainty. 		
Random uncertainty – This occurs when an experiment is repeated. To find the random uncertainty the mean (average) value must be found first and then the equation: **Random uncertainty =** $\frac{\textbf{max. value} - \textbf{min. value}}{\textbf{number of values}}$ is used to calculate the random uncertainty. The final answer must be written in what is called the absolute form which is: **'= (mean value ± uncertainty) units'**. If the random uncertainty is large, taking more repeated readings will reduce it.		
Percentage uncertainty – An absolute uncertainty can be changed to a percentage uncertainty. To do this you would use the equation: $\frac{\textbf{uncertainty}}{\textbf{mean value}}$ **x 100%** e.g. t = (0.5 ± 0.1) s ⟶ t = (0.5 ± 20%) s		
Extra space for additional information		

Section 2 – Motion – Equations and graphs.

A scalar quantity is described as having **magnitude** (a **size**). e.g. time = 30 s or mass = 20 kg.		
A vector quantity is fully described as having a **magnitude** (a **size**) and **direction**. e.g. force = 50 N downwards or velocity = 20 ms^{-1} East.		
All vector quantities **must** be added tip-to-tail to find the resultant vector. The resultant vector is the result of the addition of the original vectors.		
If the vectors are added when at right angles, the resultant vector can be found by arranging the vectors tip-to-tail. Pythagoras is used to find the magnitude and trigonometry ($\tan\theta = \frac{\text{opp}}{\text{adj}}$) is used to find the direction. θ **must** be labelled on the diagram or a 3 figure bearing **must** be used to show the direction.		
If the vectors are **NOT** at right angles Pythagoras and trigonometry **CANNOT** be used. In this case a scale drawing must be used to find the resultant vector. You must use an appropriate scale which allows you to draw out the diagram without making the drawing too small. A ruler is used to measure the magnitude and a protractor to measure the direction of each vector.		
Speed is a scalar quantity and is defined as the distance travelled per second. **d = vt**		
Velocity is a vector quantity and is defined as the displacement travelled per second. **s = vt** displacement and velocity **must** have a direction.		
A vector component is when a vector is split into either its vertical or horizontal components. The equations to find the horizontal and vertical components are;  Θ measured from **horizontal** $v_H = v\cos\Theta$ and $v_V = v\sin\Theta$ **(Not in relationship sheet!!!)**		
The four equations of motion are; $v = u + at$ $s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$ $s = \frac{1}{2}(u + v)t$ When solving these problems always start by writing **s u v a t** and then identify the correct equation to be used. Remember that only time (**t**) is a scalar quantity and so the quantities (**s u v a**) can all have + or - signs to show their direction.		
In displacement-time graphs the gradient of the line is equal to the velocity of the object. If the displacement is negative this simply means a change in direction!! A diagonal line in a displacement-time graph will be shown as a horizontal line on a velocity-time graph. A curved line represents an increasing/decreasing velocity.		
In velocity-time graphs the gradient of the line is equal to the acceleration of the object. The area under the line of the graph is equal to the displacement travelled. A line which cuts the time-axis (positive to negative velocity or the other way round) also shows a change in direction. A diagonal line in a velocity-time graph will be shown as a horizontal line on an acceleration-time graph.		

In acceleration-time graphs a horizontal line shows a constant acceleration. The area under the line of the graph is equal to the velocity of the object. Care should be taken when interpreting acceleration-time graphs as what appears to be a deceleration in one direction can also be an acceleration in the opposite direction!		
When converting from a velocity-time graph to an acceleration-time graph the acceleration of each line must be found using the equation $\mathbf{a} = \frac{\mathbf{v-u}}{\mathbf{t}}$. Each acceleration can then be drawn as a horizontal line on the acceleration-time graph.		
When drawing any graphs remember the basics!!! You must label each axis with headings and units, include an origin and numerical values must be included (they may need to be calculated using an equation) unless you are not required to do so.		
Extra space for additional information		

