I'm not a robot

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Wolfgang Kloehr 266tr, Yanlev 511; qualification and its assessment is accurate. the official specification and TWI Ltd. Cambridge: 243bl associated assessment guidance materials are the only authoritative source of information and should always be referred to tor definitive guidance. Cover images: Front: ATELIER BR0CKNEA GMBH: Michael Jungbfut All other images C Pearson Education Pearson examiners have not contributed to any sections in this resource relevant to Disclaimer. ne ither Pearson , Edexce l nor the authors take responsibility examination pape- 'C ~ i5. ~ ..L.l' - - - ' - ---'1-- - - - -r----c---\"T- - - - --,- - wave wavefront Figure 10.3 Wavefronts are created by overlapping lots of different waves. Awavefront is a line where all the vibrations are in phase and the same distance from the source. TRANSVERSE WAVES & Figure 10.6 Awave has amplitude and wavelength. Waves can be produced in ropes and springs. If you move one end of a spring The distance between a particular point on a wave and the same point on the from side to side you will see waves travelling through it. The energy carried next wave (for example, from crest to crest) is called the wavelength (A). by these waves moves along the spring from one end to the other, but if you look closely you can see that the coils of the spring are vibrating (shaking) KEY POINT If the source that is creating a wave vibrates quickly it will produce a large across the direction in which the energy is moving. This is an example of a number of waves each second. If it vibrates more slowly it will produce fewer transverse wave. A is the Greek letter lambda and is the waves each second. The number of waves produced each second by a usual symbol for wavelength. source, or the number passing a particular point each second, is called the A transverse wave is one that vibrates, or oscillates, at right angles to the frequency of the wave (I). Frequency is measured in hertz (Hz). A wave source d irection in which the energy or wave is moving. Examples of transverse waves that produces five complete waves each second has a frequency of 5 Hz. include light waves and waves travelling on the surface of water. a crest b crest - - - -ll>- direction of wave vv rruI ~TT\\ !\\ \"I ! V ; \\ vg_____ Figure 10.7 The amplitude of a wave is as shown in a, and not as in b. LONGITUDINAL WAVES & Figure 10.4 Atransverse wave vibrates at right angles tothedirection inwhich the wave is moving. I. ~~-V-7__fV7]'Ji\"7__YV7__ \\\\J\"\"JTLUVY_7_ VfT__\\V\"7__Y\\J7_CV. If you push and pull the end of a spring in a direction parallel to its axis, you 1 can again see energy travelling along it. This time however the coils of the spring are vibrating in directions that are along its length. This is an example of 1 2 t1me/s a longitudinal wave. Figure 10.8 This graph shows a wave with a frequency of 5 Hz. ~direction of wave , The time it takes for a source to produce one wave is called the time period of the wave (7). It is related to the frequency (I) of a wave by the equation: & Figure 10.5 Alongitudinal wave vibrates along thedirection in which the wave is travelling. frequency, f (Hz) 1 A longitudinal wave is one in which the vibrations, or oscillations, are along the direction in which the energy or wave is moving. Examples of longitudinal time period, T (s) waves include sound waves. f = .1. T This equation can also be written as r=.1. f100 WAVES PROPERTIES OF WAVES WAVES PMII+ THE RIPPLE TANK Calculate the period of a wave with a frequency of 200 Hz. We can study the behaviour of water waves using a ripple tank. T = .l When the motor is turned on, the wooden bar vibrates creating a series of ripples or wavefronts on the surface of the water. A light placed above the tank f creates patterns of the water waves on the floor. By observing the patterns we = - 1- can see how the water waves are behaving. 200 Hz electric motor = 0.005 or 5 ms (1000 ms = 1 s) THE WAVE EQUATION There is a relationship between the wavelength (.,\\), the frequency (f) and the wave speed (v) that is true for all waves: wave speed, v (m/s) = frequency, f (Hz) x wavelength, .,\\ (m) A Figure 10.9 You can use the triangle method I =Os distance travelled by wave in 1s = 4 x wavelength t = 1S for rearranging equations like v= f x A. ' ' HINT If an examination question asks you to write out the equation for calculating wave speed, wavelength or frequency, always give the actual equation such as v = f x A. You may not be awarded a mark if you just draw the triangle. direcliOn of movement A Figure 10.12 The light shines through the water and we can see the patterns of the waves. A Figure 10.10 A wave with a frequency of 4 Hz WAVELENGTH AND FREQUENCY Imagine that you have created water waves with a frequency of 4 Hz. This The motor can be adjusted to produce a small number of waves each second. means that four waves will pass a particular point each second. If the The frequency of the waves is small and the pattern shows that the waves wavelength of the waves is 3 m, then the waves travel 12 m each second. The have a long wavelength. speed of the waves is therefore 12 m/s. At higher frequencies, the water waves have shorter wavelengths. The speed of the waves does not change. V = f X .,\\ ab = 4 Hz x 3m side = 12 m/s view .:..Mt+ A tuning fork creates sound waves with a wavelength wavelength frequency of 170 Hz. If the speed of sound in air is 340 m/s, calculate the wavelength of the sound waves. =V f X .,\\ So .A=~ wave f pattern 340 m/s 170 Hz =2m Figure 10.11 Atuning A Figure 10.13 When the frequency of the waves is low, the wavelength is long. When the frequency fork is higher, the wavelength is shorter.102 WAVES PROPERTIES OF WAVES REFLECTION wave direction convex before striking All waves can be reflected. If they hit a straight or flat barrier, the angle at barrier which they leave the barrier surface is equal to the angle at which they meet the surface - that is, the waves are reflected from the barrier at the same angle waves diverge as they strike it. This is described by the ' Law of Reflection' which states that: after striking convex barrier The angle of incidence is equal to the angle of reflection. Figure 10.17 Waves striking a convex barrier are reflected backwards and spread out. KEY POINT flat barrier When waves are reflected by a surface that is curved outwards (convex), they diverge (spread out). A normal is a line drawn at right angles to a surface. angle of incidence reflected wavefronts The angle of incidence is the angle normal between the direction of the waves as they approach the barrier and the direction of the waves normal. after reflection The angle of reflection is the angle angle of reflection between the direction of the waves after striking the barrier and the Figure 10.14 Waves striking a flat barrier are reflected. The angle at which they strike the barrier normal. is the same as the angle at which they are reflected. EXTENSION WORK Figure 10.18 The light waves reflected from this concave make-up mirror create a magnified image. Although you will not be asked this in your exam, it is interesting to see how waves are reflected from curved surfaces. REFRACTION When the waves strike a concave barrier, they are made to converge (come together). The pencil in Figure 10.19 is straight but it seems to bend at the surface of the ftI-; ~:.concave water. This happens because light waves in water travel more slowly than ~ concave light waves in air. This change in speed as they leave the water causes the Figure 10.15 Waves striking a concave barrier are reflected and converge. light waves to change direction. This change in direction is called refraction. barrier All waves - light waves, sound waves, water waves - can be refracted. EXTENSION WORK Many optical instruments such as microscopes, telescopes and cameras use specially shaped pieces of glass or plastic (called lenses) to bend or refract light waves in a useful way. sensor object sharp focused image Figure 10.16 Radio telescopes have concave reflecting dishes so that the signals from space Figure 10.19 a The pencil seems to bend Figure 10.20 In this camera, light waves are refracted by a glass lens to create a sharp image reflect and converge onto a detector that is placed in front of the dish. at the air/water boundary. b Why the on the sensor or film. Refraction occurs because light travels more slowly in glass than in air. pencil appears to be bent Rays of light are refracted at the water surface.104 WAVES PROPERTIES OF WAVES WAVES CHAPTER QUESTIONS --THE DOPPLER EFFECT More questions on wave properties can be found at the end of Unit 3 on m D CRITICAL THINKING page 130. person A person B m D INTERPRETATION 1 a Explain the difference between a transverse wave and a longitudinal A Figure 10.21 A stationary source of sound .,,,,,,,,,,,. ANALYSIS, wave. When a car is not moving the sound waves we receive from its engine or from Iiiiiiiiii\"\" PROBLEM SOLVING b Give one example of each. its horn arrive as a series of equally (evenly) spaced wavefronts. People in front c Draw a diagram of a transverse wave. On your diagram, mark the of and behind the car hear sound of the same frequency and wavelength. m D PROBLEM SOLVING m D CRITICAL THINKING wavelength and amplitude of the wave. f??r?:~ m D REASONING 2 The diagram below shows the displacement of water as a wave travels through it. c !a--~~~~~~~~~~~~~- ~ '6 time/s From the diagram calculate: a the period of the wave b the frequency of the wave. 3 The speed of sound in water is approximately 1500 mis. e What is the frequency of a sound wave with a wavelength of 1.5 m? b What is the period of this wave? 4 a Explain why the sound produced by the horn of an approaching car seems to have a higher frequency than one that is stationary. b If the same car approached at a much higher speed how would this affect the frequency of the sound heard? c Describe the frequency of the sound heard by the observer if the car is moving away at high speed. 5 Explain why this hunter should not aim at the fish he can see. I I person A I person B air water A Figure 10.22 Amoving source of sound +~ + real position of fish If the car is moving, the wavefronts are no longer evenly spaced. Ahead of the apparent car the wavefronts will be compressed as the car is moving in this direction. position of fish The waves will have a shorter wavelength and a higher frequency. Person B therefore hears a sound that has a higher pitch than when the car was stationary. Behind the car the waves are stretched out so person A hears a sound with a longer wavelength and lower frequency - that is, the pitch appears to have decreased. These apparent changes in frequency, which occur when a source of waves is moving, is called the Doppler effect and is a property of all waves.106 WAVES THE ELECTROMAGrJETIC SPECTRUM WAVES THE ELECTROMAGNETIC SPECTRUM 11 THE ELECTROMAGNETIC SPECTRUM The electromagnetic spectrum (EM spectrum) is a continuous spectrum of waves, which includes the visible spectrum. At one end of the spectrum the waves have a very long wavelength and low frequency, while at the other end the waves have a very short wavelength and high frequency. All the waves have the following properties: 1 They all transfer energy. 2 They are all transverse waves. 3 They all travel at 300 000 000 mis, the speed of light in a vacuum (free space). 4 They can all be reflected and refracted. Remember that the wave equations we met in the previous chapter can be applied to any member of the electromagnetic spectrum. hiiiiii- Yellow light has a wavelength of 5.7 x 10-7 m. What is the frequency and period of yellow light waves? V=fX A 5.26 x 10' 4 Hz = 1.9x10- 1s s So f = !'. J.. 3 x 10a mis 5.7 X 10-7m =5.26 x 1014 Hz The table below shows the different groups of waves in order, and gives some of their uses. Radio waves MMM41NUWI Sources Detectors Uses 10'-10\" 103....10-2 radio and TV aerials radio transmitters, long-, medium- and short- TV transmitters wave radio, TV (UHF) Microwaves 1010- 1011 microwave transmitters microwave receivers mobile phone and satellite Infrared (IR) 1011-1014 and ovens communication, cooking skin, blackened hot objects thermometer, special infrared cookers and heaters, TV and stereo Visible light 1014-1015 1~10-7 luminous objects photographic film remote controls, night 10-7- 1 ~ UV lamps and the Sun THE ELECTROMAGNETIC SPECTRUM Ultraviolet 1015-1016 the eye, photographic film, vision (UV) 101\"--10\" x-ray tubes light-dependent resistors typical wavelengths in nanometres (1 nm =1 x 1Q-9 m) seeing, communication .a Figure 11.2 The complete electromagnetic spectrum X-rays skin, photographic film (optical fibres), and some fluorescent photography Gamma rays 101\"--1!)21 10-11'-10-14 radioactive materials chemicals fluorescent tubes and UV photographic film tanning lamps Geiger-Muller tube x-radiography to observe the internal structure of objects, including human bodies sterilising equipment and food, radiotherapy108 WAVES THE ELECTROMAGrJETIC SPECTRUM THE ELECTROMAGNETIC SPECTRUM HINT You do not need t o remember the values of frequency and wavelength given can also heat human body tissue! The microwaves used by mobile phones in the table but you do need to know the order of the groups and which has transmit much less energy than those used in a microwave oven, so they do To remember the order of the waves the highest frequency or longest wavelengths. Most importantly, you need to not cook your brain when you use the phone. However evidence is growing in the electromagnetic spectrum try realise that it is these differences in wavelength and frequency that give the that supports the idea that overuse of mobile phones may eventually harm the using 'Graham's Xylophone Uses Very groups their different properties - for example, gamma rays have the shortest brain. Interesting Musical Rhythms'. wavelengths and highest frequencies, and carry the most energy. Microwaves are used in communications. The waves pass easily through RADIO WAVES Radio waves have the longest wavelengths in the electromagnetic spectrum. the Earth's atmosphere and so are used to carry signals to orbiting satellites. They are used mainly for communication. From here, the signals are passed on to their destination or to other orbiting satellites. Messages sent to and from mobile phones are also carried by t J by)))transmitter microwaves. The fact that we are able to use mobile phones almost anywhere ;~~i~ra:~~7=~,itted INFRAREO in the home and at work confirms that microwaves can pass through glass, brick and so on. 1:.~,000,~~ All objects, including your body, emit infrared (IR) radiation. The hotter an ... Figure 11.3 Radio waves are emitted by a transmitter and detected by an aerial. object is, the more energy it will emit as infrared. Energy is transferred by infrared radiation to bread in a toaster or food under a grill. Electric fires also Radio waves are given out (emitted) by a transmitter. As they arrive at an aerial, transfer heat energy by infrared. they are detected and the information they carry can be received. Televisions and FM radios use radio waves with the shorter wavelengths to carry their signals. Special cameras designed to detect infrared waves can be used to create images even when there is no visible light. These cameras have many uses, including searching for people trapped in collapsed buildings, searching for criminals and checking for heat loss from buildings. MICROWAVES Microwaves are used for communications, radar and cooking foods. Radar uses radio waves to find the position of things. microwaves are reflected from metal casing metal guides direct microwaves towards rotating reflector food absorbs reflector sends microwaves and microwaves in all becomes hot directions A Figure 11.4 Food cooks quickly in a microwave oven because water molecules in the food absorb A Figure 11.5 It is not possible to see these people trapped at the bottom of a cliff using normal the microwaves. visiblelight. By using infrared detectors they can be found easily and rescued. Food placed in a microwave oven cooks more quickly than in a normal oven. A Figure 11.6 Signals are carried from this Infrared radiation is also used in remote controls for televisions, DVD players This is because water molecules in the food absorb the microwaves and remote control to a TV by infrared waves. and stereo systems. It is very convenient for this purpose because the waves become very hot. The food therefore cooks throughout rather than just from are not harmful. They have a low penetrating power and will therefore the outside. operate only over small distances, so they are unlikely to interfere with other signals or waves. Microwave ovens have metal screens that reflect microwaves and keep them inside the oven. This is necessary because if microwaves can cook food, they The human body can be harmed by too much infrared radiation, which can cause skin burns.110 WAVES THE ELECTROMAGrJETIC SPECTRUM THE ELECTROMAGNETIC SPECTRUM CMMH!Mii~ EXTENSION WORK mercury vapour inside the tube gives off when the UV light strikes the fluorescent When talking about light and colour, UV rays when a current is passed through it powder coating the tube, white light is given out we often refer to the seven colours in the visible spectrum. These colours are 4 Figure 11.10 Fluorescent tubes glow when UV light hits the fluorescent coaling inthetube. red, orange, yellow, green, blue, indigo and violet; red light has the longest 4 Figure 11.7 Using visible light Fluorescent tubes glow (shine) because the UV light they produce strikes a wavelength and lowest frequency. If special coating (covering) on the inside of the tube, which then emits visible you look back at Figure 11 .1, you may This is the part of the electromagnetic spectrum that is visible to t he human light. only be able to make out six colours - eye. We use it to see. Visible light from lasers is used to read compact discs most people have difficulty separating and barcodes. It can also be sent along optical fibres, so it can be used for X-RAYS X-rays pass easily through soft body tissue but cannot pass through bones. As indigo and violet (two types of communication or for looking into hard-to-reach places such as inside the a result, radiographs or x-ray pictures can be taken to check a patient's bones. purple). Sir Isaac Newton (1642-1727) body of a patient (see page 121). Visible light can be detected by the sensors discovered that 'white' light can be split in digital cameras, and used to take still photographs or videos. Information up into different colours. He believed stored on DVDs is also read using visible light. that the number seven had magical significance, and so he decided there were seven colours in the spectrum! ULTRAVIOLET LIGHT Part of the light emitted by the Sun is ultraviolet (UV) light. UV radiation is 4 Figure 11.12 X-rays were used to see what 4 Figure 11.11 X-ray of abroken leg harmful to human eyes and can damage the skin. was in this suitcase. 