Common Exam Questions

1. Motion in a Circle

Radian	• angle subtended at centre of circle • by arc equal in length to the radius
Angular speed	• angle swept out per unit time / rate of change of angle • [by the string]

2. Gravitational Field

Gravitational field	(region of space) where a mass experiences a force
Line of force in gravitational field	(tangent to line gives) direction of force on a (small test) mass

3. Oscillations (s.h.m.)

Damping	• Continuous/gradual loss of energy from the system • due to a force which always opposes motion.
s.h.m	• Acceleration proportional to displacement (from a fixed point) • and directed towards a fixed point

Describe one situation where resonance is useful, and where it should be avoided.

- useful: e.g. child on swing, microwave oven heating
- avoid: e.g. vibrating panels, vibrating bridges

4. Electric Field

Electric field strength	force per unit positive charge
Electric potential at a point	work done moving unit positive charge infinity to the point
Line of force in electric field	(tangent to line gives) direction of force on a (small test) positive charge

State similarities of definitions of electric potential and gravitational potential at a point.

- ratio of work done to mass/charge
- work done moving unit mass/charge from infinity
- both have zero potential at infinity

State similarity and difference between gravitational force field and electric force filed around a sphere.

- Similarity:
    - e.g. radial fields
    - lines normal to surface
    - greater separation of lines with increased distance from sphere

- $field\ strength \propto \frac{1}{(distance\ to\ centre\ of\ sphere)^2}$

- Difference:
  - e.g. gravitational force (always) towards sphere
  - electric force direction depends on sign of charge on sphere / towards or away from sphere
  - gravitational field/force is attractive
  - electric field/force is attractive or repulsive

Explain why values of gravitational potential are always negative whereas values of electric potential may be positive or negative.

- gravitational forces are (always attractive)
- electric forces can be attractive or repulsive
- for gravitational, work got out as masses come together/mass moves from infinity
- for electric, work done on charges if same sign, work got out if opposite sign as charges come together

State the relationship between electric field strength E and potential V.

- field strength = potential gradient
- $E = -\frac{\Delta V}{\Delta x}$ *or* electric field is in direction of decreasing potential field

5. Capacitance

Capacitance	Q/V, with symbols explained

Functions of capacitors in electrical circuits

- e.g. storing energy
- separating charge
- blocking d.c.
- producing electrical oscillations
- tuning circuits
- smoothing
- preventing sparks
- timing circuits

Briefly explain how a capacitor stores charges energy.

- on a capacitor, there is charge separation/there are + and - charges
- *either* to separate charges, work must be done
- *or* energy released when charges 'come together'

7. Electromagnetism

8. Electromagnetic Induction

Faraday's law of electromagnetic induction	• (Induced) e.m.f./voltage is proportional/equal to • rate of change of (magnetic) flux (linkage)
Magnetic flux density	• (numerically equal to) force per unit length • on straight conductor carrying unit current • normal to the field
Tesla	• (long) straight conductor carrying current of 1 A • current/wire normal to magnetic field • (for flux density 1 T,) force per unit length is 1 Nm^{-1}

Explain why eddy currents are induced in a metal disc swinging between poles of magnet.

- field in disc is not uniform/rate of cutting not same/speed of disc not same (over whole disc)
- so different e.m.f.'s in different parts of disc
- lead to eddy currents

Use energy principles to explain why the disc comes to rest after a few oscillations.

- eddy currents dissipate thermal energy in disc
- energy derived from oscillation of disc
- energy of disc depends on amplitude of oscillations

9. Alternating Current

R.m.s. value of a.c. (in terms of heating effect)	• the (value of the) direct current that dissipates (heat) energy • at the same rate (in a resistor)

10. Temperature

Adv of thermocouple thermometer > resistance thermometer

- small thermal capacity/measure Δθ of small object /short response time
- readings taken at a point/physically small
- can be used to measure temperature difference
- no power supply required

11. Thermal Properties of Matter

Specific latent heat of fusion	• (thermal) energy/heat required to convert unit mass of • solid to liquid with no change in temperature

Use the kinetic theory of matter to explain why melting required energy but there is no change in temperature.

- (on melting,) bonds between molecules are broken/weakened *or* molecules further apart/are able to slide over one another
- kinetic energy unchanged so no temperature change
- potential energy increased/changed so energy required

12. Ideal Gas

$<c^2>$	Mean square speed of atoms/particles/molecules
Ideal gas	Gas that obeys the law $\frac{pV}{T}$ = constant at all values of p, V and T

Explain qualitatively how molecular movement causes the pressure exerted by a gas.

- molecule(s) rebound from wall of vessel / hits walls
- change in momentum gives rise to impulse / force
- either (many impulses) averaged to give constant force / pressure
- or the molecules are in random motion

13. Charged Particles

State a fundamental property of charge that was suggested by Millikan oil-drop experiment.

- charge is quantised / discrete quantities

Explain why the path of proton in a magnetic field is an arc of a circle.