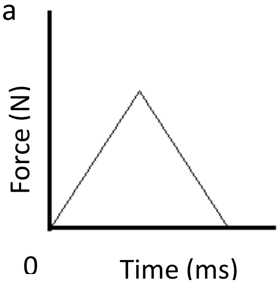
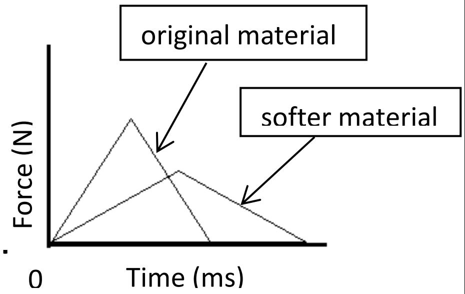
Section 3 – Forces, energy and power

Revision of Nat 5 – Objects which have balanced forces will be at rest or travel at a constant speed (terminal velocity) in a straight line. Balanced forces are both **equal in size** and **opposite in direction**. Objects which have unbalanced forces acting on them have an acceleration (could be a deceleration).		
The size of the acceleration is linked to the mass and acceleration using the equation: **F = ma** where the acceleration is directly proportional to the unbalanced force and the mass is inversely proportional to the unbalanced force.		
The resultant force is a single force which will have the same effect as all the other forces which produce it.		
Friction is a resistive force which **always** acts in the opposite direction to motion.		
When using the equation: **F = ma** **F** represents the **unbalanced** or resultant force. If the unbalanced or resultant force is not determined and then used you will only be awarded one mark for these questions.		

Weight is a downward force which all masses have due to the gravitational field strength of the Earth. This is shown by the equation: **$W = mg$** **$g = 9.8\ Nkg^{-1}$** on Earth.		
In a lift my apparent weight will change depending on the acceleration of the lift. If the acceleration is 0 ms^{-2}, (constant speed) then the apparent weight is equal to my actual weight. If the lift is accelerating up/decelerating down the apparent weight is greater than my actual weight. If the lift is decelerating up/accelerating down the apparent weight is less than my actual weight. If the lift is in free fall the apparent weight is zero. Aarrrgghhhh!!!!!		
When two objects are joined together and one is pulled/pushed there is a tension force between the two objects. The tension is a result of the object that is attached to the object that is **being pulled/pushed** (A caravan is the cause of the tension in a towbar when pulled by a car).		
When asked to calculate the tension force the equation **$F = ma$** must be used twice. First of all the acceleration is found using the pulling/pushing force and the total mass (**both objects added together**). Second the tension is found using the acceleration and **ONLY** the mass of the object that is **causing** the tension.		
Tension questions may also involve frictional forces and care must be taken when using the equation **$F = ma$** so that only the **unbalanced** force is used in the equation.		
An object on a slope will experience a force parallel to the slope due to its weight and a force perpendicular to the slope (reaction force). These equations are; **$W_{parallel} = mg\sin\theta$** and **$W_{perpendicular} = mg\cos\theta$** **(Not in relationship sheet!!!)**		
Conservation of energy means that energy cannot be created or destroyed but only transferred from one type to another. Power is the rate of energy transferred (energy transferred per second) and so both units; Watts or Joules per second can be used as a measurement of power. The following equations are linked to conservation of energy; **$E_w = Fd$** **$E_k = \frac{1}{2} mv^2$** **$E_p = mgh$** **$P = \frac{E}{t}$**		
Extra space for additional information		