4 Figure 11.8 UV light cancause sunburn so Working with x-rays can cause cancer. Radiographers, who take x-rays, are at we need to protect our skin. UV light causes the skin to tan, but overexposure (too much) will lead to GAMMA RAYS risk and have to stand behind lead screens or wear protective clothing. sunburn and blistering. Ultraviolet radiation can also cause skin cancer and blindness. Protective goggles or glasses and skin creams can block the UV X-rays are also used in industry to check the internal structures of objects - rays and will reduce the harmful effects of this radiation. for example, to look for cracks and faults in buildings or machinery - and at airports as part of the security checking procedure. The ozone layer in the Earth's atmosphere absorbs large quantities of the Sun's UV radiation. There is real concern at present that the amount of ozone Gamma rays, like x-rays, are highly penetrating rays and can cause damage in the atmosphere is decreasing due to pollution. This may lead to increased to living cells. The damage can cause mutations (negative changes), which numbers of skin cancers in the future. can lead to cancer. They are used to sterilise medical instruments, to kill microorganisms so that food will keep for longer and to treat cancer using Some chemicals glow (shine), or fluoresce, when under UV light. This property radiotherapy. Gamma rays can both cause and cure cancer. Large doses of of UV light is used in security marker pens. The special ink is invisible in gamma rays targeted directly at the cancerous growth can be used to kill the normal light but becomes visible in UV light. cancer cells completely. Like x-rays the use of lead screens, boxes and aprons can prevent the damage caused by gamma rays (overexposure). targeted cells - only here is the dose of gamma radiation high enough to damage or kill cells 4 Figure 11.9 This red code is only visible under UVlight. source of gamma rays 4 Figure 11.13 The gamma rays are aimed carefully so that they cross at theexact location of the cancerous cells.112 WAVES THE ELECTROMAGrJETIC SPECTRUM CHAPTER QUESTIONS More questions on using waves can be found at the end of Unit 3 on page 12 LIGHTWAVES m D CRITICALTHINKING 130. m D REASONING a Name four wave properties that are common to all members of the m D CRITICALTHINKING electromagnetic spectrum. m D INTERPRETATION b Name three types of wave that can be used for communicating. c Name two types of wave that can be used for cooking. d Name one type of wave that is used to treat cancer. e Name one type of wave that might be used to 'see' people in the dark. d Name one type of wave that is used for radar. 2 Explain why: a microwave ovens cook food much more quickly than normal ovens b x-rays are used to check for broken bones c it is important not to damage the ozone layer around the Earth d food stays fresher for longer after it has been exposed to gamma radiation. 3 a Explain one way in which you could prevent overexposure (damage) by the following waves: i x-rays ii ultraviolet waves. b Select one of the above waves and t hen describe one consequence of overexposure. 4 Copy and complete the table below for four more different wave groups within the electromagnetic spectrum. Type of rad,at,on Possible harm Precautions x-rays cancer lead screening SEEING THE LIGHT The patient shown in Figure 12.2 has a cataract. The front of one of his eyes has become so cloudy that he is unable to see. Nowadays it is possible to remove this damaged part of the eye and replace it with a clear plastic that will allow light to enter the eye again. A Figure 12.2 cataracts mean that light cannot enter the eye correctly.114 WAVES LIGHT WAVES WAVES There are many sources of light, including the Sun, the stars, fires, light bulbs REFRACTION and so on. Objects such as these that emit their own light are called luminous objects. When the emitted light enters our eyes we see the object. Most objects, however, are non-luminous. They do not emit light. We see these non- luminous objects because of the light they reflect. luminous object non-luminous object & Figure 12.3 Luminous objects, such as the Sun, give out light. Non-luminous objects only reflect & Figure 12.6 This rainbow is caused by refraction. light. Rays of light can travel through many different transparent media, including REFLECTION KEY POINT air, water and glass. Light can also travel through a vacuum. In a vacuum A medium is a material, such as glass When a ray of light strikes a plane (flat) mirror, it is reflected so that the angle of or water, through which light can travel. and in air, light travels at a speed of 300 000 000 mis. In other media it incidence (1) is equal to the angle of reflection (r). The plural of medium is media. travels more slowly. For example, the speed of light in glass is approximately KEY POINT - - - - - - - - - - ~ ~ - - - - - - - - - - plane mirror KEY POINT 200 000 000 mis. When a ray of light travels from air into glass or water it slows Light does travel more slowly in air than down as it crosses the border between the two media. This change in speed The angle of incidence is the angle 71\\ in a vacuum but the difference is tiny. may cause the ray to change direction. This change in direction of a ray is between the incident ray and the called refraction. normal. i = angle of incidence incident-A The angle of reflection is the angle r = angle of reflection ray between the reflected ray and the normal. air incident ray normal reflected ray Figure 12.4 Light is reflected from a plane mirror. The angle of incidence is equal to the angle of glass reflection. The normal is a line at right angles to themirror. Mirrors are often used to change the direction of a ray of light. One example of air this is the simple periscope, which uses two mirrors to c hange the direction of rays of light. light is bent away from the normal Rays from the object strike the first mirror at an angle of 45 to the normal. The rays are reflected at 45 to the normal and so are turned through an angle of .6. Figure 12.7 This light ray is being refracted twice - once as it travels from air into glass and then go by the m irror. At the second mirror the rays are again turned through go . as it travels from glass to air. Changing the direction of rays of light in this way allows an observer to use a periscope to see over or around objects. As a ray enters a glass block, it slows down and is refracted towards the normal. As the ray leaves the block it speeds up and is refracted away from the normal. If the ray strikes the boundary between the two media at 90, the ray continues without change of direction (Figure 12.8). air normal glass \\\ 4 air ' ' A~:.J 3 The diagrams below show a physics demonstration about thermal conduction. 6/ ~ c?~ched 1 2 heat 3 A cylinder is made from a piece of brass fitted to a piece of wood. A piece of paper is glued around the middle. The paper is then heated over a Bunsen burner flame. After a while one end of the paper is noticeably more burnt than the other. Explain why this happens.150 ENERGY RESOURCES AND ENERGY TRANSFER WORK AND POWER object through a greater distance, again, you do more work. The definition of work in physics is: 16 WORK AND POWER work done, W (joules) =force, F (newtons) x distance moved, d (metres) The unit of energy is named after James Joule. It was Joule who realised that heat was a store of energy. He showed that kinetic energy could be transferred W=Fxd to heat. At that time heat was measured in calories. If the force is measured in newtons and the distance through which the force is applied is measured in metres then the work done will be in joules. ENERGY AND WORK Work done is equal to the amount of energy transferred. 1 J of work done is transferred when a force of 1 N is applied through a Energy is the ability to do work. distance of 1 m in the direction of the force. This statement tells us what energy does rather than what energy is. We know that energy is found in a wide variety of different stores but we are really Piiiiiit interested in what energy can do - the answer is that energy does work. We need to define work in a way that is measurable. Some types of work are Figure 16.2 shows a AT not easy to calculate the value of. Mechanical work, like lifting heavy objects, weightlifter raising an object i is easy to measure: if you lift a heavier object, you do more work; if you lift an that weighs 500 N through a weight SOON distance of 2 m. To calculate the work done we use: W=Fxd = 500 N x 2 m = 1000 J Figure 16.2 Doing wor1< by lifting a weight This work done on the weight has increased its energy. This is explained in the section on gravitational potential energy (page 152). Pii:iiii+ car travelling at 30 mis ., ~~&.~~~ ,., 400 N force opposing motion due to air resistance and friction II ** Figure 16.3 A car travelling at a constant speed doing work In the example shown in Figure 16.3 the force acting on the car is not accelerating it - instead, it is being used to balance the forces opposing its movement. The resultant force on the car is zero, so it keeps moving in a straight line at constant speed. To work out the work done on the car in one second we substitute the force required, 400 N, and the distance through which it acts in one second, 30 m, in the equation: W=Fxd = 400 N x 30 m = 12000 J or 12 kJ152 ENERGY RESOURCES AND ENERGY TRANSFER WORK AND POWER GRAVITATIONAL POTENTIAL ENERGY (GPE) KEY POINT In Figure 16.5, we can see the GPE stored by the weight is being transferred to other stores as the weight falls. The weight accelerates because of the force The gravitational potential energy of an object that has been raised to a height, Kinetic energy (KE) is the energy stored of gravity acting on it, so it gains kinetic energy. When it reaches the ground all h, above the ground is given by: by moving objects. the initial GPE is transferred to kinetic energy. When it hits the ground all the movement energy is then transferred to oth er stores, mainly heat and sound. gravitational pot ential energy, GPE (joules) = mass of object, m (kilograms) REMINDER x gravitational field strength, g (newtons per kilogram) x height, h (metres) Gravitational field strength is the force acting per kilogram on a mass in a GPE=m xg x h gravitational field. The gravitational field strength, g, on the surface of the Earth is approximately 10 N/kg. Since the weight of an object is mg, increase in GPE is a The change in the GPE of an object will be an increase if we apply a force special version of the equation W = F x d, with F = mg and d = h. on it in the opposite direction to the pull of gravity - that is, if we lift it off the ground. When an object falls it loses GPE. To keep things simple, we usually KINETIC ENERGY, KE assume that an object has no GPE before we do work on it. The kinetic energy of a moving object is calculated using the equation: In the weight-lifting example given on page 151, the weightlifter has used some chemical energy to do the work. We know that energy is conserved kinetic energy, KE (joules) = mass, m (kilograms) x speed squared, v2 so what has happened to the chemical energy that the weightlifter used? Some has been transferred to heat in the weightlifter's body. The remainder (metres squared per seconds squared) has been transferred to the weight because he has increased its height in the gravitational field of the Earth. The energy that the weight has gained is called KE=.! mv2 gravitational potential energy or GPE. 2 work done =- F x d lforce=mgN EXTENSION WORK = mg xh distance = h m In Chapter 1 we saw the equation of uniformly accelerated motion: so, lifting the object through a distance of h m involves l v2 =u2 +2as doing mgh J of work This equation allows us to work out the final velocity, v, of an object that has a uniform acceleration, a, and that has accelerated through a distance, s, starting with mass= m kg an initial velocity of u. weight = mgN If we drop an object from rest its initial velocity, u = 0, its acceleration is g m/s2 and the distance that it falls is usually represented by h, so the equation becomes v' = 2gh Multiplying both sides of the equation by m, the mass of the object, gives: mv2 = 2mgh which can be rearranged as 1mv2 = mgh showing that the gain in KE of the object is equal to its loss of GPE. & Figure 16.4 The work done to lift an object is equal to the GPE the object has at its new height. a b We see that the amount of kinetic energy possessed by a moving object released depends on its speed and its mass. As the Earth travels through space, held above the orbiting the Sun, it runs the risk of colliding with chunks of matter that are GPE decreasing c drawn into the gravitational field of the Solar System. In fact, this is very ground KE increasing about to hit common. If you have ever seen a shooting star - or, to give it its proper name, a meteor - you have seen the line of light produced as a small piece of space eGPE maximum the ground debris (waste) burns up on entering our atmosphere. This is an example of kinetic energy being transferred to heat and light by the friction produced KEzero GPE zero between the air and the object passing through it. KE maximum d & Figure 16.6 Meteors bum up on entering our & Figure 16.7 This crater was created when ameteorite collided with Earth in Arizona. atmosphere - we see them as 'shooting stars'. on hitting the ground all the EXTENSION WORK KE is transferred to heat, sound The meteorite that caused the Arizona crater is thought to have hit the Earth & Figure 16.5 When a raised object falls, its gravitational potential energy is transferred first to travelling at 11 000 mis and to have kinetic energy and then to heat and sound. had a mass of 109 kilograms. It hit the ground with an energy equivalent to a 15 megaton hydrogen bomb, 1000 times greater than the atomic bomb dropped on Hiroshima at the end of the Second World War.154 ENERGY RESOURCES AND ENERGY TRANSFER WORK AND POWER Plilbit MIHiit Calculate the kinetic energy carried by a meteorite of mass 500 kg (less than that of an average-sized car) hitting the Earth at a speed of 1000 m/ s. KE =imv2 i= x 500 kg x (1000 m/s)2 = 250 000 000 J (or 250 MJ) CALCULATIONS USING WORK, GPE AND KE i+force=mgN . 1-;\"\"allGPE,noKE Figure 16.9 A rollercoaster ride increasing KE distancehm In a rollercoaster ride the truck falls through a height of 17 m. Calculate the at the point of hitting truck's speed at the bottom of this fall. (Take g = 10 N/kg) j the ground all the GPE If we assume that all the GPE of the truck at the top of the ride is now transferred to KE transferred to KE at the bottom we can use the equation: as the speed is at its greatest GPE = KE a b at rest c accelerating d mgh = i mv2 The mass, m, of the truck appears on both sides of the equation, so it downwards cancels out: gh = i v2 = =Substituting h 17 m and g 10 N/kg: 17 m x 1ON/ kg = i v2 v2 =2 x 17m x 10 N/kg v = / (2 x 17m x 10N/kg) = 18.44 mis (about 66 kph) Some of the GPE the truck had at the start will be transferred to heat and sound, so the speed at the bottom of the fall will be a little slower than this. object Oo'--=-- - - - tim__e _.__ _ __. b e dropped - POWER A Figure 16.8 GPE and KE of a falling object: a doing work to lift an object; ball GPE; Power is the rate of transfer of energy or the rate of doing work. c GPE transferring to KE during fall; d all KE at end of fall; e graph showing relationship between GPE and KE as the object falls James Watt (Figure 16.1 Oa) is remembered as the inventor of the steam engine and is said to have been inspired by watching the lid on a kettle being forced Work transfers energy to an object: W = Fd. An object of mass, m, weighs up by the pressure of the steam forming inside. Neither story is accurate, (m x g) newtons so the force, F, needed to lift it is mg (Figure 16.8). If we raise but what is true is that Watt, working in partnership with Matthew Boulton, the object through a distance h, the work done on the object is mg x h . This is developed improvements to the steam engine that made it a commercial also the gain in GPE. product and completely changed industry and transport. When the object is released, it falls - it loses GPE, but gains speed and so A Figure 16.10 a James Watt (1736-1819) The SI unit of power is named in honour of James Watt. The watt 0N) is the gains KE. At the end of the fall, all the initial GPE of the stationary (not moving) was a Scottish engineer who improved the rate of transfer or conversion of energy of one joule per second (1 J/s). object has been transferred to the KE of the moving object. The graphs in pertornrance of the