- force on proton is normal to velocity and field
- provides centripetal force (for circular motion)

14. Quantum Physics

Photon	• Quantum/packet of energy • of electromagnetic radiation/energy
Work function at the metal surface	• energy of photon to cause emission of electron from surface • with zero k.e
De Broglie wavelength	• wavelength of wave associated with a particle • that is moving

Explain why most electrons are emitted with E_K less than maximum in photoelectric effect.

- max. k.e. corresponds to electron emitted from surface
- energy is required to bring electron to surface

15. Nuclear Physics

Decay constant	Probability of decay per unit time
Binding energy of a nucleus	Energy required to completely separate the nucleons in a nucleus

16. Direct Sensing

State three characteristics of an ideal operational amplifier (op-amp).

- infinite (voltage) gain
- infinite input impedance
- zero output impedance
- infinite bandwidth
- infinite slew rate

17. Remote Sensing

17.1 X-ray

Sharpness	ease with which edges of structures can be seen
Contrast	difference in blackening between structures

Outline the principles of production of X-rays in an X-ray tube. The detailed structure and operation of an X-ray tube are not required.

* Electrons are emitted by thermionic emission at the hot metal filament (cathode) and are accelerated to high speeds towards the metal (anode) target.
* When high speed electrons bombard/hit the metal target, they are decelerated greatly and gives off e.m. radiation (in the x-ray region).
* The wide range of deceleration (Bremsstrahlung radiation) gives a continuous spectrum with a short cut-off wavelength.
* Some electrons in the target atoms are excited and the de-excitation of these electrons gives rise to a line spectrum / characteristic peaks.

Explain the principles behind the use of X-rays for imaging body structures.

* The x-ray beam (from the x-ray) tube is directed through the body onto a photographic film/detector plate (placed behind the body).
* As the x-ray beam passes through the body, different tissues absorb/attenuate the beam by different amounts e.g. bone absorbs or attenuates x-rays much more than soft tissues/fats.
* This produces 'shadow' image of the internal structures.
* The sharpness of image can be improved by decreasing the area of the target anode / the size of the aperture / placing a lead grid in front of the photographic film/detector to absorb the scattered x-ray photons.
* The contrast of the image can be improved by using a contrast medium (e.g. barium sulphate) which absorbs x-rays strongly.

Principles of CT scanning

* The machine (x-ray source and detector) rotates around the patient's body.
* A series of x-ray images of a slice through the body is taken from different angles.
* Then the data of each individual x-ray image and angle of viewing is entered into a powerful computer which combines the images into an image of a slice through the structure.
* The patient is moved slightly forward so an image of another slice is made. This is repeated for many slices.
* The images of a series of slices are combined to build or form a complete 3D image of the whole object which can then be rotated or viewed from any angle.
* A powerful computer is needed to store, process and combine the huge quantity of data.

Describe how the image produced during CT scanning differs from that produced by X-ray imaging.

- X-ray image is flat OR 2-dimensional
- CT scan takes many images of a slice at different angles
- these build up an image of a slice through the body
- series of images of slices is made
- so that 3D image can be built up

17.3 Ultrasound

Acoustic impedance	product of density (of medium) and speed of sound (in medium)

Briefly explain the principles of the generation of ultrasound.

* When a potential difference is applied across the silver-coated sides of a piezoelectric crystal e.g. quartz, it causes the crystal to change shape.
* So when an alternating voltage is applied, it causes the crystal to vibrate.
* When the frequency of the applied alternating voltage matches the natural vibration frequency of the crystal, resonance occurs and the crystal produces an intense sound wave.
* Frequency at which the crystal will resonate can be tuned by selecting its thickness. Dimensions of the crystal are chosen such that it vibrates at frequencies greater than 20kHz, hence producing ultrasonic waves.

Explain briefly the use of ultrasound to obtain diagnostic information about internal body structures.

* Short pulses of ultrasound are produced and transmitted into the body (via a coupling medium i.e. a water-based jelly/gel).
* These pulses are partly reflected and refracted at boundaries between media in the body.
* The reflected pulses are detected by the piezoelectric crystal and transformed into voltage pulses which are amplified, processed and displayed on an oscilloscope screen.
* The time interval/delay (between transmission and reception) of pulse gives information about the depth of the boundary while the intensity of the reflected pulse gives information about the nature of the boundary.

Adv of using ultrasound of frequency 1MHz instead of 100 kHz.

- wavelength at 1 MHz is shorter
- so greater detail is possible

Suggest and explain why ultrasound probe is made up of a number of crystals.

- crystals are at different orientations
- signals from all crystals are combined
- to build up a (2D) image

Explain why acoustic impedance is important when considering reflection of ultrasound at the boundary between two media.

- difference in acoustic impedance
- determines fraction of incident intensity that is reflected/amount of reflection

17.4 MRI

Outline briefly the use of magnetic resonance to obtain diagnostic information about internal body structures.