Section 4 – Collisions, explosions and impulse

Momentum is the measure of an object's motion and is the product of mass and velocity. **p = mv** The units of momentum are $kgms^{-1}$.		
Momentum is a vector quantity and therefor can have a positive and negative value.		
The law of conservation of momentum has two parts to it. Both parts must be stated or full marks will not be awarded! **Total** momentum **before** a **collision** equals **total** momentum **after** a collision in the **absence of external forces**.		
The law mentioned above is the starting point for any calculations involving collisions. For a collision there will always be two individual momentums before the collision. If the objects stick together on impact there will be one momentum after the collision and if the objects separate on impact there will be two momentums after the collision. The idea is to show this at the start of the calculation; **total momentum before = total momentum after** $m_1v_1 + m_2v_2 = m_3v_3$ ← Objects stick together or **total momentum before = total momentum after** $m_1v_1 + m_2v_2 = m_3v_3 + m_4v_4$ ← Objects separate		
For explosions it is a bit different. There will only be one object before the explosion and therefor only one momentum. As the object is stationary (v = 0 ms^{-1}) the momentum is zero. The object is split in to two and each part travels in the opposite direction from each other. **total momentum before = total momentum after** $m_1v_1 = m_2v_2 + m_3v_3$ ← Explosion As momentum is a vector quantity one velocity will be positive and one will be negative (opposite direction).		
For collisions you may be asked to show by calculation whether an interaction is an elastic or inelastic collision. An **elastic collision** is one where kinetic energy is **conserved** (the kinetic energy before the collision is equal to the kinetic energy after the collision). An **inelastic collision** is where kinetic energy is **NOT conserved**. To show if the kinetic energy is conserved the equation; $E_k = ½ mv^2$ is used for each momentum (if the objects stick together on impact there will be 3 momentums, 2 before the collision and 1 after, and therefor there will be 3 kinetic energies also). This is how you could start the calculation; $E_k = ½ mv^2$ **so** **Total kinetic energy before = Total kinetic energy after** $½ mv^2 + ½ mv^2 = ½ mv^2$ ← Objects stick together Then state at the end if the kinetic energy is/is not conserved and if the collision is elastic/inelastic.		

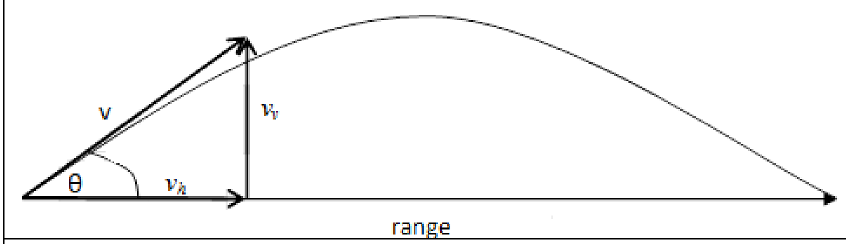
The momentum of each object will change during a collision. This is called the change in momentum and is shown as **$\Delta p = mv - mu$**		
Impulse is the product of force and time and is the cause of the change in momentum of **ONE** object during a collision. **Impulse = Ft** and has units Ns.		
Impulse is equal to change in momentum which is shown in the equation; **$Ft = mv - mu$**		
The force during a collision may not be constant and so a force-time graph is used to show how the magnitude of the force changes over the time of contact. **The area under the line in the force-time graph is equal to th impulse.** To make things easier to calculate the area in force-time graph the shape of the graph will be triangles or rectangles. To calculate the impulse this equation is used;  **Impulse = ½ (Ft)** **(Not in relationship sheet!!!)** Notice also that the time is commonly given in **ms** and so this must be changed into seconds when calculating the impulse.		
It is common for you to be asked to add a second line on the force-time graph when a condition is changed (i.e. a softer/ harder material is used). An example would be if the material is softer this would result in a **LONGER** time of contact and a **SMALLE** maximum force. This should then be added to the force-time graph as shown. 		
For the equation; **$Ft = mv - mu$** If the change in momentum of the object does not change then an **increase** in the time of contact will **decrease** the force. This is how safety features in cars are explained. Their job is to increase the time of contact which reduces the force (injury) on the occupants.		
Extra space for additional information		

Section 5 - Gravitation

A satellite is an object which is orbiting the Earth. This actually means it is falling towards the Earth. The reason the satellite never crashes into the Earth is because although it has a **constant downwards acceleration** (9.8 ms^{-2}) it also has a **very large constant horizontal velocity**. It therefor follows a curved path and as the Earth is also curved it never crashes to Earth.

A projectile is where an object has both horizontal and vertical motion. This means we need to find the vector components discussed in section 2 with equations of motion; $\mathbf{v_H = v\cos\theta}$ **and** $\mathbf{v_V = v\sin\theta}$

(Not in relationship sheet!!!)



In projectiles the first thing we must do is to calculate the horizontal and vertical velocity (as shown above). The next is to create a **'s u v a t'** table to input both horizontal and vertical information (including the horizontal and vertical velocity you have just calculated). There is more information we can add to the table;

	Horiz.	Vert.
s =		
u =		
v =		
a =		
t =		

- Horizontal acceleration is **always** zero (negligible air resistance)
- vertical acceleration is **always** -9.8 ms^{-2} (negative as it is downwards).