on energy resources can be found at the end of Unit 4 on a nuclear power station at the end of its useful working life. For conventional page 168. power stations, this is a routine demolition job, but for nuclear power stations 131D CRITICAL THINKING the task is not as straightforward. Radioactive materials must be handled with 1 Here is a list of ways of ways of producing electricity: great care and stored in a way to ensure that none escape. 131D REASONING 131D CRITICAL THINKING A wind farms E gas-fired power stations We see that, although the running costs of nuclear power are relatively low, the pay-back time is very long. (The pay-back time is how long it takes for the B coal-fired power stations F tidal power stations income from selling electricity to cover the cost of building the power station.) C hydroelectric power stations G using geothermal energy The cost of setting up a wind farm is much lower than the cost of building a nuclear power station and there are no fuel costs. However, the amount of D nuclear power stations energy produced by wind farms is comparatively low. The pay-back time for wind generators is therefore q uite long. a State which of these produces 'clean' electricity. LOOKING AHEAD b State which of these uses 'fossil' fuels. Sometimes physics is described as the study of matter and energy. As we c State which of these uses a renewable energy resource. have stated in this unit, energy, work and power affect us in everyday life. d State which of these produces waste that remains dangerous to people We use energy to move things around, keep us warm and to manufacture things. As the population of the world increases the demand for energy and animals for very long periods of time. also increases. Fossil fuels are a non-renewable resource and, although new reserves may be discovered and new methods of extracting these 2 From the list in Question 1 choose those methods of producing electricity reserves found, they will run out eventually. that are only suitable in certain places and state the type of location required for each method. Energy is needed to move an object against a force. You will learn more about the forces that govern the w ay the Universe works: gravity, 3 Nuclear power generation does not produce greenhouse gases. This is a electromagnetic and the two types of nuclear force. By understanding significant advantage of nuclear power over power stations that bum fossil fuels. how to break the forces that hold the atom together, physicists have a Describe two other advantages of using nuclear power. made power from nuclear fission. Understanding how to force atoms b Describe two disadvantages of using nuclear power. close enough together for them to form more massive atoms will provide us with nuclear power from fusion reactors. 4 The demand for electricity varies on an hourly and a daily basis. Sometimes the changes in demand are predictable, but sometimes they are not. Give Building experimental fusion reactors is a huge challenge for engineers two examples of predictable changes in demand and two examples of and scientists. If successful they may provide a long-term solution to the changes in demand that are not predictable. world's demand for energy without the problems of nuclear waste - but a fusion reactor capable of delivering energy on the scale we need has not 5 Electricity is generated by a number of different types of power station. Give yet been built. three examples of different types of power station and compare how well they are able to respond to sudden changes in demand. Scientists continue to search for new solutions to producing energy and to improving the efficiency of the devices we use to cut down on energy IUliIIQ:kWi1@tl waste.168 ENERGY RESOURCES AND ENERGY TRANSFER UNIT QUESTIONS UNIT QUESTIONS . .PROBLEM SOLVING D An electric motor is used to raise a load that weighs 800 N through a distance of30m. a How much work does it do in raising the load? (3) {) D. .PROBLEM SOLVING a A fluorescent lamp is 25% efficient. Choose the statement that correctly b Calculate the power output of the motor if it takes 16 s to raise the load. (2) . .CRITICAL THINKING describes how the lamp performs. c The motor is 75% efficient. . .PROBLEM SOLVING A the lamp only works for a quarter of the time . .CRITICAL THINKING 6,: Explain what this means. (2) B 25% of the electrical energy transferred to the lamp is wasted . .PROBLEM SOLVING ii Calculate the electrical power that must be supplied to the motor to C the lamp does not work properly . .INTERPRETATION raise this load in the time stated. Give your answer in kW. (2) d Draw a labelled Sankey diagram to represent the energy transfers that take D 25% of the energy supplied to the lamp is transferred to light (1) place as the motor raises the load. (3) b A car uses energy stored in chemical form in petrol. When the engine is (Tota l for Que stion 2 = 12 m arks) running this energy is transferred to other types of stored energy. Which of the following energy stores is useful? ...,,,,,.,.,._ ANALYSIS, D The diagram shows a toy rocket launcher that uses a spring in a tube. ~REASONING A noise rocket B heat \\ C movement (1) D hot exhaust gases c Which of the following materials is a good thermal conductor? A glass B aluminium C air spring D water (1) d Which of the following statements about thermal radiation is false? a Here are statements that describe the events leading to the launch of the A It cannot travel through glass. toy rocket: B It can travel through a vacuum. spring released C It travels at the speed of light. 2 rocket leaves launcher D It is absorbed by black objects better than shiny ones. (1) 3 rocket gains kinetic energy 4 spring stores elastic potential energy e Four students, A, B, C and D, measure their power output by running 5 child does work squashing the spring upstairs and timing how long it takes. Which of the four students has the greatest power output? 6 spring transfers stored energy to rocket A mass of 50 kg, takes 20 s to gain a height of 10 m Choose from the following list the letter that describes the events in the B mass of 40 kg, takes 30 s to gain a height of 15 m order that they must happen. (1) C mass of 45 kg, takes 10 s to gain a height of 5 m A 156324 8 541632 C 154632 0 541623 D mass of 55 kg, takes 25 s to gain a height of 15 m (1) . .CRITICAL THINKING b Describe the energy transfers that take place after the rocket leaves the launcher, up to and including when it hits the ground. (4) (Total for Question 1 = 5 m arks) (Total for Quest ion 3 = 5 m arks)170 ENERGY RESOURCES AND ENERGY TRANSFER UNIT QUESTIONS m D EXECUTIVE FUNCTION D A student wants to show that water is a poor conductor of heat. The diagram m D INTERPRETATION b On a graph grid, 18 cm by 22 cm, plot a graph of the current produced by below shows the investigation he sets up. Bl!!> PROBLEM SOLVING m D EXECUTIVE FUNCTION the PV cell against the angle of the cell to the horizontal. (5) Bl!!> INTERPRETATION c Use the graph to find: any anomalous result (1) ii the angle to get the maximum output from the PV cell in the set-up shown. (1) HEAT d When installing PV panels it is important to have them pointing towards the Sun as you would expect. In the experimental set-up shown, the lamp is modelling conditions in the UK in early March at midday (when the Sun reaches its highest position in the sky). In A the ice is How could the experiment be set up to model different positions of held at the bottom of the tube by wire Sun? (1) gauze. HEAT ii The experiment is repeated by another student at a time and place when the Sun is directly overhead at midday. Sketch a line on your graph The student measures how long it takes for each piece of ice in the water to show how this student's results might appear. Label this line 'Sun to melt. The results will help him to show whether or not water is a poor conductor. overhead'. (3) a State anything the student should do to make sure this is a fair test. (Total for Question 5 = 14 marks) (3) m D REASONING b i Assuming that this is a fair test, in which order do you think the ice will m D EXECUTIVE FUNCTION melt, starting with the slowest? Give an explanation for your answer. (4) ii How can this investigation show that water is a poor conductor? (3) (Total for Question 4 = 10 marks) D This question is about PV (photovoltaic) cells. A student wanted find the best angle to set up a PV cell to get the maximum amount of energy transferred from the Sun's rays to electrical energy. Here is the apparatus she set up and the results she obtained. Miltkfo.lM1 o 10 20 30 40 50 60 70 80 90 MM'W 111 144 155 189 202 208 210 204 191 172 The PV cell was connected to a load and she measured the current, /, (1) produced by the cell with the cell at different angles, 0, to the horizontal. (1) (1) a State: i the dependent variable ii the independent variable iii a control variable.DENSITY AND PRESSURE 173 'I SOLIDS, LIQUIDS AND GASES 18 DENSITY AND PRESSURE Matter can exist in three basic forms: as a solid, a liquid or a gas. In this photo all three are present, though we can only see the solid iceberg and the liquid ocean . Fortunately the iceberg is surrounaed by gas, the mixture of oxygen and nitrogen that makes up our atmosJ)here. Our atmosphere usually contains some water in gas form, which we cannot see. When gaseous water in the atmosphere condenses into tiny wale~ droplets we can see these as clouds UNITS The properties of a material affect how it behaves, and how it affects other materials around it. The balloon can fly because the gas inside it has a very In this section you need to use degree low density. The skis spread the weight of the skier over the snow so she does Celsius (0 C) and Kelvin (Kl as the units of not sink into it. The submersible is designed to explore the seabed - it has a temperature (these units both represent very strong hull to withstand the high pressure from water deep in the oceans. the same change in temperature but the Kelvin scale starts from absolute zero, DENSITY as explained later), kilogram per cubic metre (kg/m3) as the unit of density, Solids, liquids and gases have different properties and characteristics. One cubic metre (m') as the unit of volume, such characteristic is density. Solids are often very dense - that is, they have pascal (Pa) as the unit of pressure and a high mass for a certain volume. Liquids are often less dense than solids, and square metre (m') as the unit of area. gases have very low densities. It is important to remember 1 m3 = 1 000 000 cm3 (a cubic metre is The density (p) of a material can be calculated if you know the mass {m) of a 1 million cubic centimetres) and certain volume {\\l) of the material, using this equation: 1 m2 = 10 000 cm' (a square metre is 10 thousand square centimetres). d t mass, m ens, y, p = volume, V KEY POINl m p is the Greek letter rho (pronounced P= v 'row') and is the usual symbol for density. This is not to be confused with p which represents pressure.174 SOLIDS, LIQUIDS ANO GASES OENSITY ANO PRESSURE SOLIDS, LIQUIDS AND GASES The units for density depend on the units used for mass and volume. If mass MIHii+ is measured in kilograms and volume in cubic metres, the units for density are The m ass of 50 c m 3 of a liquid and a measuring cylinder is 146 g. T he kilograms per cubic metre (kg/m3). Density can also be measured in grams per mass of t he empty measuring cylinder is 100 g. What is t he density of the cubic cent imetre (g/cm3). liquid in kg/m3? +ma+ mass of 50 cm3 of liquid= 146 g -1 00 g A p iece of iron has a mass of 390 kg and a volume of 0.05 m3. What is its density? = 46 g density = mass volume = 0.046 kg 390 kg 0 . 05 m3 HINT 50 cm3 = 0 .000 05 m3 = 7800 kg/m3 Check the units when you are working m out density- don't mix up g and m3, for P=v example. Also check which units the question asks for in your final answer. 0.046 kg 0. 00005 m3 1 kg=1000g To convert kg to g, divide by 1000. = 920 kg/m3 1 m3 = 1 000000 cm3 To convert cm3 to m3, divide by or 1000000 (or 106). 46 g Alternatively, work out the density in =50 cm3 g/cm3, then multiply your answer by HINT ... Figure 18.2 The equation for density can be rearranged using the triangle method. 1000. = 0 .92 g/cm3 If an examination question asks you to The density of a subst ance can be determined by measuring the mass =920 kg!m3 write out the equation for calculating and volume of a sample of the material, and then calculating the density. density, mass or volume, always give PRESSURE UNDER ASOLID the actual equation in words or using You c an push a drawing pin into a piece of wood quite easily , but you cannot !/7standard symbols, such asp = make a hole in the wood with your thumb, no matter how hard you push! The small point of t he drawing pin concentrates all your pushing force into a tiny Ao. Figure 18.3 a The volume of a regular solid can be calculated by multiplying its length (ij, area, so the pin goes into the wood easily. Similarly, it is easier to cut things width (w) and height (h). b The volume of an irregular object can be determined using a with a sharp k nife than a b lunt o ne, because with a sharp knife all the force is displacement can and a measuring cylinder. concentrated into a much smaller area. Use a half-metre rule to measure the lengt h, width and height of a regular Pressure is defined as the force per unit area. Force is measured in newtons solid. When measuring the volu me of the liquid that is displaced (pu shed (N) and area is measured in square metres (m2). T he units for pressure are out) by a n irregular solid make sure t hat the measuring cylinder is o n a pascals (Pa), where 1 Pa is equivalent to 1 N/m2. level (horizontal) surface and that you look at the scale straight on as shown (to avoid parallax error). Pressure (p), force (F) and area (A) are linked by the following equation: You then need to measure the mass of the solid. Use weighing scales for pressure, p (pascals) = force, F (newtons) this. area, A (square metres) P=AF REMINDER F When answering questions, start with p xA the equation you need to use in words or recognised symbols. Ao. Figure 18.4 The equation for pressure can be rearranged using the triangle method.176 SOLIDS, LIQUIDS ANO GASES OENSITY ANO PRESSURE SOLIDS, LIQUIDS AND GASES Plilbit Gases also exert pressure on things around them. The pressure exerted by the atmosphere on your body is about 100 000 Pa (although the pressure varies An elephant has a weight of 40 000 N, and her feet cover a total area of slightly from day to day). However, the pressure inside our bodies is similar, so 0.1 m2. we do not notice the pressure of the air. A woman weighs 600 N and the total area of her shoes in contact with the ground is 0.0015 m2. Who exerts the greatest pressure on the ground? Elephant: p = E. A 40000 N 0.1 m2 = 400 000 Pa (or 400 kPa) Woman: A Figure 18.6 Pressure in liquids acts equally in all directions. A can of water with holes can be used to demonstrate this. P=AF One of the first demonstrations of the effects of air pressure was carried out 600N by Otto van Guericke in 1654, in Magdeburg, Germany. Van Guericke had two 0.0015m2 large metal bowls made, put them together and then pumped the air out. The bowls could not be pulled apart, even when he attached two teams of horses =400 000 Pa (or 400 kPa) to the bowls. They both exert an equal pressure. b a Figure 18.5 a The caterpillar tracks on this vehicle spread its weight over a large area. A Figure 18.8 a When the hemispheres are A Figure 18.7 Van Guericke's experiment at Magdeburg b Camels have large feet so they are less likely to sink into loose sand. full of air, the forces are the same inside You can do the same experiment in the laboratory, using much smaller bowls Some machines, including cutting tools like scissors, bolt cutters and knives, and outside. b When the air is taken ou1, called Magdeburg hemispheres. When air is inside the spheres, the pressure is the need to exert a high pressure to work well. In other applications, a low there is only a force on the outside of the same inside and outside. If the air is sucked out, pressure is only acting from the pressure is important. Tractors and other vehicles designed to move over mud hemispheres. outside. The hemispheres cannot be pulled apart until air is let back into them. have large tyres that spread the vehicle's weight. The pressure under the tyres is relatively low, so the vehicle is less likely to sink into the mud. Caterpillar fhi/iiif- tracks used on bulldozers and other earth-moving equipment serve a similar purpose. (In Figure 18.5a the caterpillar tracks are very large.) A laboratory set of Magdeburg hemispheres has a surface area of 0.045 m2. What is the total force on the outside o f the hemispheres? PRESSURE IN LIQUIDS AND GASES F=p xA The submersible shown in Figure 18.1 has a very strong hull to withstand the = 100 000 Pa x 0.045 m2 high pressure exerted on it by seawater. Pressure in liquids acts equally in all = 4500 N d irections, as long as the liquid is not moving. You can easily demonstrate this using a can with holes punched around the bottom, as shown in Figure 18.6. When the can is filled with water, the water is forced out equally in all d irections.178 SOLIDS, LIQUIDS ANO GASES OENSITY ANO PRESSURE SOLIDS, LIQUIDS AND GASES PRESSURE AND DEPTH EXTENSION WORK The unit for pressure is