AIMS

- To enable students to understand how the different physiotherapy equipment works, and how each modality interacts with the body.

- To enable students to understand the uses of the machines in treating different conditions.

- To enable students to understand how to safely use each modality, through practical tuition.

OBJECTIVES

At the end of this module you should be able to;

- Identify the different types of equipment available and the advantages and disadvantages of its use in different conditions.

- Show practical ability in using each machine on animals.

- Understand the safety precautions and contraindications of each machine.

- Understand the rationale behind each piece of equipment and how it interacts with the body.

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INTRODUCTION

The basic definition of physiotherapy is “to assist the body to heal itself”. It is important to understand that physiotherapy does not speed up the natural healing process but it optimises it. The body’s ability to heal at an optimum rate can be compromised by many factors. Demands on the body such as age, illness and other conditions can dramatically slow down the healing process and in many cases stop it all together. In animal physiotherapy this is magnified due to the lack of communication with the patient. Humans will usually follow advice on how to use an injured limb correctly, or for how long to rest a strained muscle. Animals are not so obliging!

Massage is very beneficial to any animal and massage techniques will be a part of your job. However there is much more to physiotherapy than palpation by hand. The depth of muscle, especially in large animals, is too great to treat by hand alone. Physiotherapy equipment is required, not only to treat muscle conditions but bones, skin, tendon and ligaments.

Animal Physiotherapy has developed over the last 30 years in the UK. Experimental research is ongoing. This research coupled with medical developments has led the way to the production of the current physiotherapy equipment available.

During this module you will learn about the workings and the practical uses of the different types of physiotherapy equipment available. There will also be ample opportunity to use the equipment on your practical training days.
Basic physics of matter

The atom.
The basic building block of matter is the atom. An atom consists of a dense nucleus containing positively charged protons and uncharged neutrons. This is surrounded by one or more, light weight, negatively charged electrons. The atom is held together by electrical attraction between the protons and the electrons.

Basic components of an atom:-

- **Electrons** - These are the smallest of the three basic particles. They have a negative charge and therefore repel other electrons. They orbit the nucleus at very high speeds forming shells of electrons, and look similar to Saturn’s rings, albeit on a much smaller scale.

- **Protons** – These are larger particles found in the nucleus of the atom and have a positive charge. Although positive charges will repel each other in the same ways as negative ones, protons are held together in the nucleus by strong nuclear forces.

- **Neutrons** – These are neutrally charged particles usually found in the nucleus. A neutron is made up of a proton with a ‘captured’ electron, essentially existing as one particle. Since the electron has a charge exactly opposite to a proton, the charges cancel out, hence the neutron remains neutral.

Elements

The periodic table of elements (Figure 1) represents all elements known to man, in mass order. The number of electrons (-) and protons (+) in an atom is equal when the atom is in its elemental form, and therefore, the atoms of each element appears uncharged. The number of electrons and protons in an atom determines the element the atom represents. This can be found in the periodic table.
as the number in the top right hand corner of each elemental box; e.g. Hydrogen (H\textsuperscript{1}) is the lightest element it contains only one electron and one proton; whereas, Potassium (K\textsuperscript{19}) contains 19 electrons and 19 protons (Figure 1).

**Figure 1. Periodic Table of Elements**

![Periodic Table of Elements](image)

**Arrangement of electrons**
The simplest atom is the Hydrogen atom (Figure 2), which consists of just one electron orbiting one proton. The nucleus does not contain a neutron.

**Figure 2. Hydrogen Atom**

![Hydrogen Atom](image)
Heavier elements have differing combinations of protons and electrons. The distance that the electrons are away from the nucleus defines their energy levels and there is a strict order of how many can exist at each level. The first and most energetic level (shell) away from the nucleus can only hold 2 electrons. The second and third levels can each hold 8. The make up of the shells along with their overall atomic number can be deduced from the table (Figure 1). The filling of the shells is analogous to filling a bus from the front seat first, once the first seat (shell) is full the second must be filled before electrons may orbit the nucleus in the third shell. For example, Potassium, found in the first column (group 1), has just 1 electron in its outer shell, the shells are filled as 2 electrons in the first shell, 8 in the second, 8 in the third and 1 in the fourth.

For example, the fictitious element “Therapium” has an atomic number of 12. This means there are 12 electrons orbiting a nucleus of 12 protons and 12 neutrons. The arrangement of the electron shells is 2, 8, and 2. Fig 3 shows the make up of a Therapium atom in two dimensions. This is for illustration purposes only. The orbits of the electrons are 3 dimensional, forming ‘shells’ or ‘clouds’ at each level. **Figure 3. The Therapium Atom**

**Ions (Ionic Bonding)**
Under some circumstances, the atom may lose or gain one or more of its electrons from the outer shell in order to result in a full complement of 8 electrons in its outermost occupied shell; atoms in this state are called ions. Ions that have lost electrons will have more protons than electrons so have a positive charge. These are called cations. Where an electron is gained, the atom has an
extra **negative charge**; these are called **anions**. There are many ions involved in biochemical processes in the body, such as Potassium (K+), Chloride (Cl-).

**Covalent bonding**
When atoms join together to form a **stable structure**, they can do this in 2 different ways. One of these involves **sharing electrons**. The ideal atomic structure is to have the outer shell full of its maximum compliment of electrons. For example, Oxygen has an atomic number of 8, this means that it has 8 electrons orbiting its 8 protons and 8 neutrons, with an overall atomic mass of 16 (only the protons and neutrons have mass). Oxygen atoms have 2 electrons in their 1st shell and 6 in their second shell; therefore oxygen has two ‘empty’ spaces in its furthest occupied shell (a full shell is 8 electrons), in order for oxygen to become ‘unreactive’ it must combine with another atom of oxygen and ‘share’ electrons. In its ‘stable’ elemental state oxygen exists as O₂ (two atoms of Oxygen) bound together by sharing 4 of their electrons. This system is called **covalent bonding**, and is very **stable** and **overall uncharged**. When these bonds are formed energy is released, and therefore energy is required to break them.

![Covalent Bond](image)

**Semiconductors**
The structure of a metal is such that it will allow free electrons to drift through its lattice structure. When a potential difference is applied, they move in one direction and form an electric current. Semiconductors have the electrons held more tightly, but as the temperature increases, some of these electrons are able to move through the material.
**p-n Junction**

Adding small amounts of impurities (doping) to semiconductors increases their ability to conduct electricity. Silicon, a semiconductor, has 4 electrons in its outer shell and can be combined with small amounts of an impurity containing 5 outer electrons. When these elements combine, they each share 4 of the others electrons. The 5th extra electron is free to move through the material. This type is called ‘n type’ material due to the excess of negative charge carriers.

If silicon is doped with an impurity that only has 3 outer electrons, this leaves a gap or ‘hole’ where there is an unpaired electron. This can attract other electrons to fill the gap, so is known as ‘p’ type material, behaving as if it has a positive charge. Where layers of each material are put together, a p-n junction exists. Electrons can move across the join from the ‘n’ layer into the ‘p’ layer. This situation also occurs in nature in bone.
SECTION 2
The Electromagnetic Spectrum

The Electromagnetic spectrum is a representation of all energies that require electrical energy and magnetic energy, at different wavelengths for their existence; and is represented below:-

Figure 5. The Electromagnetic spectrum

What are Waves?
Ocean waves travel on the surface of the water. You can see them and you can feel them. The wind creates waves in a flag on a windy day. Both the waves in the flag and the ocean waves are waves that you can see.

Sound is a type of wave that we cannot see. Like ocean waves, sound waves need a medium to travel through. Sound can travel through air because air is made of molecules. These molecules carry the sound waves by bumping into each other, like Dominoes knocking each other over. Sound can travel through anything made of molecules. Therefore there is no sound in space due to it being a vacuum, because there are no molecules there to transmit the sound.
waves. There are also other kinds of waves. We cannot see these waves, but we experience them every day. These waves are called electromagnetic waves.

**Electromagnetic waves** are unlike sound waves because they **do not need molecules to travel**. This means that electromagnetic waves can travel through air and solid materials - but they can also travel through empty space. Radio waves are a type of electromagnetic wave. This is why, for example, astronauts on space-walks use radios to communicate.

**Electromagnetic Waves**

Electromagnetic waves are produced by the motion of electrically charged particles. These waves are also called "electromagnetic radiation" because they radiate from the electrically charged particles. They travel through empty space as well as through air and other substances.

It has been observed that electromagnetic radiation has a dual "personality." Besides acting like waves, it acts like a stream of particles, called "photons" that have no mass. The photons with the highest energy correspond to the shortest wavelengths.

Electricity can be static, for example, when it holds a balloon to the wall or makes your hair stand on end. Magnetism can also be static like a refrigerator magnet. But when they change or move together, they make waves - electromagnetic waves.