The rest of the information needed will be given in the question.

<u>Remember!!</u> An upwards motion is a positive value and downwards motion is a negative value. Time is always positive as it is a scalar quantity and is the same for both horizontal and vertical motion.

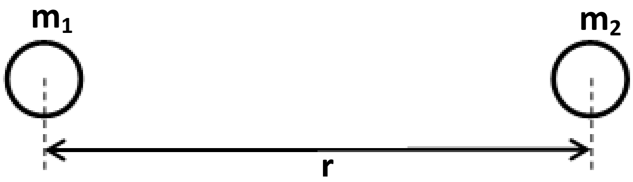
There are another few things which are helpful in these questions:

- At the maximum height the vertical velocity is zero.
- The total time of flight is **double** the time taken to get to the maximum height.
- The projectile path is symmetrical either side of the maximum height. (initial vertical velocity = - final vertical velocity)

If friction **IS** taken into account (not negligible) then this will impact on the flight of the object. The horizontal velocity ($\mathbf{v_H}$) will decrease and this will therefor decrease the horizontal displacement. The time of flight will decrease as well.

The universal law of gravitation is used to find the force of attraction between two objects. This depends on the mass of the two objects and the distance they are apart.

$$\mathbf{F = \frac{Gm_1m_2}{r^2}}$$ where **g = 6.67x10^{-11} m^{3}kg^{-1}s^{-2}.**

When using the equation above the distance, **r** is from the centre of mass of the objects. This usually will only matter if the masses involved are planets due to their size. 		
If the gravitational force is calculated between an object and a planet, this force will be equal to the weight of the object at that distance from the planet. gravitational force = weight The gravitational field strength of the planet at that point can then be calculated using **W = mg**.		
Extra space for additional information		

Section 6 – Special Relativity

Special relativity involves objects traveling at speeds close to the speed of light (usually more than 10% of the speed of light).		
The speed of light (**c**) is always 3 x 10^8 ms^{-1} in any reference frame. The velocity of the vehicle is often given as a decimal of the sepeed of light ie 0.8**c**. In this case the speed of the vehicle is found by; 0.8 multiplied by the speed of light = 2.4 x 10^8 ms^{-1}.		
When doing questions involving special relativity you must decided which reference frame is being considered when given data to a question.		
If one person has a speed of 5 ms^{-1} and another person a speed of 3 ms^{-1} then their speed relative to each other would be 2ms^{-1}. This means they would have different frames of reference. These speeds are far too low for relativistic effects but gives an idea to what is meant by a frame of reference.		
In any special relativity question there are two observers that are being considered. One will be a stationary observer and one will be a moving observer. The stationary observer is always stationary with regards to the moving vehicle and the moving observer will always be in the moving vehicle.		

Time dilation is the difference in time measured by a stationary observer compared to a moving observer. The time is only dilated (increased) for the stationary observer.		
The time measured by a stationary observer will always be greater than the time measured by a moving observer when an object is travelling at close to the speed of light.		
The equation used for time dilation is: $t' = \dfrac{t}{\sqrt{1-\left(\frac{v}{c}\right)^2}}$ where; **t** = the time measured in a stationary frame of reference. **t'** = the time measured by the stationary observer for a moving object.		
Length contraction is the decrease in length of an object moving relative to a stationary observer observer.		
The distance measured by a stationary observer will always be less than the distance measured by a moving observer when a vehicle is travelling at close to the speed of light.		
The equation used for length contraction is: $l' = l\sqrt{1-\left(\frac{v}{c}\right)^2}$ where; l = the length of the object when in a stationary frame of reference. l' = the length of the moving object when measured by a stationary observer.		
The Lorentz factor γ is a good way of showing the how the speed of the vehicle effects time dilation and length contraction. A Lorentz factor of 1 indicates that the speed is too small for special relativistic effects (no time dilation or length contraction takes place). If the Lorentz factor increases above 1 then special relativistic effects will begin to occur. This relationship is shown using the equation below: $\gamma = \dfrac{1}{\sqrt{1-\left(\frac{v}{c}\right)^2}}$ **(Equation given in exam if needed but is not in relationship sheet)**		
Extra space for additional information		