named after Blaise Pascal (1623-1662). He was the first The experiment shown in Figure 18.9 demonstrates that the pressure in a liquid person to demonstrate that air pressure decreases with height. He persuaded his increases with depth. We can work out the pressure difference by th inking brother-in-law to take a mercury barometer up a mountain and measure the air about a column of water, as shown in Figure 18.10. pressure at different stages in the climb. He also arranged for someone at the base of the mountain to measure the air pressure at different times during the day. The The force at the bottom of the column is equal to all the weight of water above measurements showed that the pressure of the air does decrease as you climb. it. The volume of this water (\\l) is found by multiplying the area of its base (A) by the height (h) of the column. We can work out the mass (m) of the water by LOOKING AHEAD - WEATHER AND PRESSURE m ultiplying the volume (A x h) by the density (p). .a. Figure 18.9 Pressure in a liquid increases .a. Figure 18.12 Weather maps show isobars (lines of equal air pressure). The centre of mass of water, m =(A x h) x p with depth. hurricane Katrina is a very low pressure region surrounded by isobars that are very close The force (F) on the bottom of the water column is equal to the weight of h this volume of water, which is the mass, m (A x h x p), multiplied by the together. The result of the pressure difference is very strong winds. gravitational field strength (g) (see page 34). Area, A F = (Axhxp) x g .a. Figure 18.10 We can work out the pressure As we are concerned with the pressure on the base of the column, we divide difference between two points in a liquid by the force by the area: considering a column of the liquid. F = Axhxpxg KEY POINT A You need to learn this equation but you do not need to know the proof given The area of the column therefore does not matter, and we can calculate the here for the exam. p ressure difference between two points in a liquid using the equation: p ressure difference, p (Pa) = height, h (m) x density, p (kg/m3) x gravitational field strength, g (N/kg) p=hxpxg Be careful not to muddle the symbol for pressure, p, with the symbol for density, p. This equation can be used for calculating pressure differences in other liqu ids or gases, as long as you k now their densities. P\\Hii+ glass tube vacuum The first experiments on air pressure were carried out using a simple barometer. This height mercury .a. Figure 18.13 Tornados regularly cause huge amounts of damage in many parts of the wo~d. was made by filling a long glass tube with of mercury mercu ry, and then inverting it into a bowl of column Variations in atmospheric pressure are partly responsible for the weather mercu ry. The mercury falls until the weight systems around the world. Meteorologists produce maps showing how of the column is supported by the pressure t= atmospheric pressure varies from place to place to help them make of the air on the mercury in the bowl. predictions about future weather systems. Regions of low pressure Figure 18.11 Asimple produce winds as air flows from surrounding areas of high pressure. If the column of mercury is 0.74 m high, mercury barometer what is the air pressure? Sometimes the wind speeds cause violent weather systems with tornadoes and hurricanes causing extensive damage and loss of life. Physics The density of mercury is 13 600 kg/m3. provides important tools to enable meteorologists to make more accurate Take the gravitational field strength as predictions about when and where these devastating events will occur. 10 N/kg. p =h x pxg = 0.74 m x 13600 kg/m3 x 10 N/kg = 100640 Pa180 SOLIDS, LIQUIDS ANO GASES OENSITY AND PRESSURE SOLIDS, LIQUIDS AND GASES ~ CREATIVITY, More questions on density and pressure can be found at the end of Unit 5 on 19 SOLIDS, LIQUIDS AND GASES page 193. lliiiiliiiil\"' REASONING 1 A Greek scientist called Archimedes was asked to check the purity of the m D PROBLEM SOLVING gold in a crown. He did this by comparing the density of the crown with the m D REASONING density of pure gold. m D PROBLEM SOLVING a Describe how he could have measured the density of an irregular-shaped m D REASONING object such as a crown. b Pure gold has a density of 19 000 kg/m3. Suppose the crown had a volume of 0.0001 m3. What mass should the crown be if it is made of pure gold? 2 People working on the roofs of buildings often lay a ladder or plank of wood on the roof. They walk on the ladder rather than the roof itself. a Explain why using a ladder or plank will help to prevent damage to the roof. b A workman's weight is 850 N, and each of his boots has an area of 210 cm2. Calculate the maximum pressure under his feet when he is walking. Give your answer in pascals. c The workman lays a plank on the roof. The plank has an area of 0.3 m2 and a weight of 70 N. What is the maximum pressure under the plank when he is walking on it? HINT Remember that all your weight is on one foot at some point while you are walking. To convert cm2to m2, divide by 10000 or 104. 3 A manometer can be used to find the pressure of a gas. The difference in the level of the liquid in each side of the tube indicates the difference in pressure on the water surface at A and the pressure of the gas on the water surface at B. (Assume atmospheric pressure is 100 kPa.) C ___ gas A rr: B water density = 1000 kgim' a What is the difference in pressure in Pa between A and B? Use g = 1O N/kg. b What is the pressure of the gas in tube C? c Describe what will happen when the gas is turned off and the pipe is removed from C.182 SOLIOS, LIQUIDS ANO GASES I'.sou ii{~OUJOS ~~D G~SES_ SOLIDS, LIQUIDS AND GASES SOLIDS U:Wi1iWEI attract one another and hold together. In liquids, there is no fixed pattern and LIQUIDS the particles can move around more freely than in solids. As we heat liquids, We think that all matter is made up of tiny particles that are moving. The way the movement of the particles becomes more energetic. that the particles are arranged and the way that they move determine the properties of a material, such as its state at room temperature or its density. GASES In gases the particles are very spread out, with large spaces between them. This means that the forces holding them together are small. Gases have THE STATES OF MATTER very low densities and no definite shape. Gases can also be squashed into a smaller space (compressed). Particles of a gas are moving randomly all the Some of the properties of a substance depend on the chemicals it is made time. The particles will bump into anything in the gas, or into the walls of the from. However, substances can exist in different states. The main states of container, and the forces caused by these collisions are responsible for the matter are solid, liquid and gas. We are used to finding some substances in pressure that gases exert. each state in everyday life - for example, water is familiar as ice, as water and as steam. There are other substances that we usually see in only one state Solids and liquids are very difficult to compress because the particles in them - for example, we rarely see iron in any state other than solid, or experience are almost as close together as they can be. oxygen in any state other than as gas. f1:lilld1l!tliil1M ---Hiii Substances can change state by the processes of melting, evaporation, boiling, freezing and condensing. melting neaung evaporating/boiling ,(a ~ (l.0)\\1\\,(Y((Q)) definite shape yes no no ~ can be easily compressed no no yes ~ s o./!io)\\o/i'o./!ll.o)\\ relative density high high low can flow (fluid) no yes yes (l.O))'q,io))OJ{l.O)) solid ~ liquid ~ gas condensing ((Q)j'Qd/1\\,cJ'iO))!\\O)) freezing cooung expands to fill all available space no no yes o./!li'o1 ((0))-q,~o)\\ & Figure 19.2 Changes of state (INTERPRETATION a Draw up a table to summarise the way that particles are arranged in 113111> CRITICAL THINKING solids, liquids and gases. KEY POINT absolute temperature, T/K, Kelvin b How do these different arrangements of particles explain the physical .t. Figure 19.13 Graph of pressure against absolutetemperaturefor afixed amount of gas at constant properties of solids, liquids and gases? eWe often use the symbol tor volume 2 Copy and complete the following paragraph about the particle theory of temperature in c. For temperature matter. For a fixed mass of gas at a constant volume: in K we always use the symbol Matter is made up of ___ that are in continuous ___. When we T. Remember to convert Celsius rP,, =rP;2 supply heat energy to matter the ___ move ___ . Gases exert a temperatures to Kelvin when using gas pressure on their containers because the ___ are continually ___ w ith law equations in which temperature NB T must be measured in Kelvin. the walls. The pressure will___ when the gas is heated in a container of change occurs. fixed volume because the ___ are moving ___.192 SOLIDS, LIQUIDS ANO GASES SOLIOS, LIQUIDS ANO GASES SOLIOS, LIQUIDS ANO GASES m D CRITICALTHINKING 3 Explain how ideas about particles can account for the absolute zero of mUDNIT QUE,.S:...,.TDIONSPROBLEMSOLVING m D PROBLEM SOLVING temperature. E : I I D ANALYSIS 4 a Convert the following Celsius temperatures to Kelvin temperatures. a A rectangular block of metal of density 8000 kg/m3 measures 2 cm by 3 cm i o c by 10 cm. What is the mass of the block? ii 100c iii 20 c A 48 g b Convert the following Kelvin temperatures to Celsius temperatures. B 0.48 kg i 250 K ii 269 K C 4.8 kg iii 305K 5 State what happens in the situations shown in the diagram. Explain your D 48 kg (1) answers using ideas about particles. b Which of the following will exert the greatest pressure when standing on the a ground? Some air, trapped in a cylinder A an elephant: weight 50 000 N, area of one foot 0.2 m2 by a low friction p iston, 11' piston is heated. B atmospheric pressure: 1os Pa C ballerina: weight 450 N, on one point, area 0.0015 m2 A sma ll beaker with some air lnheat t rap ped inside it is pu shed down D man: weight 800 N, area of one foot 0.025 m2 (1) l into a larger beaker of water. (;:)CRITICAL THINKING c Which of the following descriptions most accurately describes a gas? b A very low density, easily compressed, cannot flow ! B high density, cannot be compressed, definite shape C very low density, easily compressed, expands to fill available space D high density, difficult to compress, can flow (1) water d The specific heat capacity of a liquid is t rapped air A the amount of heat energy required to make 1 kilogram of the liquid boil cork B the amount of heat energy required to raise the temperature of 1 kilogram of the liquid by 1 F C A rigid co ntainer with a cork C the amount of heat energy required to raise the temperature of 1 kilogram sto pp ing its opening is heated . of the liquid by 1 c D the amount of heat energy required to raise the temperature of 1000 cm3 trapped air of the liquid by 1 c (1) {t e Boyle's law states that heat A if you double the pressure on a gas its volume doubles B if you double the pressure on a gas its temperature halves m D PROBLEM SOLVING C if you double the pressure on a gas its volume doubles provided its temperature is constant m D REASONING m D PROBLEM SOLVING .. ...t'a\"\"; 8 a A fixed amount of gas occupies a volume of 500 m3 when under a D if you double the pressure on a gas its volume halves provided its m D REASONING pressure of 100 kPa. Calculate the volume that this amount of gas will temperature is constant (1) occupy when its pressure is increased to 125 kPa. You should show each mD .... D=;.;INTERPRETATION (Total for Question 1 = 5 marks) .. ... stage of your calculation. ~ b What do you need to assume about the temperature of the gas? Explain Look at the diagram below showing a small gas bubble in a glass of fizzy drink, like cola. ~.# your answer. 7 a You put the lid on a jar in a kitchen where the air temperature is 20 c. The jar gets left out in the winter, and the air temperature drops to - 5 c. .~~,.. Explain what happens to the air pressure in the cold jar.~ 1~ b Explain why it might be more difficult to remove the lid of the jar when it is cold. a Copy the diagram and use eight arrows to shows how the pressure of the liquid acts on the gas bubble. (21194 SOLIDS, LIQUIDS ANO GASES UNIT QUESTIONS SOLIOS, LIQUIDS ANO GASES m D REASONING b Describe what happens to the bubble as it floats up towards the top of the Ul4i0i-1o/lEI m D EXECUTIVE FUNCTION d rink and explain the reason for your answer (assume that the amount D A beaker filled with water initially at 20 c is cooled in a freezer until its temperature drops to -20 c (the temperature inside the freezer). The of gas in the bubble does not change as the bubble rises up through the m D INTERPRETATION temperature in the beaker is measured with a digital thermometer and recorded at regular intervals until it reaches -20 c. cola). (3) digital thermometer (Total for Question 2 = 5 marks) temperaturef'C D The diagram shows part of the apparatus used by a student to find the density +20 . of a stone. thinnyl:10 line /stone c__ overflow spout CL_ water O time l;J -20 . ..... a What is the student measuring? (1) freezer ii What other piece of apparatus is required to complete the a Copy the graph axes shown and sketch how the temperature of the measurement? (1) contents of the beaker changes with time from its starting temperature of iii What precautions should the student take to ensure that the (1) measurement is accurate? ~~~rtra~~~~- ~ m D .. .=CRITICALTHINKING ~s~I mDANALYSIS b Referring to your sketch graph explain what happens to the water as it is m D PROBLEM SOLVING m D EXECUTIVE FUNCTION b State the equation that the student needs to calculate the density cooled from 20c to -20 c . (5) REASONING t.r: aPROBLEM SOLVING of the stone. (1) (Total for Question 5 = 10 marks) ii What other measurement must be made? State the name of the (1) D An electric kettle rated at 2.5 kW of mass 0.5 kg contains 1.5 kg of water at apparatus needed to make this measurement. 20 ' C. The kettle is turned on and the kettle and its contents are heated to (Total for Question 3 = 5 marks) 1oo c. The diagram shows a simple mercury barometer made by filling a strong The s.h.c. (specific heat capacity) of the metal the kettle is made of is glass tube with mercury and turning it upside down (with the open end of the 500 J/kg c and the s.h.c. of water is 4200 J/kg c . tube closed) in a dish of mercury and then opening the end below the level of mercury in the dish. Mercury runs out of the tube until the pressure of the a Calculate the total amount of heat energy needed. (5) mercury at X is equal to the pressure of the air acting on the surface of the mercury in the dish. b How long must the kettle be switched on for to heat the kettle and water to 100 C? Give your answer in minutes to two significant figures. (4) vacuum c In practice it will take longer than this to boil the water in the kettle. Explain why. (1) mercury HINT You may need to refer to Chapter 2 to find the relat ionship between electrical power, energy and time. (Total for Question 6 = 10 marks) JX The height, h, of mercury in the tube is a measure of air (atmospheric) pressure. A typical value for h is 76 cm. The density of mercury is 13 600 kg/m3. Use this value to calculate the atmospheric pressure in Pa (pascals). (3) (Total for Question 4 = 3 marks) I 'I ELECTRIC MOTORS AND ELECTROMAGNETIC INDUCTION 206 20 MAGNETISM AND ELECTROMAGNETISM There are two types ol magnets that we use mour everyday lives. These are permanent magnets and electromagnets. A permanent magnet has a magnetic field around 11 all the lime. The strength and direction of this field 1s not easy to change. An electromagnet when turned on also has a magnetic held around 11 bul its strength and direction can be changed very easily. In th,s chapter you will learn about the factors affecting the magnetic field around an electromag and how electromagnets are used in several important devices UNITS MAGNETISM AND MAGNETIC MATERIALS In this section you will need to use Magnets are able to attract objects made from magnetic materials such as iron, ampere (A) as the unit of current, volt steel, nickel and cobalt. Magnets cannot attract objects made from materials such as p lastic, wood, paper or rubber. These are non-magnetic materials. M as the unit of voltage and watt rN) as the unit of power.MAGNETIC FIELDS Around every magnet there is a volume of space where we can detect magnetism. This volume of space is called a magnetic field. Normally a magnetic field cannot be seen but we can use iron filings or plotting compasses to show its shape and discover something about its strength and direction. plastic pen lids ~ rasers ~~ b eces of paper - - . ~ s afety pins rubber bands needles steel nails Place a bar magnet between two books and place a sheet of paper or thin card over it. :: ~ J, 2 Sprinkle some iron filings on the paper ab ove the magnet. matches plastic buttons drawing pins ~ clips # 3 Tap the paper very gently. Avoid skin contact with iron filings, 4 The iron filings will move to show the magnetic field pattern. since they irritate the skin. Do not blow 4 Figure 20.2 Magnets attract some objects and not others. OR them off the paper, because they may get into the eyes, which is very painful. MAGNETS Place a bar magnet on a piece of paper. The strongest parts of a magnet are called its poles. Most magnets have two 2 Place a large number of small compasses on the paper near the magnet. poles. These are called the north pole and the south pole. 3 Look carefully at the pattern shown by the needles of the compasses. If two similar poles are placed near to each other they repel. If two dissimilar (opposite) poles are placed near to each other they attract. Repeat the same experiment using two bar magnets , placing them about 5 cm apart. similar poles if you make a pencil in each position, repel - the dot at the end of the the needle of the suspended magnet needle in each position plotting compass swings away from lines up with the the lower of the compass, you field line, pointing from north to south can plot the field line opposite poles ' - - _.. 