Speed of light in a vacuum	$c = 3.0 \times 10^{8}\ \text{ms}^{-1}$
Planck constant	$h = 4.1 \times 10^{-15} = 6.6 \times 10^{-34}\ \text{Js}$
Acceleration due to gravity	$g = 9.8\ \text{m s}^{-2}$

SECTION A – Answer SIX parts of this section

1.1) List five distinct types of joints found in the human body and indicate where each may be found.

[7 marks]

1.2) Sketch the relationship between oxygen pressure and the percentage haemoglobin saturated with oxygen. How is this relationship affected by the pressure of carbon dioxide present? Give two other factors which might affect this relationship.

[7 marks]

1.3) In relation to exposure of the human body to electricity, what is meant by (a) macro-shock and (b) micro-shock. What is the minimum magnitude of mains-frequency current necessary to produce ventricular fibrillation if the voltage is applied (i) percutaneously and (ii) directly?

[7 marks]

1.4) List three examples, with typical magnitudes, of electrical signals which may be obtained from the human body. Describe the components of a typical measurement system for one of these.

[7 marks]

1.5) A beam of ultrasound is incident perpendicularly on a planar interface between two tissues, and the intensity of the reflected beam is measured to be 6 dB less than that of the incident beam. What is the ratio of the characteristic acoustic impedances of the two tissues?

[7 marks]

1.6) A radionuclide has a decay constant of $7.2 \times 10^{-3}\ \text{hr}^{-1}$. How many atoms of the substance are required to produce an activity of 2×10^{4} Bq ?

[7 marks]

1.7) List the methods used in a medical environment to control external radiation hazards both to patients and to occupationally-exposed persons.

[7 marks]

1.8) The minimum wavelength of the x-rays emitted from a radiographic device is 0.0124 nanometres. At what kVp is the device being operated?

[7 marks]

SEE NEXT PAGE

SECTION B – Answer ONE question

2) What part of the body is most at risk from injury during lifting? With the aid of a diagram derive an expression for the tension in the back muscles and the reaction force on the lower lumbar vertebrae when lifting a weight with the back bent forward. (Assume that the mass of the head and neck, thorax and arms, and weight lifted can be represented as three single masses concentrated at their centres of mass).

[20 marks]

If an adult lifts 100 kg with his back bent at an angle of 40° to the vertical, calculate the reaction force on the lower lumbar vertebrae. (You may assume typical values for the masses of the head, trunk and arms and relevant body dimensions).

[10 marks]

3) Describe, with the aid of simple diagrams, the essential features of the circulatory system of the human body.

[15 marks]

The heart is driven by an electrical signal. With the aid of diagrams describe how the signal is generated and propagated. In your answer, include the name of the signal, its principal features and its magnitude measured at the skin.

[15 marks]

SEE NEXT PAGE

SECTION C – Answer ONE question

4) (a) Sketch a typical spectrum of the x-rays emitted by a diagnostic imaging device. Briefly discuss the physical mechanisms that affect the shape of the spectrum.

[10 marks]

(b) With the aid of a sketch, describe the design of a portable scintillation counter for radiation monitoring. Give two benefits of using NaI as the scintillator.

[12 marks]

(c) An x-ray machine is operated at 100 kVp. It is found that the exposure rate at 100 cm from the tube is 27.2 mR/min. What is the exposure suffered by a person who spends 20 minutes in the beam, at a distance of 3 m from the tube?
The half-value layer of aluminium for this x-ray beam is 12 mm. What is its linear attenuation coefficient?
What thickness of aluminium shielding is needed to reduce the dose rate at a distance of 1 m to 3.4 mR/min?

[8 marks]

5) (a) List five important characteristics of the propagation and interaction of ultrasound waves in human soft tissues, and indicate one way in which each feature is exploited in medical applications.

[10 marks]

(b) Explain the following terms used in medical ultrasound and state, where appropriate, the units employed for their measurement: (i) characteristic acoustic impedance; (ii) amplitude transmission coefficient; (iii) longitudinal wave.

[6 marks]

(c) Derive an expression for the effective half-life of a radioactive substance in the body, in terms of its physical and biological half-lives.
If the biological half-life of the material is known to be 6 hrs, and its effective half-life is measured to be 180 minutes, what is its physical half-life ?

[6 marks]

(d) 16×10^4 Bq of a radioactive pharmaceutical, with physical half-life 6 hours, is injected into a patient's blood-stream at 11.00 a.m. The next day, at 2.00 p.m., a blood sample is taken, and is found to have an activity of 14 Bq per 10 ml. Estimate the patient's blood volume, stating the approximations made in order to arrive at your result.

[8 marks]

FINAL PAGE