Q24 Describe the PHYSICAL PRINCIPLES that are involved in the flow of blood through a dialysis circuit, and, in the movement of solutes across a dialysis membrane. (March 2011)

Physical principles related to blood flow:

Resistance = $8nL/\pi r^4$ where n = viscosity, π = 3.14, r = radius and L = length
Flow = pressure change/resistance
Therefore, laminar flow through a tube = $\Delta P \pi r4/8nl$ (Poisuelle's equation)

Limitations of this concept:

- Blood vessels are elastic and contractile rather than fixed, rigid tubes
- Blood flow is often turbulent rather than laminar. The semi-rigid tubing utilized in dialysis circuits helps to maintain laminar flow through the circuit.
- Poisuelle's law relates to constant flow, while blood flow is pulsatile
- Blood is not a Newtonian fluid and is often heterogeneous, with varying viscosity. Viscosity is an intrinsic property of fluid related to the friction caused by adjacent layers of fluid sliding over one another

In a dialysis circuit, blood travels from the patient to a dialysis machine where it passes through a dialyser, allowing movement of fluid and plasma solutes across the membrane in either direction.

Fluid removal occurs via two main mechanisms:

- Osmosis: movement of water across a semipermeable membrane from a area of low concentration to an area of high concentration
- Hydrostatic forces: movement of water from an area of high hydrostatic pressure to an area of low hydrostatic pressure

Solute removal occurs via three main mechanisms:

- Diffusion: movement from an area of high concentration to an area of low solute concentration. Factors affecting the rate of diffusion include: temperature, molecule size, membrane thickness and permeability, membrane surface area, concentration gradient
- Convection: solute drag where the movement of water based on hydrostatic pressures 'pulls' large solutes along
- Adsorption: where large molecules (cytokines, coagulation factors) adhere to the membrane

The concentration gradient is developed by using dialysate fluid with low concentration of solutes that are usually cleared by the kidney (eg; Na, K, PO_4, urea, creatinine), in order to create a steep concentration gradient to encourage movement of these solutes from the blood to the dialysate. The movement of blood and dialysate in different directions ensures this concentration gradient does not reach equilibrium and reduce further solute exchange.