Electromagnetic waves are formed when an electric field couples with a magnetic field. **Magnetic and electric fields of an electromagnetic wave are perpendicular to each other and to the direction of the wave.**

**Figure 6 & 7. Electromagnetic waves**
Wavelength is the distance between one wave crest to the next (see above.)

**Electromagnetic Waves have different wavelengths.**
When you listen to the radio, watch TV, or cook dinner in a microwave oven, you are using electromagnetic waves. Radio waves, television waves, and microwaves are all types of electromagnetic waves. They only differ from each other in wavelength ($\lambda$).

**Radio waves** have the longest wavelengths in the electromagnetic spectrum. These waves can be longer than a football field or as short as a football.

**Infrared light** lies between the visible and microwave portions of the electromagnetic spectrum. Infrared light has a range of wavelengths, just like visible light has wavelengths that range from red light to violet. "Near infrared" light is closest in wavelength to visible light and "far infrared" is closer to the microwave region of the electromagnetic spectrum. The longer, far infrared wavelengths are about the size of a pin-head and the shorter, near infrared ones are the size of cells, or are microscopic. Far infrared waves are thermal, we experience this type of infrared radiation every day in the form of heat that we feel from sunlight. The temperature-sensitive nerve endings in our skin can detect the difference between inside body temperature and outside skin temperature.
Shorter, near infrared waves are not hot at all - in fact you cannot even feel them. These shorter wavelengths are the ones used by TV remote control.

**How can we "see" using Infrared?**
Since the primary source of infrared radiation is heat or thermal radiation, any object with a temperature radiates in the infrared spectrum. Even objects that we think of as being very cold, such as an ice cube, emit infrared. When an object is not quite hot enough to radiate visible light, it will emit most of its energy in the infrared. For example, hot charcoal may not give off light but it does emit infrared radiation that we feel as heat. The warmer the object, the more infrared radiation it emits.
Animals, at normal body temperature, radiate most strongly in the infrared at a wavelength of about 10 microns (a micron is the term commonly used in science for a micrometer, or one millionth of a meter).

**Visible light waves** are the only electromagnetic waves we can see. We see these waves as the colours of the rainbow. Each colour has a different wavelength. Red has the longest wavelength and violet has the shortest wavelength. When all the waves are seen together, they make white light.
When white light shines through a prism or through water vapour, e.g. rain, the white light is broken apart into the colours of the visible light spectrum, a rainbow.

**Figure 8. Visible light region**
**Ultraviolet (UV) light** has shorter wavelengths than visible light. Though these waves are invisible to the human eye, some insects, like bumblebees, can see them. The ultraviolet part of the spectrum is divided into three regions: the near ultraviolet, the far ultraviolet, and the extreme ultraviolet. The three regions are distinguished by how energetic the ultraviolet radiation is, and by the "wavelength" of the ultraviolet light, which is related to energy. The near ultraviolet, abbreviated NUV, is the light closest to optical or visible light; The extreme ultraviolet, abbreviated EUV, is the ultraviolet light closest to X-rays, and is the most energetic of the three types. The far ultraviolet, abbreviated FUV, lies between the near and extreme ultraviolet regions. It is the least explored of the three regions.

**X-rays**
As the wavelengths of light decrease, they increase in energy. X-rays have smaller wavelengths and therefore higher energy than ultraviolet waves. X-rays are referred to in terms of their energy rather than wavelength. This is partially because X-rays have very small wavelengths. It is also because X-ray light tends to act more like a particle than a wave. X-ray detectors collect actual photons of X-ray light - which is very different from the radio telescopes that have large dishes designed to focus radio waves.

X-rays were first observed and documented in 1895 by Wilhelm Conrad Roentgen, a German scientist who found them by accident when experimenting with vacuum tubes. A week later, he took an X-ray photograph of his wife's hand, which clearly revealed her wedding ring and her bones. The photograph electrified the general public and aroused great scientific interest in the new form of radiation. Roentgen called it "X" to indicate it was an unknown type of radiation.

**How do we "see" using X-ray light?**
If we could see X-rays, we could see things that either emit X-rays or halt their transmission. Our eyes would be like the X-ray film used in hospitals or dentist's offices. X-ray film "sees" X-rays, like the ones that travel through your skin. It also sees shadows left by things that the X-rays can't travel through (like bones or metal).
When you get an X-ray taken at a hospital, X-ray sensitive film is put on one side of your body, and X-rays are shot through you. At a dentist, the film is put inside your mouth, on one side of your teeth, and X-rays are shot through your jaw; this is not painful as you can't feel X-rays. Because bones and teeth are dense and absorb more X-rays than skin does, silhouettes of bones or teeth are left on the X-ray film whilst skin appears transparent. Metal absorbs even more X-rays than bone.

**Gamma-rays**

Gamma-rays have the smallest wavelengths and the most energy of any other wave in the electromagnetic spectrum. These waves are generated by radioactive atoms and in nuclear explosions. Gamma-rays can kill living cells, a fact which medicine uses to its advantage, using gamma-rays to kill cancerous cells.

**Energy is Conserved**

**Energy is never formed** - it is merely changed from one form to another, however it can be stored. It has been found that the internal energy of a system may be changed by either doing work on the system or by heating it. An example is a melting ice-cube; the ice, (solid state water), requires energy from its surroundings in the form of heat to ‘melt’ to its liquid state (water). The system is like a bank: it can take a deposit in either currency, but stores its reserves as internal energy and therefore the internal energy of an isolated system is constant. The waves that compose the electromagnetic spectrum all require energy for their movement. Ultimately, for most waves, their movement is just the transfer of energy from one molecule to the other; this phenomenon may be explained by a relay race, the baton is passed from the moving runner to a stationary runner, who, on receiving the baton, moves. The previous runner comes to a halt as the energy transfer has occurred, and so on.

**Energy Transfer to Produce Ions – “Ionising Radiation”**

Energy from any source has the ability to knock electrons from the outermost shells of atoms; therefore rendering the atom ionised—possessing an overall positive charge.

I will explain this by example: Think of yourself in a closed room, there is no-one else in the room, you run in straight lines and can only change direction when you hit something. When you hit the wall,
you inevitably will, you bounce off with an equal but opposite angle as you had when you approached the wall [The angle of incidence equals the angle of reflection \( \alpha = \beta \)] (Figure 9). You are only transferring energy from you to the wall and from the wall to you, therefore neither you, nor the wall are gaining or losing energy (you may also be losing some as heat!).

If we place other people in the room who are willing to lose one or more of their “electrons” if they are knocked, and you now run as you were previously, you will knock into them, they will lose an “electron” or electrons (depending on your energy level- speed in this case). The knocked person will now have a positive charge overall and will be “ionised”; the more people you knock the greater number of ionised particles will be present. This basic concept is used for many measuring or emitting probes in diagnostics.

**Figure 9. The Angle of Incidence equals the angle of Reflection**
Section 3
Phototherapy

Lasers: What They Are?
The word LASER is an acronym: Light Amplified by Stimulated Emission of Radiation. In the simplest terms, stimulated emission is a principle of optical physics that amplifies light (or other electromagnetic radiation) by

1) segregating light of a single wavelength or very narrow band of wavelengths
2) "pumping" the light to high intensity.

The first laser was developed in 1960 using a ruby to segregate visible light in a narrow red wavelength. Since then lasers have been developed across the electromagnetic spectrum from very short ultraviolet to long infrared wavelengths, using a variety of substances to separate radiation of the selected wavelength. These substances include gases (carbon dioxide, argon, etc.), metals and metal vapours (copper), crystals (ruby, alexandrite, etc.), and dyes.

The atoms or molecules of the substances that separate selected wavelengths of radiation are said to be "excitable" (have the ability to donate or lose their electrons). When "pumped" by an electrical, chemical or optical energy source, they become excited. Then, when hit by one unit of radiation (a photon) each excited atom or molecule is stimulated to emit another identical photon. Mirrors are used to bounce the photons back and forth, stimulating emission of more photons with each pass. At a given point in the process, the highly selected, extremely bright, monochromatic (single wavelength) radiation is allowed to emit from the laser as a coherent beam. The beam is highly controllable, allowing precise direction of radiation energy into a target area. The beam exceeds the intensity of any natural radiation source.
Electromagnetic wavelengths are measured in fractions of a meter. The wavelengths of lasers used in dermatology range from long infrared (10,600 micrometers - millionths of a meter) to short ultraviolet (193 nanometers - billionths of a meter).

**Terminology**
This laser terminology is helpful in understanding laser applications:

**Continuous wave laser beam:** Laser light emitted in an uninterrupted beam.

**Photon:** A unit of light. A photon has the unique ability to behave as a particle and as a wave. Although it is identified as a particle, its energy level is defined as wavelength.

**What is phototherapy?**
Phototherapy, or light therapy, is a form of treatment for skin conditions using artificial light wavelengths from the ultraviolet (blue light) part of the sun’s spectrum. In this way, light of certain wavelengths can be delivered with a higher intensity, but without the light of all the other wavelengths that are present in sunlight, e.g. visible light and infrared (heat producing light).

**How does phototherapy work?**
This probably varies for different skin conditions but may involve a number of factors, including a change in the skin’s immune system, reduction in inflammation and removal of abnormal cells. To do this, some damage to normal cells will usually be produced. Hence, there is the potential for short-term (e.g. burns) and long-term (skin cancer) side-effects to occur, but this will vary with the type of light treatment/phototherapy used.

