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ANSWER BOOK

Biological measurement

Medical physics · Year 13

AQA 3.10.3.1

17 questions · 51 marks

NAVY EDITION

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SECTION A · Warm-up

A1 The resting potential is the potential difference held across the cell membrane by the unequal distribution of ions, about 90 mV with the inside negative (1). During an action potential ions cross the membrane, the p.d. briefly reverses (depolarisation) and is then restored (repolarisation) (1). [2]

A2 The P wave is the depolarisation of the atria, which then contract (1). The QRS complex is the depolarisation of the ventricles, which then contract (1). [2]

A3 The T wave is the repolarisation of the ventricles as they recover and relax (1). It is broader and lower because repolarisation is slower than depolarisation and less well synchronised across the muscle, so the same recovery is spread over more time (1). [2]

A4 One R to R interval is one beat, so the rate is 60/T (1) = 60/0.60 = **100** beats per minute (1). [2]

A5 Any two of: high gain, because the signal at the skin is only about a millivolt and must reach a volt or so to be displayed; high input impedance, so that the large resistance of the skin contact does not take most of the signal; low noise, so that the 50 Hz mains interference picked up by the patient does not swamp the trace (2). [2]

A6 About 1 mV (1). That is why the amplifier is the central component of the machine. [1]

SECTION B · Standard

B1 A wave of depolarisation sweeps across the heart muscle, so at any instant part of the heart is depolarised and part is not (1). That leaves a separation of charge with a size and a direction, so the heart behaves as an electric dipole which grows, turns and shrinks through the beat (1). The body fluids conduct, so this dipole sets up small potential differences across the torso, and two electrodes on the skin measure the p.d. between the points they touch (1). [3]

B2 The electrode and the skin beneath it form a contact of considerable resistance, tens of kilohms even with gel (1). The contact and the amplifier input act as a potential divider across the source of the signal (1). If the amplifier input resistance were comparable with the contact resistance it would draw current and most of the signal would be dropped across the contact instead of reaching the amplifier, so the input impedance must be very much the larger of the two (1). [3]

B3 Gain = output/input = 2.4/(1.2 × 10^{-3}) (1) = **2000** (1). The largest input is 5.0/2000 = 2.5 × 10^{-3} V = **2.5** mV (1). Beyond that the output would be clipped flat and the shape of the trace lost. [3]

B4 The P wave is the atria depolarising and the QRS complex is the ventricles depolarising (1). The ventricles carry far more muscle than the atria, so far more charge moves at once and the p.d. produced at the skin is several times larger (1). The atria repolarise while the ventricles are depolarising, so their much smaller signal is buried underneath the QRS complex (1). [3]

B5 Time = distance/speed = 20/25 (1) = **0.80** s (1). Rate = 60/0.80 = **75** beats per minute (1). [3]

B6 The signal that has just depolarised the atria is delayed on its way to the ventricles (1). During the delay the atria are contracting and emptying into the ventricles, so the ventricles fill before they are told to contract (1). Very little muscle is depolarising during that time, so there is almost no changing separation of charge and the trace stays close to the baseline (1). [3]

B7 Dry skin makes a poor contact of high resistance, and the gel lowers that resistance so that more of the signal reaches the amplifier (1). It also keeps the contact steady, so movement of the patient produces less drift on the trace (1). Several electrodes allow the p.d. to be measured between different pairs, and so the heart's dipole to be viewed from several directions rather than only one (1). [3]

SECTION C · Stretch

C1 Cardiac muscle cells hold a resting potential across their membranes, and a wave of depolarisation sweeps across the heart, reversing that p.d. cell by cell (1). At any instant part of the heart is depolarised and part is not, so the heart acts as an electric dipole whose size and direction change through the beat (1). The conducting body fluids carry potential differences of about 1 mV to the skin, where electrodes with conducting gel pick them up (1). A differential amplifier of high gain raises the signal to a usable size, while its high input impedance stops the skin contact resistance from swallowing it (1). The amplifier responds to the difference between the electrodes and rejects what they both receive, chiefly 50 Hz mains hum, and filtering removes the rest (1). The amplified signal is plotted against time on a screen or on moving paper, giving the P wave, QRS complex and T wave of one beat (1). [6]

C2 Intervals: 0.78 s, 0.70 s and 0.75 s (1). Mean interval = (2.95 - 0.72)/3 = 0.743 s (1). Mean rate = 60/0.743 = **81** beats per minute (2). The three intervals differ by at most 0.08 s, a spread of about 10 per cent, so the rhythm is regular within the accuracy of reading the trace (1). [5]

C3 Mains cables around the room produce alternating electric and magnetic fields at 50 Hz, and the patient and the leads act as an aerial that picks them up (1). The interference is comparable with or larger than the millivolt signal being measured, so it would otherwise dominate the trace (1). It arrives at every electrode almost equally, while the wanted signal is a difference between two electrodes, so an amplifier that amplifies only the difference between its inputs and ignores what is common to both rejects the hum (1). Screened leads and a filter tuned to remove what is left complete the job (1). [4]

C4 An ECG plots potential difference at the skin against time, and that p.d. comes from the wave of depolarisation crossing the muscle, not from any movement (1). The electrical event is the cause rather than the record: each chamber contracts shortly after it has depolarised, so the mechanical action follows the trace rather than appearing on it (1). A normal trace has the P wave, QRS complex and T wave present and in that order, with the QRS much the largest and the T wave broader and lower (1), the intervals within their usual ranges and the beats evenly spaced (1). [4]