4 Figure 20.4 We can see the shape of the magnetic field around a magnet by using iron filings or plotting compasses. attract - the suspended ~ magnet swings towards the lower magnet strong magnetic We draw magnetic fields like that in Figure 20.5 using magnetic field lines. field - field lines Magnetic field lines don 't really exist but they help us to visualise the main EXTENSION WORK 4 Figure 20.3 Similar poles repel and opposite poles attract. features of a magnetic field. are widely spaced Ancient travellers would construct a Penmanent magnets like the bar magnets shown in Figure 20.3 are made from 4 Figure 20.5 Themagnetic field around a The magnetic field lines: basic compass by placing a splinter a magnetically hard material such as steel. A magnetically hard material keeps (thin piece) of magnetised rock called its magnetism once it has been magnetised. Iron is a magnetically soft material bar magnet follows a pattern like this. show the shape of the magnetic field lodestone onto a piece of wood floating and is not suitable for a permanent magnet. Magnetically soft materials lose in water. The splinter would turn to their magnetism easily and are therefore useful as temporary magnets. show the direction of the magnetic force - the field lines 'travel' from north point in the direction of north-south. to south The end pointing towards the north was called the north pole. show the strength of the magnetic field - the field lines are closest together where the magnetic field is strongest.EXTENSION WORK OVERLAPPING MAGNETIC FIELDS INDUCED MAGNETISM Point X in Figure 20.6 is called a If two magnets are placed near each other, t heir magnetic fields overlap If we place an object made from a magnetic material, for example, an iron nail, neutral point. It is a position where the and affect each ot her. We can investigate this using iron filings or plotting inside a magnetic field it b ecomes a magnet. We say that magnetism has been effects of the two magnetic fields have compasses. Figure 20.6 shows the different field patterns we would see. induced in the nail. Because iron is a magnetically soft material, its induced cancelled each other out, meaning magnetism is temporary and disappears if the permanent magnet is removed. that there is no resultant magnetic ab If the nail is made from a magnetically hard material such as steel it will retain field here. Can you find any other some of its magnetism after the magnet is removed. neutral points in these magnetic field patterns? N sj Inside the magnet's T magnetic field When the magnetic ____-;\\ these iron nails become magnetised. field is removed the They behave like mini-magnets and induced magnetism ~ stick together. disappears. / .l Figure 20.8 Introducing magnetism in iron nails Cd IW1Mi1@tl ELECTROMAGNETISM When there is a current in a wire a magnetic field is created around it. This is called electromagnetism. The field around the wire is quite weak and circular in shape. ~~~~ll---1- ~~battery iron fil ings The shape and direction of .l Figure 20.6 Magnetic fields around pair.; of magnets the magnetic field around a current-carrying wire can be CREATING AUNIFORM MAGNETIC FIELD plotting seen using iron filings and compass plotting compasses. If we look very carefully at the magnetic field created b etween the north pole of Changing the direction of the one magnet and the south pole o f a different magnet we will see t hat the field current, changes the direction is shown as a series of straight field lines that are evenly spaced. A field like of the magnetic field. this is described as a uniform magnetic field - that is, its strength and direction is the same everywhere. Creating a uniform field like this is extremely useful as .l Figure 20.9 A current-carrying wire has a magnetic field aroundit. we will see later in this chapter and in the next chapter. N s u-shaped permanent s magnets can be EXTENSION WORK used to create uniform a uniform The direction of the magnetic field magnetic magnetic field depends upon the direction of the field current. It can be found using the right- hand grip rule (for fields). uniform field between the With the thumb of your right hand pointing in poles of the the direction of the current, your fingers magnets will cur1 in the direction of the field. .l Figure 20.7 Two examples of uniform magnetic fields .l Figure 20.10 You can work out the direction of the field using the right-hand grip rule (for fields).If the w ire is m ade into a flat, single-turn coil (circular wire), the magnetic field The strength of the field around a solenoid can be increased by: around the wire changes shape and is as shown in Figure 20.11 . increasing the c u rrent in the solenoid & Figure 20.11 The magnetic field around a flat coil 2 increasing the number of turns on the solenoid The strength of the magnetic field around a current- carrying wire can be 3 wrapp ing the solenoid around a magnetically soft core such as iron. increased by: This combination of soft iron core and solenoid is often referred t o as an increasing the current in the wire electromagnet. 2 wrapping the wire into a coil or solenoid (a solenoid is a long coil). & Figure 20.14 Altering the strength of the field around an electromagnet IUl11IIQ:kW+iuMS'I EXTENSION WORK It is not necessary to memorise how an electric bell or a circuit breaker works but understanding how they work might help reinforce some of the basic principles of magnets and electromagnets you will need in your exams. The electric bell When the bell push is pressed the circuit is complete and there is current in the circuit. As a result the soft iron core of the electromagnet becomes magnetised and attracts the piece of iron that is attached to the hammer (this is called the armature). When the armature is pulled down, the hammer strikes the bell. At the same time a gap is created at the contact screw. The circuit is now incomplete and the current stops. The electromagnet is now turned off so the springy metal strip pulls the armature up to its original position. The circuit is again complete and the whole process begins again. EXTENSION WORK contact screw You will not be asked questions about springy metal strip bell this but it is included in more advanced push Physics courses. The positions of the poles for a & Figure 20.12 The field around a solenoid looks like this. solenoid can be found using the right- hand grip rule (for poles). The shape of the magnetic field around a solenoid is the same as that around If the direction of the current in the a bar magnet. solenoid is reversed, so too are the positions of the poles. Ns ., Figure 20.13 You can work out the polarity of the solenoid by imagining that your right hand is electromagnet wrapped around it. Your fingers point in the direction of the current and your thumb points to the Figure 20.15 An electric bell relies upon an electromagnet. north pole of the solenoid. This is the right-hand grip rule (for poles).Circuit breaker m D INTERPRETATION 4 a Draw a diagram to show the shape of the magnetic field around a Circuit breakers also use electromagnets. The circuit breaker in Figure 20.16 uses m D REASONING solenoid. electromagnetism to cut off the current if it becomes larger than a certain value. If the b How does your diagram show where the magnetic field is strong or current is too high the electromagnet becomes strong enough to pull the iron catch out weak? of position so that the contacts open and the circuit breaks. Once the problem in the c Explain what happens to the magnetic field if the direction of the current circuit has been corrected the catch is repositioned by pressing the reset button. through the solenoid is reversed. reset button reset button 5 In 1819 a scientist named Hans Christian Oersted was using a cell to produce a current in a wire. Close to the wire there was a compass. When aI Ib iron catch there was a current in the wire, Oersted noticed - much to his surprise - that the compass needle moved. contacts contacts a Why did the compass needle move? Figure 20.16 a The circuit breaker allows a normal sized current. b When there is too large a current the circuit becomes incomplete. b When there is a current in a horizontal wire, the needle of a compass placed beneath the wire comes to rest at right angles to t he wire, pointing from left to right. In which direction will the compass needle point if it is held above the wire? Explain your answer. c Would your answer to part b still be correct if the direction of the current in the wire was changed? Explain your answer. f!\\\" 6 The diagram below shows a simple electromagnet. t _, ie Figure 20.17 These circuit breakers control the supply of electricity to different circuits in a a Explain why the core (centre) of an electromagnet is made of soft iron building. The circuit breaker will 'trip' if there is something wrong with the circuit and the and not steel. current is too high. b Suggest two ways in which the strength of this electromagnet could be increased. CHAPTER QUESTIONS More questions on electromagnetism

charge, forming ions. Unstable nuclei decay at random. This means that it is not possible to predict which unstable Beta particles are very light - they have only 0.000 125 times the mass of an alpha nucleus in a piece of rad ioactive material will decay, or when decay will happen. We shall see that we can make measurements that w ill enable us to particle. The relative charge of a 13- is - 1 and the relative charge of a J3+ is+1. predict the probability t hat a certain proportion of a radioactive material will decay in a given time. Beta particles interact w ith matter in their paths less frequently than alpha particles. This is because they are smaller and carry less charge. This means that beta particles have a greater range than alpha particles. Beta particles can travel long distances through air, pass through paper easily and are only absorbed by denser materials like aluminium. A millimetre or two of aluminium foil will stop all but the most energetic beta particles. ---ionising GAMMA RAYS (y) Gamma rays are electromagnetic waves (see page 106) with very short wavelengths. As they are waves, they have no mass and no charge. They are radiation EXTENSION WORK weakly ionising and interact only occasionally with atoms in their paths. They Gamma radiation is emitted in 'packets' are extremely penetrating and pass through all but the very densest materials of energy called photons. with ease. It takes several centimetres thickness of lead, or a metre or so of concrete, to stop gamma radiation. neutral positive NEUTRON RADIATION Neutrons are emitted by radioactive material. T hey have roughly the same atom ion mass as a proton but have no electric charge. The symbol used for a neutron EXTENSION WORK in radioactive decay equations is: .6. Figure 22.6 When a neutral atom (or molecule) is hit by ionising radiation it loses an electron and As neutrons cause other atoms to emit becomes a positively charged ion. radiation they must be screened. This 6n is done using materials that have a lot There are three basic types of ionising radiation. They are: alpha (a), beta (J3) of light atoms like hydrogen. Concrete If a neutron is emitted by a nucleus its mass number (A) goes down by 1 but and gamma (y) radiation. and water are used to prevent neutrons the atomic number (Z) is unchanged. If a neutron is absorbed by a nucleus its escaping from nuclear reactors. mass number (A) goes up by 1 but the atomic number (Z) is unchanged. ALPHA (n) RADIATION Alpha radiation consists of fast-moving particles that are thrown out of unstable nuclei when they decay. These are called alpha particles. Alpha KEV POINT .6. Figure22.7 An alpha particle (a particle) particles are helium nuclei - helium atoms without t heir orbiting electrons. EXTENSION WORK Figure 22.7 shows an alpha particle and the notation that is used to denote it As neutrons are not electrically charged they do not directly cause ionisation. They Nucleons have roughly 2000 times in equations. are absorbed by nuclei of other atoms and can cause them to become radioactive. the mass of an electron, and alpha The radioactive nuclei formed in this way will then decay emitting ionising radiation. particles are made up of four nucleons, Alpha particles have a relatively large mass. They are made up of four Neutrons are the only type of radiation to cause other atoms to become radioactive. so an alpha particle has 8000 times the nucleons and so have a mass number of 4. They are also charged because of We shall see later (Chapter 25) that neutron radiation plays an important part in the mass of a beta particle. the two protons that they carry. The relative charge of an alpha particle is +2. process of fission used in nuclear reactors. Alpha particles have a short range. The range of ionising radiation is the SUMMARY OF THE PROPERTIES OF We have said that ionising radiation causes uncharged atoms to lose electrons. d istance it can travel through matter. Alpha particles can only travel a few IONISING RADIATION An atom that has lost (or gained) electrons has an overall charge. It is called an centimetres in air and cannot penetrate more than a few millimetres of paper. ion. The three types of radioactive emission can all form ions. They have a limited range because they interact with atoms along their paths, causing ions to form. This means that they rapidly give up t he energy that they As ionising radiation passes through matter, its energy is absorbed. This had when they were ejected from the unstable nucleus. means that radiation can only penetrate matter up to a certain thickness. This depends on the type of radiation and the density of the material that it is BETA RADIATION (p- ANO p) Beta minus particles (J3-) are very fast-moving electrons that are ejected by a passing through. decaying nucleus. The nucleus of an atom contains protons and neutrons, so where does the electron come from? The stability of a nucleus depends on the The ionising and penetrating powers of alpha, beta and gamma radiation are proportion of protons and neutrons it contains. The result of radioactive decay compared in the table on page 226. Note that the ranges given in the table are is to change the balance of protons and neutrons in the nucleus to make it typical but they do depend on the energy of the radiation. For example, more energetic alpha particles will have a greater range than those with lower energy.226 RADIOACTIVITY AND PARTICLES 1 RADIOACTIVITY AND PARTICLES Ei@H:EIHH:ilHIIHIMt::rrt:::t'lttl:l't'N i l i W I M h E t - . Here is an example of alpha decay: alpha, a strong weak ~cm paper 2~ Ra 2~ Ra + ~He + energy radium atom a particle + energy beta,~ medium medium 500-1000cm thin aluminium radonatom + gamma, v weak strong virtually infinite thick lead sheet The radioactive isotope radium-222 decays to the element radon by the emission of an alpha particle. The alpha particle is sometimes represented by the Greek letter a. Radon is a radioactive gas that also decays by emitting an alpha particle. Note that the atomic number for radon, 86, is two less than the atomic number for radium. radioactive counter stopwatch This is a balanced equation: source paper, aluminium [GOO !Olfl REMINDER The total of the A numbers on each side of the equation is the same. or lead sheets (Remember that A is the total number of protons and neutrons.) GM tube A is the mass number of the element and Z is the atomic number. The The total of the Z numbers on each side of the equation is the same. .A Figure 22.8 Measuring the penetrating power of different types of radiation letters W and Y are not the symbols of (Remember that the Z number tells us the number of protons in the nucleus any particular elements as this is the - the number of positively charged partic les.) general equation. The general form of the alpha decay equation is: ~Y --+ ~j w + ~ He + energy i alpha particle, a All work with radioactive sources must Radioactive sources m ust be stored in lead-lined boxes and kept in KEY POINl In alpha decay, element Y is transformed into element W by the emission of be closely supervised by qualified a metal cupboard with a radiation warning label. The source must be an alpha particle. Element W is two places before element Y in the periodic science staff and no sources must handled with tongs away from the body. (See Chapter 24 page 247 for It is worth pointing out that the mass table. The alpha particle, a helium nucleus, carries away four nucleons, which be touched or pointed towards any more details of safe practice with radioactive materials.) number refers to the number of nuclear reduces the mass number (A) by four. Two of these nucleons are protons so part of the body. Source usage must particles, or nucleons, involved in the the atomic number of the new element is two less than the original element, be logged and they must be returned Before the source is removed from its storage container, measure the transformation - not the exact mass. Z - 2. Notice that the mass number and the atomic number are conserved to their secure storage immediately background radiation count by connecting a Geiger-MOiier (GM) tube to Mass is not conserved in nuclear