**There are two types of phototherapy in the UV range – UVA and UVB.**
UVA is part of the UV spectrum associated with pigmentation. UVB phototherapy utilises the sunburning part of the UV spectrum. “Narrowband” UVB uses light of one wavelength only.

**Photo Chemical Effect**
When photons strike tissue, the energy is dispersed (spread) into that tissue. Sometimes this is in the form of heat or it may alter chemical structures within the tissue. At the therapeutic level the frequencies have the general effect of altering or causing temporary changes to biological structures.

Typical examples of these changes are as follows; -

- **Photon Energy**

**A** is the excitation of electron bonds causing temporary displacement out of the structure that they should be forming, making the molecule more reactive to other molecules, because, at the point of loss, they are themselves, unstable.

- **B** is the excitation of the molecules. This could be a thermal effect (effect caused or causing heat absorption or release) increasing thermal agitation of the molecules within the target tissue that may lead to flushing and/or inflammation and

**Figure 10. Photon energy**

**Photon absorption in molecules**

- **A** is the excitation of electron bonds causing temporary displacement out of the structure that they should be forming, making the molecule more reactive to other molecules, because, at the point of loss, they are themselves, unstable.

- **B** is the excitation of the molecules. This could be a thermal effect (effect caused or causing heat absorption or release) increasing thermal agitation of the molecules within the target tissue that may lead to flushing and/or inflammation and
therefore vascular changes.

- C shows a possible effect on the rotational aspect of some molecules, which may change absorption potential in cells; therefore either increasing or decreasing the rate of absorption or adsorption of the molecule with the changed conformational shape. If the rotational conformation of some molecules is changed, it can render the molecule toxic to the body.
These effects may change conditions at injury sites and stimulate the body into a reaction that is beneficial. Thermal change (heating of the wound area) is thought to occur and have effects with the low light levels used. Effects on cellular membranes may be such that the membrane voltage is affected to attract anionic flows of nutrients into them. Another example is that, a photochemical effect on serum bilirubin has been well documented in jaundiced babies. Isomerisation (changing the rotational conformation [C]) of the bilirubin molecule is caused by phototherapy so that the kidneys can then excrete it.

**Effect on Bacteria**
The use of blue light phototherapy is becoming more accepted as a therapy for new open wounds. The effect of the light appears to inhibit bacterial proliferation at the site and this reduces the possibility of infection. Some bacteria have a built in blue light filter. Applying this logic to bacterially infected ‘dirty’ wounds it would appear that the higher energy levels available in blue light causes an adverse photochemical reaction in the bacteria and damages or kills it. It should also be noted that the peak frequency of visible light radiated by the sun is at 470nm. This is the frequency applied with blue SLD emitters.

**Treatment times and Joule Calculations**
Treatment times are now based upon an energy calculation of 1J/cm² (one joule of energy is used for every square centimetre of wound area to be treated). Light intensities vary with the type of light source used and if the light source pulses (strobe light), the pulsating frequency also varies. With pulsation, the percentage ratio between ‘light on’ and ‘light off’ times needs to be taken into account.

**Example.**
The treatment with a constant intensity light source is 20 seconds (not therapeutically accurate). But if the light source has a pulse every second, for one second, the treatment time would have to be doubled as the light is ‘off’ for the same amount of time as it is ‘on’, therefore doubling the time frame that the light is ‘on’. Pulsing light is believed to increase the therapeutic effectiveness as it allows an assimilation time for cells to process the changes caused.
True lasers provide a spot of about 1 – 2mm\(^2\) at power levels up to 5 mw/cm\(^2\) (milli watts per square centimetre); A watt = 1 joule per second therefore, to therapeutically get a total of 1 joule in a square centimetre of wound, the following calculations are required.

5 mW (=0.005W=5x10\(^{-3}\)W) is the available energy per square centimetre. Since 1 J/s = 1 watt, it would take 1/(5 x 10\(^{-3}\)) seconds to transfer 1 watt in a square centimetre, that is 200 seconds (3 minutes+).

\[
\frac{1}{\text{Power output of laser used}} = \text{Time (seconds) to transfer 1 watt to a squared cm}
\]

Now you need to know the size of the area you are treating. The time is calculated in seconds per squared cm, therefore:

\[
\text{Time} \times \text{area of wound to be treated} = \text{Seconds required to treat area „A”}
\]

e.g. The total treatment time may be calculated by estimating the size of the treatment area, i.e. 5cm\(^2\) area of injury = 1000 seconds treatment time (16 min +). These calculations are based on the example of a very low powered true laser.

**Therapeutic uses in animal physiotherapy**

**Blue light**

The application of blue light phototherapy has an antibacterial effect at a superficial level. Used promptly on fresh wounds the risk of contamination will be reduced.

The use of blue light is invaluable where regular cleaning of a wound is made difficult. An unhandled or aggressive animal who particularly objects to regular, uncomfortable cleaning of a wound will usually accept phototherapy treatment as it is not painful and can be applied without contact if necessary. This may avoid the need for repeated sedation and stress to the animal.

The use of phototherapy in post-operative care is becoming more utilised within veterinary practices. Prompt use of blue light phototherapy to the site of the incision can reduce the chance of
infection. This will also reduce the chance of sutures breaking down or not holding. For use where sutures have broken down, phototherapy can assist in the repair of the wound, again helping to control any infection and optimise healing.

Skin conditions caused by bacterial infection, such as mud fever and rain scald can be treated with blue light. Once again animals with such conditions commonly get very upset with continual invasive cleaning and phototherapy can provide a pain free alternative. It should be noted that under the vets supervision the area should be thoroughly cleaned and cleared of scabs and debris before treatment can start. The blue light will not penetrate through the thick scabs that are common in these conditions and the bacteria causing the infection will continue to breed underneath if the wound is not thoroughly cleaned. It is common for animals suffering from all types of skin conditions to develop a secondary bacterial infection. This can also be prevented or treated with blue light phototherapy.

**Ultra bright visible red and infrared phototherapy**
Visible red and infra red compliment each other well and are usually used in the same LED applicator. These two frequencies have numerous effects;
- The proliferation of cells essential for tissue repair
- Increase in vasodilation at capillary level.
- Infrared works just below the skins surface accelerating collagen synthesis, the base requirement for tissue repair.
- Visible red stimulates epithelial cells, reduces scar tissue and used correctly helps prevent proud flesh.

Proud flesh is a common problem particularly on the limbs of the horse. Using visible red light around the margins of the wound has shown excellent results in optimising the rate at which the edges of the wound come together.

The use of phototherapy is not restricted to wounds. Application over acupuncture points changes the conductivity of the skin and causes the body to react with a release of endorphins- ‘happy hormones’. When used before massage, in most cases, the animal will relax and show signs of submission, even if they are very tense. This allows the therapist to palpate and identify problems more effectively and
makes it easier to get a true reaction from the animal. It also allows the therapist to work on relaxed muscles, this, along with capillary vasodilation significantly reduces bruising and discomfort. The use of phototherapy over acupuncture points has a similar effect to acupuncture therapy.

Phototherapy is a relatively safe form of treatment suitable for acupuncture point stimulation and a variety of superficial injuries.

**Laser therapy**

The therapeutic spectrum of wavelengths is generally considered to be 600nm-1000nm. It is unclear if some wavelengths are 'better' than others. It should be noted that attenuation (loss of power) occurs in animals with a darker skin or coat, or a wet animal. Lasers are classified by the number of milliwatts of power:

**Classification of Laser**

- **Class I** – less than 0.5mW, eg. garage door opener
- **Class II** – less than 1mW
- **Class IIIa and b** – 1mW to 500mW – therapeutic, ‘cold’ lasers which do not produce heat. Eye protection essential.
- **Class IV - >500mW** – ‘hot’ lasers which produce heat, can be used for cutting tissue and present a fire hazard.

The majority of therapeutic Lasers are class IIIa or b; newer Class IVa Lasers are available which deliver the treatment faster, but do not penetrate any deeper and can burn so present potential safety issues.

Laser therapy is used to decrease inflammation and oedema, improve wound healing, and decrease pain. Indications for the use of Laser include pain, decreased circulation, tendonitis, bursitis, capsulitis, over scar tissue, for the treatment of muscle spasm, inflammation, wounds and arthritis. Contraindications for its use include treatment over the eyes, cancerous lesions, thrombophelbitis, pregnancy, over areas of haemorrhage, and over reproductive organs.

The wavelength of the Laser determines the depth of penetration, although this will also be affected by the tissue type. In general, a 600nm Laser penetrates between 0.5-1cm, and a 900nm Laser penetrates up to 5cm. The power of the probe is measured in mW and
determines how fast the joules are delivered, eg. 250mW, 500mW, etc. 1W of power will deliver 1J of energy in 1s. The energy given = power (mW) x time (seconds of treatment), so a 500mW probe delivers 1J in 2 seconds.