- When a large/strong uniform magnetic field is applied, all the hydrogen nuclei in the body are aligned and precess about the direction of the field.
- When a radio frequency pulse (r.f. pulse) at Larmour frequency is applied, it causes resonance in the nuclei.
- When the applied r.f. pulse ends, on relaxation, the nuclei de-excite and emit r.f. pulse which is detected by the coil and then sent to the computer to be processed.
- A non-uniform field that is superimposed on the large uniform magnetic field allows the position for the nuclei to be determined and the location of detection to be changed.

Adv of MRI > X-ray

- e.g. cost, portability of equipment, time taken

18. Telecommunications

18.1 Modulation (AM & FM)

Frequency modulation (FM)	• frequency of carrier wave varies (in synchrony) with information signal • constant amplitude *or* carrier frequency >> signal frequency • change in frequency measures displacement of information signal • rate at which carrier frequency varies gives frequency of information signal
Amplitude modulation (AM)	• amplitude of the carrier wave varies • in synchrony with the displacement of the information signal
Modulation	• variations in either amplitude or frequency of a wave

	• in synchrony with displacement of information signal

Adv and disadv of FM > AM

- ✓ Adv: better quality/less interference
- × Disadv: more transmitters/more expensive

Why is cost of FM broadcasting to an area is greater than that of AM broadcasting?

- e.g. more radio stations required / shorter range
- more complex electronics
- larger bandwidth required

Why are modulated carrier waves used rather than direct transmission of electromagnetic waves having audio frequency?

- Less attenuation
- Less distortion
- Lower transmission power
- Longer transmission range
- Allow >1 station in a region
- Shorter aerial required.

18.2 Digital transmission

Outline briefly the principles involved in the analogue-to-digital conversion of the signal and its transmission.

- signal sampled at regular intervals
- signal voltage converted to a digital number
- transmitted as a series of groups of pulses
- pulses could be IR pulses in optic fibre (allow any sensible example)
- any other relevant physics (e.g. sample at twice max frequency, use parallel to series converter)

Adv of transmission of data in digital form.

- e.g. can be regenerated to remove noise
- data can be added to check for/correct errors

Effects on society of the change to the transmission of signals in digital form, rather than analogue.

- E.g. digital more reliable than analogue
- fewer people employed in telephone industry
- greater multiplexing means reduced cost per call
- reduced costs means available to more people
- huge expansion international calls
- huge expansion of non-voice communications

- development/expansion of internet
- introduction of multichannel cable TV companies

Suggest two ways in which the reproduction of the original analogue signal could be improved.

- sample more frequently
- greater number of bits

18.3 Channel of communication

Fibre-optic transmission of a signal	• signal is in the form of a series of pulses of light/IR • pulses pass along a glass fibre • as a result of total internal reflection

Technological and social adv of fibre-optic transmission compared to metal cable transmission

- Tech: e.g. greater bandwidth, less noise, less power loss per unit length
- Social: e.g. increased security, cheaper, less bulky

Adv of co-axial cables or optic fibres over wire pair.

- e.g. greater bandwidth, less noise, less attenuation

Purpose of copper braid in co-axial cable and how the purpose is achieved

- electromagnetic shielding for the inner conductor
- the braid is earthed

Why does increased bandwidth lead to a reduction in cost of telephone calls?

- increased bandwidth means more information can be carried
- so more calls can be transmitted simultaneously
- fewer links are required

Example of use of wire pair in communication system.

- E.g. link between house and exchange for a telephone

18.4 Satellites

Describe the orbit of a geostationary satellite.

- period (or orbit) is 24 hours
- equatorial (orbit)
- (satellite orbits) from west to east
- Remain at one point above the Earth

Suggest why the frequency of transmission from the satellite is different from that received by the satellite from Earth.

- prevent swamping of the (low power) signal received from Earth

Adv and disadv of the use of geostationary satellites when compared with polar-orbiting satellites for telephone communication.

- ✓ e.g. fewer satellites required
- ✓ aerials point is fixed direction/no tracking required
- × e.g. noticeable time delay in messages
- × reception difficult at Poles

Suggest one adv of launching satellite from the Equator in the direction of rotation of the Earth.

- e.g. satellite will already have some speed in the correct direction

18.5 Signal Attenuation

Attenuation	loss of energy/power (in the signal)
Noise	unwanted (random) signal
Cross-talk	picking up of signal in one cable from a second (nearby) cable

Sources of attenuation and noise in metal cables

- Attenuation: thermal energy (in the cable) / resistance
- Noise: e.g. molecular/lattice vibrations, pick-up of e.m. signals, cross-talk/cross-linking

18.6 Mobile network

Explain how reception of signals to and from the mobile phone is maintained during a phone call whilst moving through several different cells.

- computer at cellular exchange
- monitors signal strength
- switches call from one base station to another
- to maintain maximum signal strength

Outline what happens at the base station and the cellular exchange when a mobile phone handset is switched on, before a call is made.

- handset sends out an (identifying) signal
- communicated by base stations to (computer at) exchange
- computer selects base station with strongest signal
- and allocates a (carrier) frequency

Suggest and explain why a country is divided into a number of cells.

- carrier frequencies can be re-used (simultaneously without interference)
- so that number of handsets possible is increased