Examination Questions I

1 **(a)** length, temperature, current, also amount of substance or luminous intensity

(b) **(i)** F: kg m s^{-2}; ρ: kg m^{-3}; v: m s^{-1}

(ii) Equating units on both sides of the equation:

kg m s^{-2} = m^2 × kg m^{-3} × (m s^{-1})^k

equating the powers of m, 1 = 2 − 3 + k

or using powers of s, -2 = -k

Thus k = 2

2 **(a)** **(i)** volume of fuel used = $\frac{210}{14}$ = 15 litres

volume remaining = 60 − 15 = 45 litres

(ii) from the 'full' mark to the '¾' mark

(b) **(i)** The graph does not go through the origin (0,0). There is an intercept on the volume axis.

(ii) When the meter shows empty (0), there is still some fuel in the tank as a 'reserve' and so the car can travel further

3 **(a)** a frequency in the range 20 Hz to 20 kHz

(b) a wavelength between 10 nm and 400 nm

(c) a mass between 10 g and 100 g

(d) a density of about 1 kg m^{-3}, any value between about 0.2 kg m^{-3} and 5 kg m^{-3}

4 **(a)** **(i)** $Q = It$

(ii) the current I and the time t

(b) **(i)** base unit of I is A

base unit of n is m^{-3}

base unit of S is m^2

base unit of q is A s

base unit of v is m s^{-1}

(ii) The equation in terms of base units is:

$A = m^{-3} \times m^{2} \times A\ s \times (m\ s^{-1})^{k}$
the power of the base unit for m gives: 0 = -3 + 2 + k
the power of the base unit for s gives: 0 = 1 − k
k = 1

Examination Questions II

1 **(a)** The moment of a force is the product of the force and the *perpendicular* distance of the force to the point about which the moment is taken
A couple is a pair of equal and opposite forces that produce rotation only and the torque of the couple is one of the forces × the *perpendicular* distance between the two forces

(b) **(i)** Taking moments about the pivot:
W × 4.8 = (2.5 × 72) + (12 × 84)
W = 248 N (= 250 N to 2 sig. fig.)
(ii) The weights would need only a very small movement if 25 N is hung from the hook; it is difficult to measure the small distance or notice the deviation of the rod from the horizontal. There may also be friction at the pivot which means that an extra 25 N on the hook does not cause the rod to move from the horizontal.

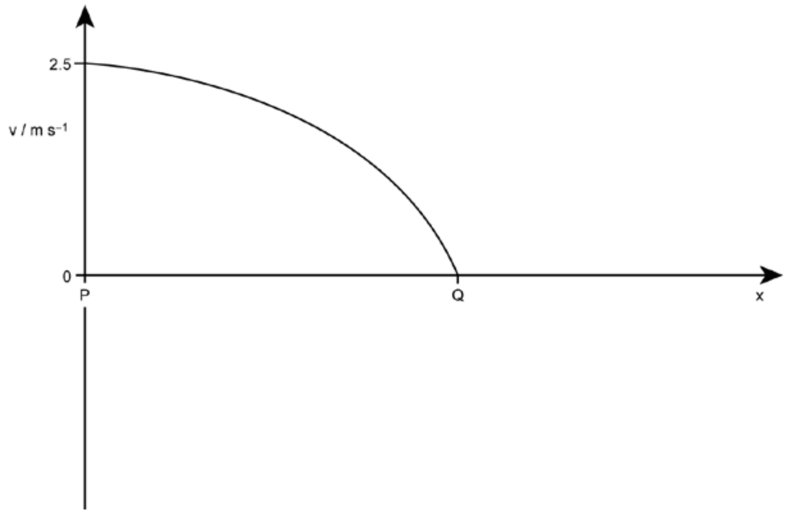
Examination Questions III

1 **(a)** Work is the product of a force and the distance moved in the direction of the force

(b) kinetic energy = $\frac{1}{2} mv^2 = \frac{1}{2} \times 0.4 \times (2.5)^2 = 1.25$ J
(= 1.3 J to 2 sig. fig.)

(c) **(i)** area under graph = work done = $\frac{1}{2} Fx$
$1.25 = 0.5 \times (14x)$
$x = 0.179$ m (= 0.18 m to 2 sig. fig.)

(ii)



2 **(a)** **(i)** Acceleration is the rate of change of velocity or the velocity change per unit time

(ii) A body continues in its state of rest or uniform motion in a straight line unless acted on by a resultant external force

(b) **(i)** distance = the area under graph = ½ × 29.5 × 3 = 44.3 m (= 44 m to 2 sig. fig.)

(ii) At A (the start) the frictional force = 0 and the resultant force is the weight of the parachutist. The frictional force increases with the speed of the parachutist and since the resultant force = weight of parachutist − frictional force, the resultant force decreases. At C (the end) the weight = frictional force and the resultant is zero.