Dosing guidelines
Acute condition: up to 2J/cm²
Sub-acute condition: 3-4J/cm²
Chronic condition: 5-8J/cm²

The frequency of treatment varies; it can be performed daily or even several times a day for the first 1-2 weeks, with a decreasing frequency over time. This is often determined by client availability or finances. YOU AND THE CLIENT MUST WEAR LASER GOGGLES!
Section 4
Pulsed Electromagnetic Therapy

What is Electromagnetism?
The interaction of electrical and magnetic effect is known as electromagnetism. Electromagnetism was first discovered in the 1800s by the English physicist Michael Faraday, who determined that a magnetic field could be generated by running an electric current through a wire coil. Conversely, a changing magnetic field can generate an electric voltage; the magnetic field must change to have any electrical effect (hence, the term pulsating electromagnetic field therapy, which generates rising and falling levels of a magnetic field.) Electromagnetism is one of the most important concepts in physical science. An electromagnet consists of a piece of soft iron with electrical wire wrapped around it. When an electric current flows through the wire, it produces a magnetic field around the wire and the iron is magnetised. The greater the current, the stronger the magnetic field. By coiling up the wire many times, the magnetic field produced can be made even stronger.

What has Lorenz force to do with PEMF?
Electrical current in a coil, as stated, causes a magnetic field. The magnetic field curls around electric wire in which the current flows. Electricity and magnetism are interrelated in many ways. They are manifestations of the same fundamental physical concepts. Maxwell equations (below) show the relation between the electricity and magnetism. The combined effects of electrical and magnetic fields, is called Lorenz force. As result of induced Lorenz force pulsing electromagnetism will produce electricity in cells and this is the basis for Pulsing Electromagnetic Field Therapy.

Polarisation
The magnetic field has another property called polarisation. This is a directional property. The direction of polarity can be deduced by
looking into the negative end of the wire and imagining tightening a screw along the line of the wire. Thus the polarity would have a clockwise direction. The polarity is deducible as **North and South poles**. Where the field leaves the centre of the coil is said to be the North and the other side where it enters the coil, the South.

**Figure 11. 2 dimensional views of magnetic field formed from a coil and permanent Magnet**

The biological effects of pulsating electromagnetic fields are hypothesised to be due to electrical rather than magnetic forces. Magnetism generates a voltage in tissue according to the equation:

\[ V = n \times a \times \frac{dB}{dt} \]

\( V \) = Voltage

\( n \) = number of turns in the electromagnetic coil

\( a \) = area of the loop

\( \frac{dB}{dt} \) = The rate of change of magnetic field with respect to time, with \( B \) representing the strength of the magnetic field (in Teslas). For example, if \( B \) goes from zero to 1 Tesla in 1 millisecond, then \( \frac{dB}{dt} = 1000 \text{ Teslas/sec} \).

Based on this equation, a static magnetic field cannot generate an
electrical voltage, as the dB/dt component of the equation, is zero, as is the voltage induced by the field. Thus, any effects of a static magnetic field on tissue cannot be electrical in nature.
Electromagnetic interference caused by all forms of electrical devices from power lines to home appliances and computers can cause serious health hazards to human beings and animals.

**Electricity within the body?**
It is long known that there is electricity in the body: electrocardiogram (ECG), electroencephalogram (EEG) and electromyogram (EMG) are ways to measure the electrical activity of the heart, brain and muscles. The combined effects of electric and magnetic force explain that pulsing electromagnetic fields induce electrical changes on a cellular level within the body and cell metabolism is influenced.

**Electromagnetic Therapy**
Electromagnetic therapy is found to be successful in treating various forms of physical as well as emotional pain. There are various electromagnetic devices including magnets being used worldwide to laminate pain, to heal broken bones, to relieve many forms of stress, and to relieve symptoms involving the skeleton and the joints of the body. The body produces very subtle electromagnetic fields, which have been generated in the body through chemical reactions within cells and ionic currents passing through the nervous system.

**Positive vs. Negative polarities** which exist in all magnets have contrary effects on the biological systems they come in contact with. The negative magnetic field produced by a magnet can have a beneficial effect on living organisms. However, prolonged exposure to the positive magnetic pole of the magnet has been shown to interfere with the metabolic processes, increases acidity, interferes with oxygenation, and other undesirable effects. Of particular interest, a significant increase in pain can be experienced due to the interference of metabolic functions.

**Static Magnets**
There are a large number of devices used to generate magnetic fields in electromagnetic therapy. Larger machines are needed to generate a strong enough to magnetic field to treat bone fractures in joint related problems. There are magnetic blankets that reduce stress and promote sound sleep. There are other devices that are placed in clusters around portion of the body including the head. There are other tiny magnets designed to stimulate acupuncture points in order to promote a balanced flow of energy through the meridians.
What is the difference between regular magnets and PEMF?
Our body's natural magnetic field is created by the flow of electrically charged ions in and out of cells and the transmission of electric impulses through cell membranes. Only Pulsing Electro Magnetic Field (PEMF) force and not static magnets can influence on a cellular level. The magnetic strength value of static magnets (measured in Gauss units) is not relevant at all, since the measured field strengths of permanent magnets range from 300 gauss to 16000 gauss at the surface, at 2 cm distance around 10 gauss and at 10 cm distance absolutely nothing. In addition static magnets cannot create any electrical induction at all without being mechanically moved the whole time!

Two methodological applications of electromagnetic energy are used in therapy. One application exposes the body or a portion of the body through just the north (negative) pole of the magnet. The second application uses below gauss level of both negative and positive poles simultaneously. Practitioners using negative pole therapy typically use gauss intensity ranging from 2000 to 4000. The application is straightforward, the magnet is placed on the particular portion of the body being treated in his often-held in place by tape. Practitioners who employee spatially alternating magnetic poles typically use magnets in which the poles a spatially alternating in either a concentric circles pattern or a checkerboard pattern.

As a rule of thumb the longer a magnet remains in place the quicker the healing process occurs.

Pulsed magnetic therapy – How does it work?
Pulsing Electro Magnetic Fields influence cell behaviour by inducing electrical changes around and within the cell. Improved blood supply increases the oxygen pressure, activating and regenerating cells. Improved calcium transport increases absorption of calcium in bones and improves the quality of cartilage in joints. It was found that disturbances in blood circulation and in metabolism play a key role in the development of diseases.

All living cells within the body possess potentials between the inner and outer membranes of the cell, which, under normal healthy
circumstances, are fixed. Different cells, e.g. Muscle cells and Nerve cells, have different potentials across their cell membranes of about -70 mV respectively. When cells are damaged, these potentials change such that the balance across the membrane changes, causing the attraction of positive sodium ions into the cell and negative trace elements and proteins out of the cell. The net result is that liquid is attracted into the interstitial area and swelling or oedema occurs. The application of pulsed magnetic fields has been shown to help the body to restore normal potentials at an accelerated rate, thus aiding the healing of most wounds and reducing swelling faster. The most effective frequencies are very low frequency pulses of a 50Hz base. These, if gradually increased to 25 pulses per second for time periods of 600 seconds (10 minutes), condition the damaged tissue to aid the natural healing process.

**Pain reduction** is another area in which pulsed electromagnetic therapy has been shown to be very effective. Pain signals are transmitted along nerve cells to pre-synaptic terminals. At these terminals, channels in the cell alter due to a movement of ions. The membrane potential changes, causing the release of a chemical transmitter from a synaptic vesicle contained within the membrane. The pain signal is chemically transferred across the synaptic gap to chemical receptors on the post-synaptic nerve cell. This all happens in about 1/2000th of a second, as the synaptic gap is only 20 to 50 nmeter wide. As the pain signal, in chemical form, approaches the post- synaptic cell, the membrane changes and the signal is transferred. If we look at the voltages across the synaptic membrane then, under no pain conditions, the level is about -70 mV. When the pain signal approaches, the membrane potential increases to approximately +30 mV, allowing a sodium flow. This in turn triggers the synaptic vesicle to release the chemical transmitter and so transfer the pain signal across the synaptic gap or cleft. After the transmission, the voltage reduces back to its normal resting level until the next pain signal arrives. The application of pulsed magnetism to painful sites causes the membrane to be lowered to a hyperpolarization level of about -90 mV. When a pain signal is detected, the voltage must now be raised to a relatively higher level in order to fire the synaptic vesicles. Since the average change of potential required to reach the trigger voltage of nearly +30 mV is +100 mV, the required change is too
great and only +10 mV is attained. This voltage is generally too low to cause the synaptic vesicle to release the chemical transmitter and hence the pain signal is blocked. The most effective frequencies that have been observed from research in order to cause the above changes to membrane potentials, are a base frequency of 200Hz and pulse rate settings of between 5 and 25Hz.