through this equation - that is, the total numbers of nucleons and protons on after use. In the UK, students under a counter. Write down the number of counts after 5 minutes. Repeat this transformations, as some of it is each side of the equation are the same. 16 years are not permitted to handle three times and find the average background radiation count. transformed into energy. sources; over 16, they are allowed to Piiiii3t do this with close supervision. Take a source of alpha radiation and set it up at a measured distance (between 2 and 4 cm) from the GM tube. Complete the following nuclear equation which shows the decay of KEY POINI uranium-238 to the element thorium by alpha decay (emitting an alpha The Geiger- Muller (GM) tube is a Measure the counts detected in a 5 minute period. Repeat the count particle). detector of radiation. It is described in with a sheet of thick paper in front of the source. You should find that the the next chapter. counts have dropped to the background radiation count. This shows that : u _,2 ~Th _, ; He alpha radiation does not pass through paper. Now replace the alpha source w ith a beta source. After measuring the The atomic mass numbers (A) on bot h sides of the equation must add up new count for 5 minutes place thin sheets of aluminium between the to the same, so the atomic mass for thorium must be 234 (238 = 234 + 4). source and detector. When the thickness of the aluminium sheet is 1-2 mm thick you will find that the count has dropped to the background KEY POINT The atomic numbers (Z) on both sides of the equation must add up to the radiation level. This shows that beta radiation is blocked by just a few same, so the atomic mass for thorium must be 90 (92 = 90 + 2). So the millimetres of aluminium. A complete periodic table is shown in answer is: Appendix A on page 277. The numbers shown in the top left corner are the 2~u _, 2t Th _, ~He atomic numbers of the elements - the Finally carry out the same steps using a gamma radiation source. Now Z numbers in the nuclear equations. Figure 22.9 shows the effect of alpha particle decay. Losing an alpha particle you will find that gamma radiation is only blocked when a few centimetres Remember that the Z numbers tell us from the nucleus of a uranium atom turns it into thorium, two places back in of lead are placed between the source and the detector. the number of protons in the nucleus of the periodic table. an element. Some periodic tables show As we said earlier, an unstable atom, or strictly speaking its nucleus, w ill decay the atomic mass too but as elements Ac Th Pa u I by emitting radiation. If the decay process involves the nucleus ejecting either have a number of different isotopes the an alpha or a beta particle, the atomic number will c hange. This means that mass numbers will be an average for Actinium Thorium Protactinium Uranun Np alpha or beta decay causes the original element to transform into a different the different isotopes. 90 element. 89 91 92 Neptunium J 93 (.A Figure 22.9 Apart of the periodic table of elements228 RADIOACTIVITY AND PARTICLES RADIOACTIVITY AND PARTICLES SETA (P) DECAY Here is an example of beta minus decay: The general form of the beta plus decay equation is: :c1 -+ 1j N + Je + energy ~X -+ z-~Y + .~e + energy carbon-14 atom -+ nitrogen-14 atom + beta particle, p- + energy (also an f antineutrino) beta plus particle, f3' In p decay, element Xis transformed into element Y by the emission of a beta plus The radioactive isotope of carbon, carbon-14, decays to form the stable isotope of the gas nitrogen, by emitting a beta particle. Remember that the beta minus particle. Element Y is the element in the periodic table that comes before element X. particle is formed when a neutron splits to form a proton and an electron. The beta plus particle, a positron, has practically no mass so the mass number, A, is Figure 22.10 shows the standard atomic notation for a beta particle (p-). the same in X and Y. As this beta particle has a charge of +1, the atomic number of the new element is decreased to Z - 1. The electron has very little mass, The symbol for so the mass number, A, is zero. ~ an electron is an e. Piiiii+ oe / An isotope of caesium '~~Cs decays by emitting an electron (13-) and forms an atom of barium (Ba). Write a balanced nuclear equation for this decay. -1 ' ~ Cs -+ i Ba + -?e + energy / An electron has practically no mass so the mass number does not change. The electron does not have an atomic The emission of an electron happens when a neutron becomes a proton and an electron, so the atomic number increases by one. The barium number but does carry an equal and isotope formed is therefore 'UBa and the completed equation is: opposite electric charge to a proton so ' ~ Cs -+ '~Ba + Je + energy its Z number is - 1. When an element decays by emitting an electron it changes to the element & Figure 22.10 Abeta minus particle with the next higher atomic number. You can check this by looking at the periodic table on page 277. The general form of the beta minus decay equation is: fhiiiiii- ~X -+ z.~Y + -~e + energy REMINDER An isotope of magnesium ~~Mg decays by emitting a positron (13') and t You will not be asked questions forms an atom of sodium (Na). Write a balanced nuclear equation for this involving positrons in the exam. decay. beta minus particle, p- ~~Mg -+ ~Na+ .Ve in p- decay, element X is transformed into element Y by the emission of a A positron has practically no mass so the mass number does not change. beta minus particle. Element Y is the next element in the periodic table after The emission of a positron happens when a proton in the nucleus becomes element X. The beta particle, an electron, has practically no mass so the mass a neutron and a positron, so the atomic number decreases by one. The sodium isotope formed is therefore n Na and the completed equation is: number, A, is the same in X and Y. As the p- particle has a charge of - 1, the ~~Cs-+ nNa + .~e atomic number of the new element is increased to Z + 1. Again the mass number and the atomic number are conserved through this equation. When an element decays by emitting a positron it changes to the element with the next lower atomic number. You can check this by looking at the l:\\iHiifjfaf~ EXTENSION WORK periodic table on page 277. You will not be asked about p decay but the example here is included to show that the atomic mass numbers (A) and the atomic numbers (Z) on each side of the decay equation must balance. Here is an example of beta plus decay: ~~Na ijNe + ..?e + energy sodium-22 atom -, neon-22 atom + beta particle, p + energy (also a neutrino) The radioactive isotope of sodium (Na), sodium-22, decays to form the stable isotope of the gas neon (Ne), by emitting a beta plus particle. Remember that the beta plus particle is formed when a proton splits to form a neutron and a positron. Figure 22.11 shows the standard atomic notation for a beta particle (P'). The positron has very little mass, iiiMMifijfaf~ Here is an example of neutron decay: so the mass number, A, is zero. ~ ~He -+ ~He + Jn oe helium-5 atom -+ helium-4 atom + neutron +1 As a neutron has no electric charge, the total positive charge is unchanged by / the emission of a neutron - the Z number is 2 before and after the decay. The total number of particles (protons and neutrons) in the nucleus of the helium The electron does not have an atomic atom has decreased by 1 because of emission of the neutron. number but has the same electric charge as a proton so its Z number is + 1. Figure 22.11 A beta plus particle230 RADIOACTIVITY AND PARTICLES 1 GAMMA (V) DECAY RADIOACTIVITY AND PARTICLES PMl!t 8'1M;11;tu11+11Mm~ More questions on the structure of the atom can be found at the end of Unit 7 on page 255. An isotope of beryllium.'~Be, decays by emitting a neutron. Write a m D CRITICAL THINKING Copy and complete the table below. Identify the particles and complete the balanced nuclear equation for this transformation. missing data. Write down what you know: Atomic particle Relative mass of particle Relative charge of particle 1l Be ~ ~? + 6n The emission of a neutron has no effect on the charge so the atomic -1 number (Z) is unchanged at 4. Each element has its own atomic number so the element in this decay is unchanged - it is still an isotope of beryllium. +1 The loss of a neutron from the beryllium nucleus means that the atomic mass decreases by one. The completed equation is: 2000 6n1~Be~1 + ~ Be 2 Identify the following atomic particles from their descriptions: a an uncharged nucleon Gamma radiation is high-energy electromagnetic radiation (see page 106). After an unstable nucleus has emitted an alpha or beta particle it sometimes b the particle with the least mass has surplus energy. It emits this energy as gamma radiation. Gamma rays are pure energy, so they do not have any mass or charge. When a nucleus emits c; the particle with the same mass as a neutron a gamma ray there is no change to either the atomic number or the mass d the particle with the same amount of charge as an electron number of the nucleus. e a particle that is negatively charged. LOOKING AHEAD 3 Explain the following terms used to describe the structure of an atom: a atomic number b mass number. - - - -4 Copy and complete the table below, describing the structures of the different atoms in terms of numbers of protons, neutrons and electrons. protons neutrons electrons ... Figure 22.12 Inside the Large Hadron Collider m D PROBLEM SOLVING 5 Copy and complete the following sentences: e An alpha particle consists of four ___. Two of these are ___ and Understanding the particles that make up all matter in the Universe, how two are ___. An alpha particle carries a charge of ___. they interact and the forces involved holding matter together remains b A beta minus particle is a fast-moving ___ that is emitted from the a major area of research for physicists. This is an introduction to what nucleus. It is created when a ___ in the nucleus decays to form a has been called the 'particle zoo'. Large particle accelerators, like the _ _ and the beta particle. Large Hadron Collider (LHC) on the Swiss/French border, have identified c; A third type of ionising radiation has no mass. It is called ___ radiation. many new particles. Energy turned into matter! Research has recognised This type of radiation is a type of wave with a very ___ wavelength. patterns in these particles and we now have a model that explains many complex nuclear processes - some of which have increased our d Gamma radiation is part of the ___ spectrum. understanding of how the Universe was formed. 6 The following nuclear equation showing beta plus decay: We also understand how matter can be transformed into energy and the amazing amount of energy that results, revealed by Albert Einstein in his Be;p --+ ~D + famous equation: a From the following list of particles: E=mc2 A electron B neutron C proton D alpha particle i State which is the particle on the left of this balanced equation. ii State which is the first of the terms on the right of this equation. b The second term on the right of this equation is a positron - the antiparticle of an electron. Copy and complete the above equation filling in the empty boxes shown.232 RADIOACTIVITY AND PARTICLES 1 RADIOACTIVITY AND PARTICLES llilo!!illll!!lal!!iiiili\",. ANALYSIS, 7 A certain radioactive source emits different types of radiation. The sample 23 RADIATION AND HALF-LIFE REASONING is tested using a Geiger counter. When a piece of card is placed between the source and the counter, there is a noticeable drop in the radiation. When HINT a thin sheet of aluminium is added to the card between the source and the In this chapter you will learn about ways of detecting rad1at,on, and where some of the rad1at1on around us comes from. Look at the table on page 226. counter, the count rate is unchanged. A thick block of lead, however, causes You will also learn why we use a value called hall-hie to describe the act1v1ty of rad1oact1ve isotopes. the count to fall to the background level. I . I D PROBLEM SOLVING LEARNING OBJECTIVES Know the definition of the term half-life and What type (or types) of ionising radiation is the source emitting? Explain understand that it is different for different radioactive I . I D CRITICALTHINKING your answer carefully. Know that photographic film or a Geiger-Muller isotopes I . I D PROBLEM SOLVING detector can detect ionising radiation 8 a The nuclear equation below shows the decay of thorium. Copy and Use the concept of the half-life to carry out simple D D CRITICALTHINKING Explain the sources of background (ionising} radiation calculations on activity, including graphical methods complete the equation by providing the missing numbers. from Earth and space ~ Th -, Pa+ -~e Know that the activity of a radioactive source decreases over time and is measured in becquerels b What type of decay is taking place in this transformation? c The nuclear equation below shows the decay of polonium. Copy and complete the equation by providing the missing numbers and letters. :o2/j Po _, ~ Pb + d What type of decay is taking place in this transformation? USING PHOTOGRAPHIC FILM DETECTING IONISING RADIATION Wilhelm Rontgen (Figure 23.1 a} discovered x-rays in 1895. Henri Becquerel (Figure 23.1 b} believed that uranium emitted x-rays after being exposed to sunlight. To test this idea he placed some wrapped, unused photographic plates in a drawer with some samples of uranium ore on top of them. He found a strong image of the ore on the plates when he developed them. He later realised that this was due to a new type of ionising radiation. He had discovered radioactivity. The unit of radioactivity is named after Becquerel. The becquerel (Bq} is a measure of how many unstable nuclei are disintegrating (breaking up) per second - one becquerel means a rate of one disintegration per second. The becquerel is a very small unit. More practical units are the kBq (an average of 1000 disintegrations per second} and the MBq (an average of 1 000 000 disintegrations per second}. Photographic film can still be used to detect radioactivity. Some scientists who work with radioactive materials wear a piece of photographic film in a badge. If the film becomes fogged (unclear} it shows that the scientist has been exposed to a certain amount of radiation. These badges are checked regularly to ensure that scientists are not exposed to too much ionising radiation. ab .& Figure 23.1 a Wilhelm Rontgen (1845-1923), b Henri Becquerel (1852-1908). Nobel prize winners in 1901 and 1903234 RADIOACTIVITY AND PARTICLES RADIOACTIVITY AND PARTICLES THE GEIGER-MULLER (GM) TUBE Figure 23.2 shows the basic construction of a Geiger-Muller (GM) tube. It is a NATURAL BACKGROUND RADIATION Some of the radiation we receive comes from rocks in the Earth's crust (hard glass tube with an electrically conducting surface on the inside. The tube has FROM THE EARTH outer layer). When the Earth was formed, around 4.5 billion years ago, it a thin window made of mica (a naturally occurring mineral that can be split into contained many radioactive isotopes. Some decayed very quickly but others thin sheets). The tube contains a special mixture of gases at very low pressure. KEY POINT are still producing radiation. Some of the decay products of these long-lived In the middle of the tube, electrically insulated from the conducting surface, When an atom of a radioactive radioactive materials are also radioactive, so there are radioactive isotopes there is an electrode. This electrode is connected, via a high-value resistor, to element decays it gives out radiation with much shorter half-lives (see page 237) still present in the Earth's crust. a high-voltage supply, typically 300-500 V. and changes to an atom of another element. This may also be radioactive, One form of uranium is a radioactive element that decays very slowly. Two When ionising radiation enters the tube it causes the low pressure gas inside and decay to form an atom of yet of its decay products are gases. These are the radioactive gases radon and to form ions. The ions allow a small amount of current to flow from t he another element. The elements formed thoron. Radon-222 is a highly radioactive gas produced by the decay of electrode to the conducting layer. This is detected by an electronic circuit. as a result of a radioactive element radium-226. Thoren, or radium-220, is an isotope of radium formed by the experiencing a series of decays are decay of a radioactive isotope of thorium (thorium-232). glass tube called decay products. As these decay products are gases, they come out of radioactive rocks. They 300-SOO V NAfURAL BACKGROUND RADIATION are dense gases so they build up in the basements of buildings. Some parts FROM SPACE of the Earth's crust have higher amounts of radioactive material so the amount ~ - -~ to the detecting circuit of background radiation produced in this way varies from place to place. In Cornwall in the UK, for example, where the granite rock contains traces of conducting coating central electrode, uranium, the risk of exposure to radiation from radon gas is greater than in called the anode some other parts of the UK. .