Section 7 – Expanding Universe

The Doppler effect is the change in the observed frequency of a wave when a source is moving relative to an observer.		
When a source is moving **toward** you at a constant speed the observed frequency will be **greater** than the frequency of the sound when the source is at rest. This occurs as the observed wavelength of the sound will decrease as there are more wavefronts per second observed due to the forward motion of the object. Remember! The source is **NOT** emitting more waves per second!		
When a source is moving **away from** you at a constant speed the observed frequency will be **less** than the frequency of the sound when the source is at rest. This occurs as the observed wavelength of the sound will increase as there are less wavefronts per second observed due to the forward motion of the object. Remember! The source is **NOT** emitting less waves per second!		
The equation for the Doppler effect is: where; **v** = speed of wave v_s = speed of source f_s = frequency of source f_o = observed frequency $$f_o = f_s\left(\frac{v}{v \pm v_s}\right)$$ For a source moving **toward** an observer the **negative sign** is used in the equation (a greater observed frequency) and for a source moving **away from** an observer the **positive sign** is used in the equation (a lower observed frequency).		
An example of the Doppler effect is redshift. Redshift is when galaxies that are **moving away** from us emit light which has a wavelength shifted **towards red**. The colour of the galaxy is **NOT** red! This can be observed by comparing line spectra of an element from a galaxy to the same element on Earth. The emission lines in the line spectra from the galaxy will have greater wavelengths than the line spectra on Earth. A galaxy that is moving toward us will exhibit blueshift (wavelengths moving **towards** blue).		
The change in wavelength of a line in the spectra of an element when observed from a galaxy compared to Earth can be used to calculate the redshift of the galaxy using the equation; $$z = \frac{\lambda_{observed} - \lambda_{rest}}{\lambda_{rest}}$$ where; $\lambda_{observed}$ = the wavelength of light from the galaxy λ_{rest} = the wavelength of light on Earth **z** = redshift (no units)		
Redshift is defined as the ratio of the **recessional** velocity of a galaxy (speed the galaxy is moving away from Earth) to the speed of light. This is shown in the equation; $$z = \frac{v_{galaxy}}{c}$$		

Hubble's law is a relationship between the recessional velocity of a star and the distance the star is from Earth. The **farther away** the star is from Earth the **greater** the recessional velocity of the star. This is shown in the equation; **$v = H_o d$** where Hubble's constant**,** $H_o = 2.3 \times 10^{-18}\ s^{-1}$		
Hubble's constant can be used to estimate the age of the universe using the equation; $\mathbf{t = \frac{1}{H_o}}$ (This equation is not in the relationship sheet).		
The temperature of stars can be estimated by observing the peak wavelength of radiation emitted by the star. A star with a higher temperature will emit radiation with a greater peak frequancy and therefor a smaller peak wavelength. The **greater** the **temperature,** the **lower the value of the peak wavelength**. This is shown as: **$T \lambda_{peak} = constant$**		
There are two theories about the beginning of the Universe: 1. Closed universe: the universe will slow its expansion and eventually begin to contract. 2. Open universe: the universe will continue to expand forever.		
The mass of the Universe is the major factor which will determine which theory is correct. The mass of a galaxy can be estimated by the orbital speed of stars within it and this allows scientists to estimate the total mass of the Universe.		
Scientists believe there is more mass in the Universe than can be measured. This extra mass is called 'dark matter' and cannot be detected by scientists.		
Scientists believe the Universe is expanding at a greater rate than is expected. This is due to energy that cannot be detected which is called 'dark energy'.		
The big bang theory (open Universe) suggests that the Universe began from a single point and then expanded. There are some pieces of evidence to support this which are; 1. Cosmic Microwave Background Radiation is spread evenly in every direction in the sky with a temperature of around 3 Kelvin. 2. The relative abundances of hydrogen and helium in the universe. 3. There are many more galaxies which show redshift compared to blueshift. 4. Olber's Paradox – the sky is dark at night due to the finite age of the universe (the light from every star cannot be observed). You must be able to explain why these are evidence for the big bang theory.		
Extra space for additional information		