**Figure 12. Normal Action Potential Voltage Levels**

Resolution of soft tissue injuries
Over the past few years, research has shown that its effectiveness is not through heat production - as is the case with some modern treatments - but is at the cellular level. One significant outcome of this is the effect it has on soft tissue injuries. As early as 1940 it was suggested that magnetic fields might influence membrane permeability. It has since been established that magnetic fields can influence ATP (Adenosine Tri-phosphate) production; increase the supply of oxygen and nutrients via the vascular system; improve the removal of waste via the lymphatic system; and help to re-balance the distribution of ions across the cell membrane. Healthy cells in tissue have a membrane potential difference between the inner and outer membrane. This causes a steady flow of ions through its pores. In a damaged cell the potential is raised and an increased sodium inflow occurs. As a result, interstitial fluid is attracted to the area, resulting in swelling and oedema.

The application of PMFT to damaged cells accelerates the re-establishment of normal potentials increasing the rate of healing and reducing swelling. This can help to disperse bruising also. A magnetic field pulsed at 5Hz with a base frequency of 50Hz can have the same effect as an ice pack in that in that it causes vasoconstriction.
Effects on fracture repair
Acceptance of magnetic fields in medicine came about foremost in the field of orthopaedics. Low frequency and low intensity fields have been used extensively for the treatment of non-union fractures. Magnetic fields influence the process of bone formation in the intercellular medium; bone healing is promoted by means of the influence of the magnetic field on the crystal formation of calcium salts.

A number of points have been established regarding PMFT:
(1) The field must be pulsed, with low frequency to achieve the best effect.
(2) Different conditions require different frequencies. For example, 5Hz causes vasoconstriction whilst 10Hz and above causes vasodilatation.
(3) Biological effectiveness is achieved in just 10 minutes for most injuries, so that long treatment sessions are not required.

How can pulsed magnetic therapy help in the repair of bone?
Bone is essentially calcium structure that contains trace elements. One particular element recently identified is Alpha Quartz. This is the same type of material, which is used in computers and digital or electronic watches. When this material is compressed, it develops a voltage across its two compressive faces, a phenomenon known as the piezoelectric effect. The old crystal pickups on record players used this effect to generate electrical sound signals. Gas appliances and some cigar lighters also utilise the same effect to generate a spark for ignition.

In bone, areas of stress generate small electric charges which are greater than those of less stressed areas, so that polarised bone-laying cells (osteoblasts) are believed to be attracted to these areas and begin to build up extra bone material to counter the stress. With bone injuries, bleeding occurs to form a haematoma in which capillaries quickly form, transporting enriched blood to the injury site.

Pulsed Magnetic Field therapy of a base frequency of 50Hz, pulsed at above 10Hz, causes vasodilatation and capillary dilation, so helping to speed up the process of callus formation. Within the bone itself, pulsed electromagnetism causes the induction of small eddy
currents in the trace elements, which in turn purify and strengthen the crystal structures. These have the same effect as the stress-induced voltages caused by the alpha quartz and as such, attract bone cells to the area under treatment. This can, therefore, accelerate the bone healing process to allow earlier mobilisation and eventual full union. Ligaments and tendons are affected in similar ways to solid bone by pulsed electromagnetic therapy, since they are uncalcified bone structures in themselves.

**PEMF influences oxygen levels within cells**
This can only be accomplished when the pulsing electromagnetic fields penetrate sufficiently deep within the body. The electrical influence and increase of the membrane cell potential, causes an increase in oxygenation, which in turn increase the supply of nutrients. This results in disposal of waste products from the cells and cell detoxification.

**Magnetic field therapy** is ideally suited for the treatment of many physical conditions and health maintenance. This modality is of great value because you may continue treatment over a long period of time if necessary. Pulsed electromagnetic field therapy can be used as the sole treatment in many cases but is often even better with other accepted modalities. Magnetic fields penetrate the body as if it was air. They are noninvasive and nontoxic, which makes them ideal for the gentle and gradual body rebalancing and healing. Magnetic fields work individually on the natural healing systems of the body but also work through the acupuncture systems. A whole body treatment with magnetic fields can be as strong as acupuncture in many cases. Magnetic fields, like other therapies, can help to rebalance the individual but full recovery is unlikely unless the cause of the problem is also managed.

**Therapeutic uses in animal physiotherapy**
In an ideal situation when treating any injury with PEMF you would aim for maximum usage. You will achieve optimum results if you can use the PEMF on the relevant settings for a minimum of 10 minutes every four hours. However unless the owner is prepared to rent a machine and treat the animal under your instruction every four hours,
this optimum regime will not be possible. Therefore you need to provide the maximum treatment possible in each individual case.

The soft tissue treatment times should be a minimum of 10 minutes. After this you reach a plateau and the levels will be maintained but will no longer increase. In orthopaedic treatments however the therapy is working to maximum efficiency from the time you turn it on until the time you turn it off, so the longer you can maintain the session the better.

![Image of horse with blanket]

**Figure 13. Electromagnetic field small blanket on a horse**

A 4-hour resting period is advised between sessions. In soft tissue this is how long it takes for the levels to return to normal. If you use PEMF again before this time you will simply raise the levels back up to maximum. In orthopaedics this allows bone, tendon or ligaments to rest. However it is not dangerous to apply treatment again before this time is up.
Chronic vs Acute
Before understanding PEMF settings you need to be able to differentiate between chronic and acute pain and the chronic and acute stages of injury.

An acute injury is an injury in the initial stage. Once you are into the repair stage (sub-acute) you are treating a chronic injury. When applying therapy to an injury in the acute stage (injury and inflammation) use settings of base 50Hz and pulse 5Hz. This will cause slight capillary constriction, slowing the bleeding and swelling. Once you are into the chronic stage (repair and remodelling) use a base of 50Hz and a pulse of 17.5 for soft tissue and constant for bone. This will start therapy to the area. The increase in capillary dilation will bring fresh blood and nutrients to the area to clear debris and optimise healing. If you apply PEMF at maximum vasodilation to an injury that is still in the inflammation stage (acute), the inflammation will increase. The body will only heal enough to achieve what is being asked of it. For example; a horse with sacrolilac injury could be turned out for a year and be perfectly sound and happy grazing and running around...
the field. However when he is bought back into work the injury has not healed enough to take the extra strain and the horse goes lame. Commonly, you will be asked to treat a **chronic injury** that has not healed. What is required of the physiotherapist is to kick start the body’s healing process and provide the optimum conditions for repair. To do this, start the appropriate treatment for the injury. This will initiate the healing process. It is likely that the injury will get worse before it gets better.

Treating pain is a separate issue. **Acute pain** is intense pain. The purpose of **acute pain** is a warning to stop doing whatever you are doing to cause damage to your body. For example; you burn yourself on the fire. The reaction that makes you jump away from the fire is the **acute pain** you feel. What follows is **chronic pain**. **Chronic pain** is the nagging burning pain you now feel as the site of injury reacts to what has happened. It is rare as a therapist that you get to an animal in true **acute pain**. However if it is still intensely painful you can treat it as **acute pain**. To do this you use a base setting of 200Hz and constant. This blocks pain to the full potential of the PEMF machine. If you are treating a **chronic** (nagging) pain, the same results have been achieved using a pulse of 5Hz. However each animal is an individual and you can adjust the pulse setting to the response of the animal. Treating pain can be very counter-productive. As already explained **acute pain** is a warning. If the pain is reduced the animal is likely to overuse the injured area and make it worse.
Figure 15. Electro magnetic leg applicator

**PEMF** has many uses in therapy. The pain setting is most useful to maintain comfort in conditions such as joint disease where the prognosis is poor. Lack of movement only proves to make the condition worse. If the animal is reluctant to move, many secondary problems occur, these are often more painful than the original condition. Sore muscles, muscle wastage and stiffness all contribute to the discomfort. This can go on to cause lack of appetite, depression and general deterioration. These conditions cannot be reversed but if the animal can be encouraged to use the joints to their full range of movement, the deterioration can be slowed down and quality of life can be improved. This animal could first be treated with PEMF on a setting of base 200Hz and constant, over the joints and affected tissue. The animal can then be stretched and encouraged to do some gentle exercise. The soft tissues can continue to be treated with base 50Hz and pulse 17.5. This will:

- Increase blood flow and clear fluid and toxins from the muscles.
• Improve the supply of blood and nutrients to the affected areas.
• Optimise the healing of tears, adhesions and bruising.
• Reduce the chance of further atrophy.

It has been noted by Physiotherapists using this equipment that care should be taken in introducing therapy to areas that have been deprived of fresh blood. Some animals show signs of discomfort thought to be similar to pins and needles. To do this, in initial treatments gradually increase the pulse settings through 5hz and 10Hz, using the animals’ reactions as a guide.

Treat all soft tissue injuries with base 50Hz pulse 17.5. Tendons and ligaments react best when treated as bone. They should be treated with base 50Hz and constant or pulse 25Hz where possible. However there are certain conditions where you would not use the orthopaedic setting and would stay at 17.5. These will be discussed in the section on contraindications. It is important to identify what you are treating. Usually it will be apparent that you are treating an “area” rather than a specific muscle, more than one muscle may be involved. If pain is found at the origin or insertion of a muscle it could be that the tendon is injured at the point of attachment. In this situation, you will achieve best results using base 50Hz and constant. At this setting you still have maximum vasodilation so the muscles will also be treated.