& Figure 23.2 AGeiger-Muller tube is used to measure the level of radiation. Violent nuclear reactions in stars and exploding stars called supernovae produce cosmic rays (very energetic particles) that continuously hit the Earth. The GM tube is usually linked up to a counting circuit. This keeps a count of Lower energy cosmic rays are given out by the Sun. Our atmosphere gives how many ionising particles (or how much y radiation) have entered the GM us fairly good protection from cosmic rays but some still reach the Earth's tube. Sometimes GM tubes are connected to rate meters. These measure surface. the number of ionising events per second, and so give a measure of the radioactivity in becquerels. Rate meters usually have a loudspeaker output so RADIATION IN LIVING THINGS The atoms that make up our bodies were formed in the violent reactions that the level of radioactivity is indicated by the rate of clicks produced. take place in stars that exploded (supernovas) billions of years ago. Some of these atoms are radioactive so we carry our own personal source of radiation BACKGROUND RADIATION around with us. Also, as we breathe we take in tiny amounts of the radioactive isotope of carbon, carbon-14. Because carbon-14 behaves chemically just Background radiation is low-level ionising radiation that is produced all the like the stable isotope, carbon-12, we continuously renew the amount of the time. This background radiation has a number of sources. Some of these are radioactive carbon in our bodies (see page 245). natural and some are artificial. Carbon-1 4 and other radioactive isotopes are eaten by humans (and animals ~ - ,- -ground and buildings which are in turn eaten by humans) because they are present in all living things. 14.0% ARTIFICIAL RADIATION We use radioactive materials for many purposes. Generating electricity in nuclear power stations has been responsible for the leaking of radioactive radon gas nuclear power material into the environment. The levels are usually small, but there have 50.0% 0 .3% been a number of major incidents around the world, especially at Three Mile Island in the USA in 1979 and at Chernobyl in the Ukraine in 1986. The tsunami food and drink and earthquake that caused major damage and loss of life in Japan in 2011 11.5% also damaged the Fukoshima nuclear power station resulting in the release of radioactive materials into the air and the ocean as well as making a large area .& Figure 23.3 Sources of background radiation in the UK. These are the average values - the true of land around the damaged power station unsafe for humans to live there. amounts and proportions vary from place to place. Testing nuclear weapons in the atmosphere has also increased the amounts of radioactive isotopes on the Earth. Radioactive tracers are used in industry and medicine. Radioactive materials are also used to treat certain forms of cancer. However, the majority of background radiation is natural - the amount produced from medical use in industry is very small indeed.236 RADIOACTIVITY AND PARTICLES 1 - RADIOACTIVITY AND PARTICLES 3 4 RADIOACTIVE DECAY 5 Number of cams remaining 6 1000 Radioactive decay is a random (unpredictable) process, just like throwing 519 a coin. If we throw a coin we cannot say with certainty whether it will come 264 down heads or tails. If we throw a thousand coins we cannot predict which will 140 land heads and which will land tails. The same is true for radioactive nuclei. It 72 is impossible to tell which nuclei will disintegrate (break down) at any particular 33 time. However, if we threw a thousand coins we would be surprised if the 19 number that landed as heads was not around 500. We know that a normal coin has an equal chance of landing as a head or a tail, so if we got 600 heads we would think it was unusual. If the proportion of heads were much greater than this we would be right to think that the coin was not fair. EXTENSION WORK ' head tail The coin-throwing experiment is a model of radioactive decay. A good model will show the features of the real process. We must remember that models have A Figure 23.4 Throwing a coin limitations, however, and do not perfectly represent the actual process. One limitation of the experiment is that of scale. In just 1 g of uranium-235 there are EXPERIMENTAL DEMONSTRATIOtl We could, if we had the time, take 1000 coins and throw them. We could millions of nuclei, and our model uses just 1000 coins. The model would be better OF NUCLEAR DECAY then remove all the coins that came down heads, note the number of coins if we used, say, 1000000 coins, but would take too long to perform. If we use a remaining and then repeat the process. If we did this for, say, six trials we computer model to throw the coins we could deal with more realistic numbers. would begin to see the trend. A set of typical results is shown in the following table and in Figure 23.5. Notice that the graph in Figure 23.5 falls steeply at first and more slowly after each throw. How quickly the graph falls depends on how many heads occur 1200 on each throw. But as the number of coins decreases, the number of coins that come up heads also gets smaller. This graph follows a rule: the smaller the quantity, the more slowly the quantity decreases. The quantity here is the number of coins still in the experiment. The name for this kind of decrease proportional to size is called exponential decay. If we have a sample of a radioactive material, it will contain millions of atoms. The process of decay is random, so we don't know when an atom will decay but there will be a probability that a certain fraction of them will disintegrate in a particular time. This is the same as in the coin toss - there was a 50% probability that the coins would land heads each time we conducted a trial. Once an unstable nucleus has disintegrated, it is out of the game - it won't be around to disintegrate during the next period of time. If we plot a graph of number of disintegrations per second against time for a radioactive isotope we would, therefore, expect the rate of decay to fall as time passes because there are fewer nuclei to decay. 1uo:1 600 HALF-LIFE 0 Our coin-tossing model of radioactive decay shows a graph that approaches .1l 400 the horizontal axis more and more slowly as time passes. The model will produce a number of throws after which all the coins have been taken out of E the game. The number is likely to vary from trial to trial because the model becomes less and less reliable as the number of coins becomes smaller. With :, real radioactive decay we use a measure of activity called the half- life. This is C: defined as follows. 200 The half-life of a radioactive sample is the average time taken for half the original mass of the sample to decay. If the amount of radioactive matter has 0 halved then the activity of the decay halves - this activity is what is measured 0 2 3 4 56 in finding the half-life of an isotope. The half-life is different for different trial radioactive isotopes. A Figure 23.5 Coin-throwing experiment. Each time the coins are thrown about 50% of them land as 'heads' and are removed from the pile. The graph decreases steeply at first but then does so more and more slowly.Click on the page number above to read more~ INTERNATIONALGCSEPhysics (9-1)SPECIFICATIONPearson Edexcel International GCSE in Physics (4PH1)For first teaching September 2017First examination June 2019Issue 2 Edexcel, BTEC and LCCI qualificationsEdexcel, BTEC and LCCI qualifications are awarded by Pearson, the UKs largest awardingbody offering academic and vocational qualifications that are globally recognised andbenchmarked. For further information, please visit our qualification websites atqualifications.pearson.com. Alternatively, you can get in touch with us using the details onour contact us page at qualifications.pearson.com/contactusAbout PearsonPearson is the world's leading learning company, with 35,000 employees in more than70 countries working to help people of all ages to make measurable progress in their livesthrough learning. We put the learner at the centre of everything we do, because whereverlearning flourishes, so do people. Find out more about how we can help you and yourlearners at qualifications.pearson.comThis specification is Issue 2. We will inform centres of any changes to this issue. The latestissue can be found on our website qualifications.pearson.comAcknowledgementsThis specification has been produced by Pearson on the basis of consultation with teachers,examiners, consultants and other interested parties. Pearson would like to thank all thosewho contributed their time and expertise to the specifications development.References to third party material made in this specification are made in good faith. Pearsondoes not endorse, approve or accept responsibility for the content of materials, which maybe subject to change, or any opinions expressed therein. (Material may include textbooks,journals, magazines and other publications and websites.)All information in this specification is correct at time of going to publication.ISBN 978 1 446 93119 6All the material in this publication is copyright Pearson Education Limited 2018 Summary of Pearson Edexcel International GCSE inPhysics (4PH1) specification Issue 2 changesSummary of changes made between previous issue and this Page numbercurrent issueA `P` reference has been added to specification point 5.2 21in sub-topic (a): Units.The final statement in the section Assessment requirements has been 29reworded for clarity.Information on sample assessment materials has been added. 30The qualification `Pearson Edexcel International GCSE in Science 33(Single Award) (4SS0)` has been removed from the section: Forbiddencombinations.The formatting of Appendices 2 and 3 has been updated. Also, the 41-44names and titles in Appendix 2 have been updated.The title of Appendix 5 has been amended. 47The subheading in the table of Appendix 5 has been corrected to `Verb 48preceding a command word`.If you need further information on these changes or what they mean, contact us viaour website at: qualifications.pearson.com/en/support/contact-us.html. Contents1 About this specification 1 Specification updates 1 Using this specification 1 Course introduction 2 Qualification aims and objectives 3 Why choose Edexcel qualifications? 4 Why choose Pearson Edexcel International GCSE in Physics? 5 Supporting you in planning and implementing this qualification 6 Qualification at a glance 7 Paper overview 72 Physics content 93 Assessment information 29 Assessment requirements 29 Sample assessment materials 30 Experimental skills 30 Calculators 30 Assessment objectives and weightings 31 Relationship of assessment objectives to units 314 Administration and general information 33 Entries 33 Forbidden combinations 33 Access arrangements, reasonable adjustments, special consideration and malpractice 33 Language of assessment 33 Access arrangements 34 Reasonable adjustments 34 Special consideration 34 Further information 34 Candidate malpractice 35 Staff/centre malpractice 35 Awarding and reporting 35 Student recruitment and progression 36 Prior learning and other requirements 36 Progression 36 Appendices 37 Appendix 1: Codes 39 Appendix 2: Pearson World Class Qualification design principles 41 Appendix 3: Transferable skills 43 Appendix 4: Mathematical skills 45 Appendix 5: Command word taxonomy 47 Appendix 6: Suggested practical investigations 49 Appendix 7: Physics formulae for relationships 51 Appendix 8: Electrical circuit symbols 53 Appendix 9: Glossary 55 1 About this specificationThe Pearson Edexcel International GCSE in Physics is part of a suite of International GCSEqualifications offered by Pearson.This qualification is not accredited or regulated by any UK regulatory body.This specification includes the following key features.Structure: the Pearson Edexcel International GCSE in Physics is a linear qualification.Two written examinations must be taken in the same series at the end of the course ofstudy.Content: relevant, engaging, up to date and of equivalent standard to Pearsons regulatedGCSE in Physics.Assessment: untiered, written examinations with questions designed to be accessible tostudents of all abilities.Approach: a solid basis for students wishing to progress to the Pearson Edexcel AS andAdvanced GCE Level or equivalent qualifications, focusing on key physics theory.Specification updatesThis specification is Issue 2 and is valid for the Pearson Edexcel International GCSE inPhysics examined from 2019. If there are any significant changes to the specificationPearson will inform centres. Changes will also be posted on our website.For more information please visit qualifications.pearson.comUsing this specificationThis specification has been designed to give guidance to teachers and encourage effectivedelivery of the qualification. The following information will help you get the most out of thecontent and guidance.Content: this is arranged as eight topics in 2: Physics content. A summary ofsub-topics is included at the start of each topic. As a minimum, all the bullet points in thecontent must be taught. The word including in the content helps specify the detail of whatmust be covered.Examples: throughout the content, we have included examples of what could be covered orwhat might support teaching and learning. It is important to note that examples are forillustrative purposes only and that centres can use other examples. We have includedexamples that are easily understood and recognised by international centres.Practical investigations: these are included within 2: Physics content as specificationpoints in italics. Students will develop knowledge and understanding of experimental skillsthrough the context of the physics they are learning. Experimental skills are assessedthrough written examinations.Referencing: specification statements that are in bold with a P reference relate to contentthat is only in the International GCSE in Physics and is not found in the International GCSEin Science (Double Award).Pearson Edexcel International GCSE in Physics 1Specification Issue 2 April 2018 Pearson Education Limited 2018 Course introductionThe Pearson Edexcel International GCSE in Physics is designed for use in schools andcolleges. It is part of a suite of International GCSE qualifications offered by Pearson.The course gives students the opportunity to experience physics within the context of theirgeneral education.How assessment relates to the qualifications available is shown below. Biology Paper 1 Biology Paper 2 International + Untiered Untiered GCSE in Biology + InternationalChemistry Paper 1 Chemistry Paper 2 + GCSE in Untiered Untiered Chemistry + Physics Paper 1 Physics Paper 2 International + Untiered Untiered GCSE in Physics International GCSE in Science (Double Award)A Pearson Edexcel International GCSE in Science (Single Award) qualification is alsoavailable. This will cover approximately 50% of the Pearson Edexcel International GCSE inScience (Double Award) specification, while still having a comparable level of rigour anddemand.2 Pearson Edexcel International GCSE in Physics Specification Issue 2 April 2018 Pearson Education Limited 2018 Qualification aims and objectivesThe aims and objectives of this qualification are to enable students to: learn about unifying patterns and themes in physics and use them in new and changing situations acquire knowledge and understanding of physical facts, terminology, concepts, principles and practical techniques apply the principles and concepts of physics, including those related to the applications of physics, to different contexts evaluate physical information, making judgements on the basis of this information appreciate the practical nature of physics, developing experimental and investigative skills based on correct and safe laboratory techniques analyse, interpret and evaluate data and experimental methods, drawing conclusions that are consistent with evidence from experimental activities and suggesting possible improvements and further investigations recognise the importance of accurate experimental work and reporting scientific methods in physics select, organise and present relevant information clearly and logically using appropriate vocabulary, definitions and conventions develop a logical approach to problem solving in a wider context select and apply appropriate areas of mathematics relevant to physics as set out under each topic prepare for more advanced courses in physics and for other courses that require knowledge of physics.Pearson Edexcel International GCSE in Physics 3Specification Issue 2 April 2018 Pearson Education Limited 2018 Why choose Edexcel qualifications?Pearson the worlds largest education companyEdexcel academic qualifications are from Pearson, the UKs largest awarding organisation.With over 3.4 million students studying our academic and vocational qualificationsworldwide, we offer internationally recognised qualifications to schools, colleges andemployers globally.Pearson is recognised as the worlds largest education company, allowing us to driveinnovation and provide comprehensive support for Edexcel students to acquire theknowledge and skills they need for progression in study, work and life.A heritage you can trustThe background to Pearson becoming the UKs largest awarding organisation began in 1836,when a royal charter gave the University of London its first powers to conduct exams andconfer degrees on its students. With over 150 years of international education experience,Edexcel qualifications have firm academic foundations, built on the traditions and rigourassociated with Britains education system.Results you can trustPearsons leading online marking technology has been shown to produce exceptionallyreliable results, demonstrating that, at every stage, Edexcel qualifications maintain thehighest standards.Developed to Pearsons world class qualifications standardsPearsons world-class standards mean that all Edexcel qualifications are developed to berigorous, demanding, inclusive and empowering. We work collaboratively with a panel ofeducation thought leaders and assessment experts to ensure that Edexcel