When introducing therapy to fracture sites the same care should be applied as with soft tissue. The optimum setting for fracture repair is base 50Hz and constant. However if initially applied at this level, in some animals the site will ache. Once again introduce the pulse settings gradually.

**PEMF** can help with neurological conditions. Animals suffer muscle atrophy as a result of damaged nerves. It is vital to keep the muscles working. It is recognised that maintaining muscle form increases the chances of nerve regeneration. In conditions where the nerves will not regenerate, quality of life can be improved by maintaining muscle form. This can slow down the deterioration of the animal and prolong his life. Applying **PEMF** at base 50Hz and pulse17.5 keeps the muscles enriched with fresh blood and nutrients. If the muscles have
already atrophied PEMF alone will not strengthen them, electro-stimulation and exercises will be needed.

There are a number of ways to apply PEMF. Hand held units are particularly useful for treating small animals but are also used to treat specific areas on large animals. Boots and wraps are available for applying therapy to the legs of large animals. Blankets can be laid over areas for treatment or attached to rugs. Rugs are available to treat the whole animal. However when treating a specific injury, best results are shown when the PEMF is concentrated on that area rather than over the whole body. The above appliances are the most used. Certain circumstances such as unusual injury sites or wild animals create the need for customised applicators. These can be made to meet any unusual requirements.

**Recommended settings and treatment times**

**Pain relief** – Treat for a minimum of 10 minutes, as many times as possible with 4 hours between sessions.

<table>
<thead>
<tr>
<th></th>
<th>Base setting</th>
<th>Pulse setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic</td>
<td>200Hz</td>
<td>5Hz</td>
</tr>
<tr>
<td>Acute</td>
<td>200Hz</td>
<td>C</td>
</tr>
</tbody>
</table>

**Soft tissue injuries** – Treat for a minimum of 10 minutes, as many times as possible with 4 hours between sessions. Continue treatment until desired effect is achieved.

<table>
<thead>
<tr>
<th></th>
<th>Base setting</th>
<th>Pulse setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capillary constriction (acute/initial stage of injury)</td>
<td>50Hz</td>
<td>5Hz</td>
</tr>
<tr>
<td>Disperse bruising</td>
<td>50Hz</td>
<td>17.5Hz</td>
</tr>
<tr>
<td>Reduce oedema</td>
<td>50Hz</td>
<td>17.5Hz</td>
</tr>
</tbody>
</table>
Orthopaedics – Treat for along as possible as many times as possible with 4 hours between sessions.

<table>
<thead>
<tr>
<th></th>
<th>Base setting</th>
<th>Pulse setting</th>
<th>Continue until</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal fracture</td>
<td>50Hz</td>
<td>C</td>
<td>Mobilisation.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>After mobilisation reduce to once a day until healed</td>
</tr>
<tr>
<td>Non union fracture</td>
<td>50Hz</td>
<td>C</td>
<td>Shows signs of uniting, then treat as normal fracture</td>
</tr>
<tr>
<td>Tendons and ligaments</td>
<td>50Hz</td>
<td>C</td>
<td>Until desired effect is achieved</td>
</tr>
</tbody>
</table>

**Warnings and Contraindications**

There are certain situations where the use of PEMF is not advised;

- PEMF must not be used if there is a chance of infection. Applying Magnetic field to an infected area provides bacteria with the perfect conditions for growth.
- It is advised not to use the orthopaedic settings where a laying down of bone would be counter-productive
- Do not use when pregnant
- Do not use if you have a pacemaker
Section 5
Ultrasound

Introduction to Ultrasound and Echolocation

Terminology
HERTZ is the number of sound waves per second.
KILOHERTZ is 1000 waves/second and is abbreviated KHz.
MEGAHERTZ (MHz) is one million waves/second.
ULTRASOUND is sound with a frequency too high for the human ear to hear (over 20 KHz).

What is ultrasound?
The use of soundwaves in order to “see”.

Sound transformed from wave, just like ripples with different sizes and densities. Different waves bring us sounds high and low. Human's hearing range is from 20 to 18000Hz. The higher the Hz is, the higher the tone we hear. Like the strings of violins, the thinnest one always pulls out the higher sound. Ultrasound is the sound that human beings cannot hear. In engineering, a rate over 20000Hz is called ultrasound, i.e. the threshold above 20000 vibrations per second. To human's hearing, ultrasound might mean nothing, while to many animals, it is heard clearly.

Echolocation is the ability of certain animals to produce pulses of sound (either audible or ultrasonic) and then to receive the returning echoes that are processed by the brain to give information about prey or obstacles.

Many animals are adapted to niches where vision is not a particularly useful sense. The best known animal echo-locator is the bat. There are more than 600 species of bats who use ultrasound in order to catch flying insects at night and to avoid obstacles. By rapidly vibrating their vocal cords they can emit short pulses of ultrasound at a frequency of up to 120KHz. These beams of ultrasound are beamed directionally into the darkness by means of the lips or noseflaps. If a moth happens to be flying by, the sound waves are reflected from its body and return to the bat’s ears as echoes. When his brain has processed this information, he knows the size of the
insect and its speed and direction and thus can swoop in on his prey in the darkness with great accuracy. Just as a bat “sees” in the dark by emitting pulses of soundwaves, so the sonographer (ultrasound technologist) can “see” inside the body by aiming high-frequency soundwaves, produced by a crystal with very special properties. There are however, a few differences. The frequencies used in medical ultrasound are much higher (from 1 to 5 MHz) whereas the maximum frequency for bats is 120 KHz. Another major difference is that the bat uses one organ to send sound (the vocal cords) and another to receive the echoes (the ears). In diagnostic ultrasonography the same crystal in the transducer both emits soundwaves and receives the returning echoes.

**Diagnostic Ultrasound**

**How ultrasound scans are made**

There are many advantages to imaging the body with ultrasound. Most importantly, there is no ionizing radiation as with X-rays, so that ultrasound is used safely. Furthermore, soft tissues, such as the liver, spleen, kidneys and pancreas can be imaged directly without the injection of any sort of radio-opaque substances or isotopes to make them visible.

**What are the drawbacks to ultrasound?**

Probably the most serious is the fact that sound is not able to travel through certain organs; their surfaces reflect almost 100% of soundwaves, so that the interiors of these organs and those lying directly beneath them cannot be imaged. Organs filled with air such as the lungs, stomach and intestines are opaque to sound, as are hard tissues such as bone.

**Ultrasound Therapy**

Ultrasound is simply high frequency sounds waves above the range that we can hear. It is applied to the body from the 'head' of an ultrasound machine. A gel is used to help the waves travel into the body rather than be reflected off the skin via any trapped air.

**What are the benefits of ultrasound therapy?**

1. Increased blood supply which promotes healing
2. Produces a pain killing effect that can reduce muscle spasm and promote normal function
(3) softens fibrous tissues and scar tissue which are formed during healing by increasing tissue extensibility

(4) Decreases inflammation

Ultrasound has both thermal and mechanical effects on tissues. The thermal effects increase tissue temperature, increasing the circulation, increasing collagen tissue extensibility, and increasing the metabolic rate of the tissues. The therapeutic mechanical affects are twofold: acoustic streaming and stable cavitation. Acoustic streaming causes a ‘micromassage’ of fluids and tissue, and leads to increased cell and vascular wall permeability. Stable cavitation causes bouncing of gas bubbles and changes cell activity. There is also a detrimental mechanical effect called unstable cavitation. This causes collapse of gas bubbles, leading to cell damage or death and blood vessel damage. This is avoided by using the appropriate intensity.

How is it used?

Gel is applied to the skin and the head of the ultrasound machine is placed on the skin. Usually it will be moved in circles. Treatment time can vary according to the injury but is usually a few minutes. Ultrasound can be applied in two modes, pulsed and continuous. With continuous the beam of ultrasound waves constantly on. This means that heat will be transferred to the body tissues. Pulsed means the waves go in short pulses which prevents the tissues heating. In general, therefore, for its therapeutic application, a pulsed ultrasound wave is preferred.
Figure 16. Application of ultrasound. Use large circles or strokes not small ones.

Physical Foundation of Ultrasound
The unit of the rate of ultrasound is Hertz and that of the intensity (the density of the output power) of ultrasound is Watt, while the action strength is W/cm², i.e. one unit of output intensity working on one square centimetre. We have to set for different intensities for different purposes, or else powerful ultrasound could hurt very much like a knife.

The frequency (rate) of ultrasound
The frequency of ultrasound means the number of vibrations that occur in a second and this is measured in Hertz. This determines the depth of penetration. 1MHz penetrates approximately 4-5cm; 3MHz penetrates approximately 1-2cm.

The intensity of ultrasound
The intensity of ultrasound is measured in Watts, while the action strength is W/cm², i.e. one unit of output intensity working on one square centimetre. For safe therapeutic use, the maximum intensity of continuous ultrasound is 1 W/cm² and the maximum pulsed waveform is 240m W/cm², which is far beyond the capability of a therapeutic ultrasound machine. Other applications of ultrasound require different intensity, for example ultrasound used to break up kidney stones is a continuous wave of W/cm² and ultrasonic cleaning equipment uses 10 to 100 W/cm². When therapeutic
applications are desirable, the intensity ranges from $<0.3$ W/cm$^2$ at the lower end, to 1.2-3W/cm$^2$ at the upper end. In general, use lower intensity over superficial tissues such as tendons, and higher intensity for deeper tissues such as deep muscle spasms.

**The transmission of ultrasound**

Ultrasound cannot transmit through air. If the treatment head does not have complete contact with the skin, the results will be poor. The proportion of ultrasound transmitted in the air is 0, about 50% in general water, 60% in distilled water, close to 70% in glue, and over 70% through special transmission gel. Ideally, to maximise the effectiveness of treatment, you would clip and clean the area to be treated before using ultrasound transmission gel. However, unless the area to be treated has recently had a surgical procedure (or a diagnostic ultrasound scan), it will not be clipped, and most owners will be reluctant to allow you to clip the area. Using water to wet the hair and copious amounts of ultrasound transmission gel will optimize your treatment under normal circumstances.
Therapeutic uses in animal physiotherapy
It is not advised to rent ultrasound machines out to clients, unlike PEMF. If used incorrectly there are potential dangers. Therefore ultrasound is usually used by the Physiotherapist as a one off treatment. However in some cases a course of treatment will be required.

Ultrasound is most commonly used for its effect on muscle spasm and localised muscle pain. Large and small animals with “sore backs” are treated usually 48 hours after the initial treatment of phototherapy or and massage. If the muscles are very sore this “rest period” serves to allow them to settle before further treatment. Immediate treatment of ultrasound could aggravate the area.

Figure 17. A horse with severely contracted tendons being treated with ultrasound
What is it used for?
- Soft tissue, tendon and ligament injuries
- Sore, tight and painful muscles
- Contracted tendons
- Scar tissue
- Increasing elasticity of muscles before stretching and breaking down adhesions

Contraindications
- Where a pacemaker is present
- In pregnancy and over the testicles
- Over cancerous lesions
- Thrombophlebitis
- Infection
- Over the spinal cord after a laminectomy
- Over unclosed growth plates
- Over the eyes

Use with caution
- Unhealed fractures
- Bony prominences
- Areas of decreased circulation or sensation
- Over plastic or metal implants

Recommended settings and treatment times.
Low frequency long-wave or pulsed (short-wave) ultrasound is used in therapy. The use of shortwave continuous ultrasound is not recommended. Further information on the use of therapeutic ultrasound will be included on your practical days.

Warnings and contraindications
- The use of shortwave continuous ultrasound is not recommended due to the increased chance of creating harmful cavitation effects
- Ensure that the treatment head is kept moving throughout treatment
- Do not use directly over the spine or bony areas
- Sometimes a high-pitched noise can be heard by the animal when the ultrasound passes close to a bone. This is not harmful but may be a surprise.
• Do not use in pregnant animals
Section 6
Electrostimulation

The use of electric current on the body largely has been used to facilitate the healing of musculoskeletal injuries and control pain. It is fairly arbitrarily applied in two broad categories:

* Macro-current Stimulation (currents over about 1 milliamp)
* Micro-current Stimulation (currents below about 1 milliamp)

The former usually refers to Faradic, Interferential, Galvanic and TENS (Transcutaneous Electrical Nerve Stimulation) devices. The latter refers to specialised micro-current devices for application either to the musculoskeletal system or as a non-invasive form of electroacupuncture via the acupuncture points of the body or the auricular points of the ears.

Electrostimulation
Electrostimulation has uses in clinical applications such as muscle rehabilitation, relief of muscular spasm, reduction of swelling and pain control. Electrostimulation usually involves feeding the muscles low current electrical impulses via moistened electrode pads placed firmly on the skin.

The effectiveness, comfort and depth of excitation depends on factors such as pulse shape, frequency, duration, intensity and modulation pattern.

The typical clinical machine supplies pulsating direct (galvanic) and/or alternating (faradic) current in the form of brief pulses. The frequency of faradic current is most commonly chosen in the range of about 50-100 Hz, while pulse duration (width) ranges from about 100 microseconds to several hundred milliseconds.

This brevity of pulse duration is important for minimising skin irritation and tissue damage. However, the duration at any particular intensity of faradic stimulation should not be too brief. Although they may be suitable for decreasing pain, pulses that are too brief will supply insufficient energy to cause full, tetanic muscle contraction.

Machines are designed to apply alternating currents directly at a preset or selected frequency (conventional faradism), or in the form of
low frequency currents superimposed on a medium frequency (2000 to 5000 Hz) carrier wave.

A variation of the latter method, using two pairs of electrodes each supplying medium frequency waves carrying low frequency waves differing slightly in frequency, forms the basis of what is called interferential stimulation.

A major advantage of using a higher frequency carrier wave is that impedance between the electrodes and skin is lowered, enhancing comfort and effectiveness.

**Macrocurrent Stimulation**

**TENS**

TENS is a method of electrical stimulation that primarily aims to provide a degree of pain relief (symptomatic) by specifically exciting sensory nerves. It can be used in several different ways, each being best suited to different pain relief mechanisms.

Success is not guaranteed with TENS, and the percentage of patients who obtain pain relief will vary, but would typically be in the region of 60%+ for acute pains and 40%+ for more chronic pains.

The technique is non-invasive and has few side effects when compared with drug therapy. The most common complaint is an allergic type skin reaction and this is almost always due to the material of the electrodes, the conductive gel or the tape employed to hold the electrodes in place.

**Machine parameters:**

The current intensity (strength) will typically be in the range of 0 - 80 mA (milli Amps), though some machines may provide outputs up to 100mA.

The machine will deliver ‘pulses’ of electrical energy, and the rate of delivery of these pulses (the pulse frequency) will normally be variable from about 1 or 2 pulses per second (pps) up to 200 or 250 pps. In addition to the stimulation rate, the duration (or width) of each pulse may be varied from about 40 to 250 micro-seconds (μs). (a micro second is a millionth of a second).
In addition, most modern machines will offer a BURST mode in which the pulses will be allowed out in bursts or ‘trains’, usually at a rate of 2 - 3 bursts per second. Finally, a modulation mode may be available which employs a method of making the pulse output less regular and therefore minimising the accommodation effects that are often encountered with this type of stimulation.

The reason that such short duration pulses can be used to achieve these effects is that the targets are the sensory nerves which tend to have relatively low thresholds (i.e. they are quite easy to excite) and that they will respond to a rapid change of electrical state. There is generally no need to apply a prolonged pulse in order to force the nerve to depolarise, therefore stimulation for less than a millisecond is sufficient.

Some machines offer a dual channel output - i.e. two pairs of electrodes can be stimulated simultaneously. In some circumstances this can be a distinct advantage.

The most commonly used electrodes are of carbon silicone which are coated with a conductive gel prior to attachment to the skin. There are several other electrode types available now (including the metal mesh with solid conductive gel, which are self adhesive and have become more popular as the price has dropped over the last couple of years).

The pulses delivered by TENS stimulators vary between manufacturers, but tend to be asymmetrical **biphasic modified square wave pulses**.

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\[ \text{\includegraphics[width=0.5\textwidth]{biphasic.png}} \]
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The biphasic nature of the pulse means that there is usually no net DC component, thus minimising any skin reactions due to the build up of electrolytes under the electrodes.
Mechanism of Action:
The type of stimulation delivered by the TENS unit aims to excite different elements of the sensory nerve system, and by so doing, activate specific natural pain relief mechanisms; the Pain Gate Mechanism and the Endogenous Opioid System.

Electrode placement:
Target the stimulus at the appropriate spinal cord level (appropriate to the pain). Usually start with the electrodes either side of the lesion. Can use other stimulation points so long as the electrical stimulation activates the sensory nerves that enter the cord at the same neurological level. One can therefore employ nerve roots, the course of the appropriate peripheral nerve, motor points, trigger/acupuncture points, the same dermatome, myotome or scelerotome.

If the pain source is vague, diffuse or particularly extensive, one can employ both channels simultaneously, and some authorities use a cross over technique in an attempt to increase the intensity of the stimulation.

Applications of Macrocurrent Stimulation
1. Increase in muscle strength
2. Re-education of muscle action
3. Facilitation of muscle contraction in dysfunctional or unused muscle
4. Increase of muscular and general endurance
5. Increase in speed of muscle contraction
6. Increase in local blood supply
7. Provision of massage
8. Relief of pain
9. Reduction of muscle spasm
10. Promotion of relaxation and recuperation
11. Increase in range of movement
12. Reduction of swelling
13. Reduction of musculoskeletal abnormalities
14. Preferential recruitment of specific muscle groups
15. Acute increase in strength
16. Improvement in metabolic efficiency
Micro current Stimulation
The Emergence of Microcurrent Stimulation
Clinical experience has revealed that electric currents as much as 1000 times smaller than that of all the traditional physical therapy modalities can be far more successful than the latter in achieving many of the benefits outlined in the previous section.