qualifications areglobally relevant, represent world-class best practice and maintain a consistent standard.For more information on the world class qualification process and principles, please go toAppendix 2: Pearson World Class Qualification design principles or visit our website:uk.pearson.com/about-us/news-and-policy/reports-and-campaigns/world-class-qualifications/design-principles.html4 Pearson Edexcel International GCSE in Physics Specification Issue 2 April 2018 Pearson Education Limited 2018 Why choose Pearson Edexcel International GCSE inPhysics?Weve listened to feedback from all parts of the International and UK school subjectcommunity, including a large number of teachers. Weve made changes that will engagestudents and give them skills that will support progression to further study in physics and arange of other subjects, in physical sciences and elsewhere. Our content and assessmentapproach has been designed to meet students needs and be consistent with our approachacross the sciences.At Pearson we offer separate science qualifications in Biology, Human Biology, Chemistry andPhysics, as well as Double Award and Single Award Science qualifications these have beendesigned to meet different students needs. The content and assessment approach in all ourscience qualifications has been designed to meet students needs in the following ways. Content that is interesting and engaging for students but is also designed to ensure good preparation, both for those continuing to further study and for those wishing to work in a physics-related field. There are opportunities to localise the content to make it more relevant for students in their own country. Question papers are clear and straightforward our question papers are clear and accessible for all students of all ability ranges and learning styles. Our mark schemes are straightforward, so that the assessment requirements are clear. Students skills are broadly developed we have designed the International GCSE to extend students knowledge by broadening and deepening skills, for example: developing students practical skills by including a number of practicals in the specification content. These can be supplemented with other suggested practicals. The skills developed will be assessed through questions in written examinations improving students analytical and logic skills by applying understanding of scientific concepts and principles to a range of situations. This will include some examination questions that are more problem solving in style addressing the need for mathematical skills to complement students physics skills by covering a range of mathematical areas.Progression to A Level International GCSEs enable successful progression to A Level andbeyond. Through our World Class Qualification development process we have consulted withInternational Advanced Level and GCE A Level teachers as well as higher educationprofessors to validate the appropriateness of the qualification, including its content, skillsdevelopment and assessment structure.Courses to suit your students needs and interests teachers of physics have a choiceof International GCSE courses to deliver, each giving different levels of depth to meetstudents needs. As well as the Pearson Edexcel International GCSE in Physics, students canalso be taught our International GCSE in Science (Double Award) or our International GCSEin Science (Single Award). These courses offer a reduced amount of content, but areassessed to the same standard. Progression routes for these courses may vary slightly fromthose for the Pearson Edexcel International GCSE in Physics.More information about all our qualifications can be found on our Edexcel International GCSEpages at qualifications.pearson.comPearson Edexcel International GCSE in Physics 5Specification Issue 2 April 2018 Pearson Education Limited 2018 Supporting you in planning and implementing thisqualificationPlanning We will give you a course planner and editable schemes of work. Our mapping documents highlight key differences between the new and the 2011 legacy qualifications.Teaching and learning Our Getting Started Guide gives you an overview of the Pearson Edexcel International GCSE in Physics to help you understand the changes to content and assessment

the activity of a radioactive source decreases over a period of time and is measured in becquerels7.12 know the definition of the term half-life and understand that it is different for different radioactive isotopes7.13 use the concept of the half-life to carry out simple calculations on activity, including graphical methods7.14 describe uses of radioactivity in industry and medicine7.15 describe the difference between contamination and irradiationPearson Edexcel International GCSE in Physics 25Specification Issue 2 April 2018 Pearson Education Limited 2018 Students should:7.16 describe the dangers of ionising radiations, including: that radiation can cause mutations in living organisms that radiation can damage cells and tissue the problems arising from the disposal of radioactive waste and how the associated risks can be reduced.(c) Fission and fusionStudents should:7.17 know that nuclear reactions, including fission, fusion and radioactive decay, can be a source of energy7.18 understand how a nucleus of U-235 can be split (the process of fission) by collision with a neutron, and that this process releases energy as kinetic energy of the fission products7.19 know that the fission of U-235 produces two radioactive daughter nuclei and a small number of neutrons7.20 describe how a chain reaction can be set up if the neutrons produced by one fission strike other U-235 nuclei7.21 describe the role played by the control rods and moderator in the fission process7.22 understand the role of shielding around a nuclear reactor7.23 explain the difference between nuclear fusion and nuclear fission7.24 describe nuclear fusion as the creation of larger nuclei resulting in a loss of mass from smaller nuclei, accompanied by a release of energy7.25 know that fusion is the energy source for stars7.26 explain why nuclear fusion does not happen at low temperatures and pressures, due to electrostatic repulsion of protons26 Pearson Edexcel International GCSE in Physics Specification Issue 2 April 2018 Pearson Education Limited 2018 8 AstrophysicsThe following sub-topics are covered in this section.(a) Units(b) Motion in the universe(c) Stellar evolution(d) Cosmology(a) UnitsStudents should:8.1 use the following units: kilogram (kg), metre (m), metre/second (m/s), metre/second2 (m/s2), newton (N), second (s), newton/kilogram (N/kg)(b) Motion in the universeStudents should:8.2 know that: the universe is a large collection of billions of galaxies a galaxy is a large collection of billions of stars our solar system is in the Milky Way galaxy.8.3 understand why gravitational field strength, g, varies and know that it is different on other planets and the Moon from that on the Earth8.4 explain that gravitational force: causes moons to orbit planets causes the planets to orbit the Sun causes artificial satellites to orbit the Earth causes comets to orbit the Sun.8.5 describe the differences in the orbits of comets, moons and planets8.6 use the relationship between orbital speed, orbital radius and time period: 2 orbital radius orbital speed = time period 2 r v= TPearson Edexcel International GCSE in Physics 27Specification Issue 2 April 2018 Pearson Education Limited 2018 (c) Stellar evolutionStudents should:8.7 understand how stars can be classified according to their colour8.8 know that a stars colour is related to its surface temperature8.9 describe the evolution of stars of similar mass to the Sun through the following stages: nebula star (main sequence) red giant white dwarf.8.10 describe the evolution of stars with a mass larger than the Sun8.11P understand how the brightness of a star at a standard distance can be represented using absolute magnitude8.12P draw the main components of the HertzsprungRussell diagram (HR diagram)(d) CosmologyStudents should:8.13P describe the past evolution of the universe and the main arguments in favour of the Big Bang8.14P describe evidence that supports the Big Bang theory (red-shift and cosmic microwave background (CMB) radiation)8.15P describe that if a wave source is moving relative to an observer there will be a change in the observed frequency and wavelength8.16P use the equation relating change in wavelength, wavelength, velocity of a galaxy and the speed of light: change in wavelength velocity of a galaxy = reference wavelength speed of light 0 v = = 0 0 c8.17P describe the red-shift in light received from galaxies at different distances away from the Earth8.18P explain why the red-shift of galaxies provides evidence for the expansion of the universe28 Pearson Edexcel International GCSE in Physics Specification Issue 2 April 2018 Pearson Education Limited 2018 3 Assessment informationAssessment requirementsComponent/paper Level Assessment information Number of marksnumber and unit title allocated in the paperPaper 1P 1/2 Assessed through a 2-hour written 110 examination set and marked by Pearson. The paper is weighted at 61.1% of the qualification. A mixture of different question styles, including multiple-choice questions, short-answer questions, calculations and extended open-response questions. Assesses the content that is not in bold and does not have a P reference. Questions may come from any topic area across the specification.Paper 2P 1/2 Assessed through a 1-hour and 70 15-minute written examination set and marked by Pearson. The paper is weighted at 38.9% of the qualification. A mixture of different question styles, including multiple-choice questions, short-answer questions, calculations and extended open-response questions. Assesses all the content including content that is in bold and has a P reference. Questions may come from any topic area across the specification. Bold statements cover some sub-topics in greater depthThe total number of marks for this qualification is 180. This total is obtained by adding themark for Paper 1P (out of 110 marks) to the mark for Paper 2P (out of 70 marks). Themarks for the papers are not scaled.Based on the overall mark, students will be awarded a grade. The grades available rangefrom 9 to 1, where 9 is the highest grade.Pearson Edexcel International GCSE in Physics 29Specification Issue 2 April 2018 Pearson Education Limited 2018 Sample assessment materialsSample papers and mark schemes can be found in the Pearson Edexcel International GCSEin Physics Sample Assessment Materials (SAMs) document.Experimental skillsThe best way to develop experimental skills is to embed practical investigations in teachingor theory. The development of knowledge and experimental skills can then happen together,leading to secure acquisition of both knowledge and skills.Our practical investigations are embedded within 2: Physics content as specification points initalics. The skills developed through these and other practicals will be assessed throughwritten examinations.In the assessment of experimental skills, students may be tested on their ability to: solve problems set in a practical context apply scientific knowledge and understanding in questions with a practical context devise and plan investigations, using scientific knowledge and understanding when selecting appropriate techniques demonstrate or describe appropriate experimental and investigative methods, including safe and skilful practical techniques make observations and measurements with appropriate precision, record these methodically and present them in appropriate ways identify independent, dependent and control variables use scientific knowledge and understanding to analyse and interpret data to draw conclusions from experimental activities that are consistent with the evidence communicate the findings from experimental activities, using appropriate technical language, relevant calculations and graphs assess the reliability of an experimental activity evaluate data and methods taking into account factors that affect accuracy and validity.CalculatorsStudents will be expected to have access to a suitable electronic calculator for allexamination papers. Calculators that allow for the retrieval of text or formulae orQWERTY keyboards will not be allowed for use in examinations.30 Pearson Edexcel International GCSE in Physics Specification Issue 2 April 2018 Pearson Education Limited 2018 Assessment objectives and weightings International GCSE AO1 Knowledge and understanding of physics 3842% AO2 Application of knowledge and understanding, analysis and 3842% evaluation of physics AO3 Experimental skills, analysis and evaluation of data and 1921% methods in physics 100%Relationship of assessment objectives to unitsUnit number Assessment objective AO1 AO2 AO3Physics Paper 1 23.225.7% 23.225.7% 11.612.8%Physics Paper 2 14.816.3% 14.816.3% 7.48.2%Total for 3842% 3842% 1921%International GCSEAll components will be available for assessment from June 2019.Pearson Edexcel International GCSE in Physics 31Specification Issue 2 April 2018 Pearson Education Limited 2018 32 Pearson Edexcel International GCSE in Physics Specification Issue 2 April 2018 Pearson Education Limited 2018 4 Administration and general informationEntriesDetails of how to enter students for the examinations for this qualification can be found inour International information manual. A copy is made available to all examinations officersand is also available on our website.Students should be advised that if they take two qualifications in the same subject, colleges,universities and employers are very likely to take the view that they have achieved only oneof the two GCSEs/International GCSEs. Students or their advisers, who have any doubtsabout subject combinations should check with the institution to which they wish to progressbefore embarking on their programmes.Forbidden combinationsThis qualification may not be taken alongside: Pearson Edexcel International GCSE in Science (Double Award) (4SD0).Access arrangements, reasonable adjustments, special considerationand malpracticeEquality and fairness are central to our work. Our Equality Policy requires all students tohave equal opportunity to access our qualifications and assessments, and our qualificationsto be awarded in a way that is fair to every student.We are committed to making sure that: students with a protected characteristic (as defined by the UK Equality Act 2010) are not, when they are undertaking one of our qualifications, disadvantaged in comparison to students who do not share that characteristic all students achieve the recognition they deserve for undertaking a qualification and that this achievement can be compared fairly to the achievement of their peers.Language of assessmentAssessment of this qualification will only be available in English. All student work must be inEnglish.We recommend that students are able to read and write in English at Level B2 of theCommon European Framework of Reference for Languages.Pearson Edexcel International GCSE in Physics 33Specification Issue 2 April 2018 Pearson Education Limited 2018 Access arrangementsAccess arrangements are agreed before an assessment. They allow students with specialeducational needs, disabilities or temporary injuries to: access the assessment show what they know and can do without changing the demands of the assessment.The intention behind an access arrangement is to meet the particular needs of an individualstudent with a disability without affecting the integrity of the assessment. Accessarrangements are the principal way in which awarding bodies comply with the duty underthe UK Equality Act 2010 to make reasonable adjustments.Access arrangements should always be processed at the start of the course. Students willthen know what is available and have the access arrangement(s) in place for assessment.Reasonable adjustmentsThe UK Equality Act 2010 requires an awarding organisation to make reasonableadjustments where a student with a disability would be at a substantial disadvantage inundertaking an assessment. The awarding organisation is required to take reasonable stepsto overcome that disadvantage.A reasonable adjustment for a particular student may be unique to that individual andtherefore might not be in the list of available access arrangements.Whether an adjustment will be considered reasonable will depend on a number of factors,including: the needs of the student with the disability the effectiveness of the adjustment the cost of the adjustment the likely impact of the adjustment on the student with the disability and other students.An adjustment will not be approved if it involves unreasonable costs to the awardingorganisation or unreasonable timeframes or if it affects the security or integrity of theassessment. This is because the adjustment is not reasonable.Special considerationSpecial consideration is a post-examination adjustment to a student's mark or grade toreflect temporary injury, illness or other indisposition at the time of theexamination/assessment, which has had, or is reasonably likely to have had, a materialeffect on a candidates ability to take an assessment or demonstrate their level ofattainment in an assessment.Further informationPlease see our website for further information about how to apply for access arrangementsand special consideration.For further information about access arrangements, reasonable adjustments and specialconsideration, please refer to the JCQ website: www.jcq.org.uk34 Pearson Edexcel International GCSE in Physics Specification Issue 2 April 2018 Pearson Education Limited 2018

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