Currents as low as 10 microamps (millionths of an amp) pulsating at between 0.1 to 400Hz are too weak to cause muscle contraction, block pain signals or cause local heating, yet their effectiveness and safety is often superior in many applications to that of faradism, interfaerentialism and conventional TENS.

Cellular and subcellular processes not involving cell discharge, propagate electrical impulses, or muscle contraction, appear to be involved with cellular growth and repair. Electric currents can stimulate the flow of ions along the blood vessels and through the cell membranes that constitute the body's closed electric circuits. A cell involved in the inflammatory process demonstrates a reduced cell membrane potential & consequently, the cell function is disturbed. The altered potential affects ion transport across the membrane, & the resulting ionic imbalance alters cellular osmotic pressures. It is suggested that the main clinical effects of this are pain & oedema (probably indirectly).

Electrochemical information transfer across cell membranes can also be affected. Here, the function of a cell at any instant is determined by feedback between DNA in the cell nucleus and a macromolecule inducer liberated from the membrane by means of a protein (enzyme) regulator derived from messenger RNA activity within the cell. The activity of these membrane-bound proteins is strongly modulated by changes in the concentration of divalent ions (such as calcium Ca++) absorbed on the membrane. ES may elicit these ionic changes and thereby modify cell function.

Microcurrent stimulation (MICS - currents below one milliamp) elicits biochemical changes associated with enhanced adaptation, growth and repair. Since MICS appears to operate more on the basis of resonant attainment of the stimulus to cellular and subcellular processes, the specific therapeutic effects are determined by how efficiently the stimulation parameters match the electrical
characteristic of the different cells, in particular, their impedance at different frequencies. MICS may be applied in several ways to facilitate restoration:

- locally over specific soft tissues
- transcranially via electrodes on the earlobes or on sites on the surface of the skull
- at acupuncture points on the body, hands or ears.

It is generally entirely safe to apply MICS anywhere on the body, because the current and energy transmitted is too low to produce any thermal or electrolytic effects on vital tissues. Under no circumstances should MACS be applied across the brain, as it can cause serious harm.

Neuromuscular electrical nerve stimulation (NMES)

NMES causes excitation of nerve cells which innervate muscle fibres. The goal is to elicit muscle contraction. NMES is used to preserve or recover muscle mass in cases of weakness or atrophy, in pain management, to treat swelling, and in muscle spasm. Contraindications are where there is infection, in animals with seizure disorders, in some skin conditions, over tumours, and in the pregnant animal.

The electrodes may be placed over muscle motor points, acupuncture points, over the course of a nerve (proximal to distal), or in a ‘surround and drown’ manner for pain management. In a surround and drown configuration, the electrodes are placed surrounding the painful area (for example, around the stifle joint following cruciate ligament repair). The use of NMES will be covered in your machine practical days.

**Therapeutic uses in animal physiotherapy**

In the early days of Animal Physiotherapy electrostimulation was used more frequently than it is today. This is due to the development of other modalities. The application of PEMF and ultrasound is easier, cleaner and less time consuming than that of electrostimulation machines, so electrostimulation may be used less frequency in your day-to-day practice.

**Recommended treatment times**

Care should be taken to introduce treatment gradually. Depending on the level of atrophy, treatments should be started in short, gentle
bursts twice a day. This can eventually be increased to up to 2 hours twice daily. Treating an animal for this length of time is not very practical and is not always necessary. By following an exercise programme, alongside sessions of electrostimulation, treatment times can be kept to a more practical length.

Warnings and contraindications
- Care must be taken to introduce therapy slowly to avoid stressing the muscle
- Muscle strains should be settled before treatment
- Occasionally animals will object to the sensation of the electrostimulation
Section 7
Massage equipment

Massage equipment is useful to rent out to clients as a means to continue treatment in the periods between visits. The massage equipment available can be divided into two categories; cycloidal and percussion. The lower priced massage equipment available on the high street has a percussion action, similar to a knocking effect. This only works very superficially and on sore tense muscles this can be counter-productive, causing bruising and inflammation.

The higher priced machines available provide a cycloidal massage. This works much deeper into tissues and has a much more beneficial effect.

Figure 18. Equissage massage pad
The Equissage is a massage pad. This is attached to the horse in the saddle area. Used for 20 minutes it increases blood flow and warms muscles. This is an excellent machine to recommend for horses who are always very stiff or who suffer from conditions such as azotouria.

Equissage also market a hand unit that can be useful for treating small animals. Small animals can usually be effectively massaged by hand, but this does provide a less tiring option.
Section 8
Other applications

Static magnets
Despite the lack of scientific explanation, static magnets do appear to have a very beneficial effect. They have been used for years, and in the absence of a placebo effect, have produced some amazing results. A magnetic field can be detected on a gauss meter, but only when the magnets are moved. Application of magnets increases the temperature in the target tissue. This may contribute to the effect on the body.

Static magnets can be used to:
- Help the reduction of splints and boney lumps. Applied with a little pressure the lump will elongate and reduce in size.
- Increase blood flow to muscles, reducing pain and spasm.
- Increase blood flow to joints, reducing pain associated with joint disease.
- Increase blood flow to tendons and ligaments to aid repair.
- Reduce synovial swellings. Used with a little pressure over the joint, the swelling can be reduced.
- Reduce general aches and pains.

Warnings and contraindications
- Magnets should not be used when pregnant.
- Magnets should not be used where an infection is present or suspected.
- Due to the heating effect underneath the magnet and the increase in blood flow, sweating may occur. It is advised that the target area and the magnet are wiped and allowed to dry to avoid rubbing. This should be done every twelve hours or more often if required.

Heat therapy and cold therapy (cryotherapy)
Heat and ice are the two most common types of passive, non-invasive, and non-addictive therapies. Heat and cold can be used alternatively and are often used as a prelude to exercise therapy.
Heat Therapy
Heat therapy induces vasodilation: drawing blood into the target tissues. Increased blood flow delivers needed oxygen and nutrients, and removes cell waste. The warmth decreases muscle spasm, relaxes tense muscles, relieves pain, and can increase range of movement. It increases metabolic activity in the cells, producing more demand for local oxygen delivery. Heat neutralises trigger points, which are nodules of tender muscle that can be a source of pain, by increasing local circulation so the irritated muscle spindle at the heart of the trigger point can relax and causes relaxation of muscle fibres. Pain is caused by muscle spasm, connective tissue ischaemia and shortened fascia putting pressure on nerves; heat can address all of these causes and stimulates tissue repair. Heat reduces joint stiffness by decreasing synovial fluid thickness and the increasing the stretch of surrounding connective tissue. Heat also causes a reflex pain-inhibiting effect by increasing the temperature of the sensory nerves. The message of heat travels to the brain, where its recognition blocks out the pain message, raising the threshold of sensory nerve endings and leading to longer term pain relief.

"Horse Hotties" are available to warm up an area before exercise. These are heated in the microwave. These are particularly useful for horses who get tense and who always have a ‘sore area’. Advise the owners to put over the area whilst they are getting the horse ready (for about 20 minutes). Hot packs are freely available commercially and can be very useful in treating muscle spasm and pain in small animals as well, placing the hot pack over the sore area for 10-15 minutes, 4 times a day can be hugely beneficial in terms of pain relief, as well as allowing the owner to have an active role in the treatment program.

Cold Therapy (Cryotherapy)
Cold therapy constricts capillaries at the site of application, reducing local tissue metabolism. This leads to lower levels of chemical mediators of inflammation being released from tissues, and slower pain message transmission, leading to less ‘pain information’ reaching the brain. Cold therapy helps to prevent swelling by reducing the production of histamine. The combination of cold and compression will restrict blood and fluid leaking from damaged tissues (for example following surgery), minimising oedema and its damaging effects. Cold therapy can be very useful in swollen, painful areas for example following a surgical procedure or in chronic arthritic conditions to
reduce inflammation and the pain associated with inflammation. Again, cold packs are available commercially (eg. Kool Pack) and owners can be advised to use 10 minutes of cold therapy every 4 hours throughout the day for post-operative cases or those with painful, swollen joints.

Owners can also be advised to alternate hot and cold pads to an area before massaging. This is especially good for over exuberant dogs with bad backs as a consequence. Hot and cold treatment and massage given by the owner can help to keep the animal comfortable between visits. Five minutes of hot, followed by five minutes of cold, followed by another five minutes of hot will prepare the area for massage.

**Water wellies**

Water wellies are Jacuzzi boots for horses. These provide hydrotherapy to the legs to increase circulation, helping to heal a number of complaints. They are also a good alternative to the original form of ‘tubbing’. Water wellies are very successful in providing therapy but are rather ‘messy’ to use. Care must also be taken in introducing horses to the boots as some will object. More modern (but expensive) solution is the Game Ready or Zamar units, which produce compression and cold therapy without the need for water, eliminating the mess but hugely increasing the cost. Some commercial yards will have one or the other of these units which can be extremely useful for swellings and prevention and treatment of limb injuries.

These are more useful to hire out or advise clients to buy, rather than to use yourself.