(iii) **1.** The frictional force increases since the parachute opens

2. The frictional force is constant and then decreases from D to E

(iv) **1.** acceleration = $\frac{v-u}{t} = \frac{20-50}{17-15}$ = -15 m s^{-2}

2. weight of parachutist = 95 × 9.81 = 932

weight − frictional force = *ma*

frictional force = (95 × 15) + 932 = 2360 N

(= 2400 N to 2 sig. fig.)

3 **(a)** **(i)** m^3 (metres cubed)

(ii) Pressure = $\frac{\text{force}}{\text{area}}$

the units of force are N or kg m s^{-2}

so base units of pressure = $\frac{\text{kg m s}^{-2}}{\text{m}^2}$ = kg m^{-1} s^{-2}

(b) Rearranging formula $C = \frac{\pi P r^4 t}{8lV}$

Base units of C = $\frac{\text{kg m}^{-1}\text{ s}^{-2} \times \text{m}^4 \times \text{s}}{\text{m} \times \text{m}^3}$ = kg m^{-1} s^{-1}

4 **(a)** **(i)** horizontal component of velocity = 15 cos 60° = 7.5 m s^{-1}
(ii) vertical component of velocity = 15 sin 60° = 13 m s^{-1}

(b) **(i)** Using $v^2 = u^2 + 2as$ vertically from S to P with final vertical velocity zero
$s = \frac{13^2}{2 \times 9.81}$ = 8.61 m (= 8.6 to 2 sig. fig.)
(ii) Using $v = u + at$ vertically,
$t = \frac{13}{9.81}$ = 1.325 s (= 1.33 s to 3 sig. fig.)
(iii) Ball takes approximately 1.33 s to go from P to F at a constant horizontal velocity
velocity = $\frac{6.15}{1.33}$ = 4.62 m s^{-1}

(c) **(i)** change in momentum = 60 × 10^{-3} × (7.5 − (-4.6))
= 0.726 N s (= 0.73 N s to 2 sig. fig.)
(ii) The collision is inelastic because the kinetic energy is less after the collision than it was before. Kinetic energy = ½ MV^2, Mass is the same after the collision, while velocity has decreased. Therefore kinetic energy is lower.

5 **(a)** Gravitational potential energy is the energy stored when a mass is moved and work is done against a gravitational field. Electrical potential energy is the energy stored when a charge is moved and work is done against the force provided by an electric field.

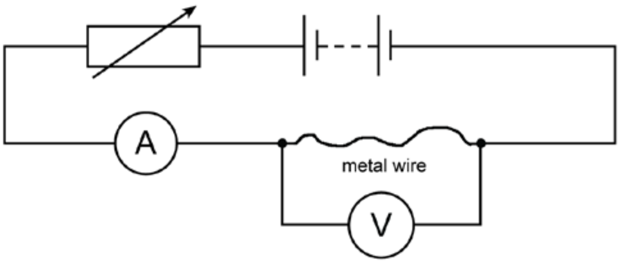
(b) P.E. change = work done on mass
= force × distance moved in direction of force
and force = weight of mass = *mg*
So P.E. change = *mgh*

(c) **(i)** K.E. of water with mass m = ½ mv^2 = 0.1 × mgh
0.5 × v^2 = 0.1 × 9.81 × 120
v = 15.3 m s^{-1}
(ii) In 1 s 110 kJ of energy are produced and the energy input is $\frac{110}{0.25}$ kJ.
If m is the mass of water flowing per sec,
$\frac{1}{2}mv^2 = \frac{110 \times 10^3}{0.25}$
$m = \frac{2 \times 110 \times 10^3}{0.25 \times 15.3^2}$ = 3759 kg s^{-1} (= 3760 kg s^{-1} to 3 sig. fig.)

Examination Questions IV

1 **(a)** The resistance of a component is the ratio of the potential difference across it to the current in it, or the potential difference per unit current
(resistance = $\frac{\text{potential difference}}{\text{current}}$)

(b) **(i)** A variable resistor in series with a variable voltage power supply, or a potential divider arrangement, and an ammeter and the wire. Voltmeter in parallel with the metal wire. (See diagram.)



(ii) **1.** There is an intercept on the current axis, when the p.d. is zero, the current is not zero
2. The readings are sometimes above and sometimes below the best fit line

(iii) Taking into account the zero error, a value of 0.05 A can be subtracted from each current reading,
e.g. at 4.0 V the current is 0.23 − 0.05 = 0.18 A.
$R = \frac{V}{I} = \frac{4.0}{0.18}$ = 22.2 Ω

(c) $R = \frac{6.8}{0.64}$ = 10.625
% uncertainty in R = % uncertainty in V + % uncertainty in I
$= \frac{0.1}{6.8} \times 100 + \frac{0.01}{0.64} \times 100$ = 1.47 + 1.56 = 3.0%
absolute uncertainty in R, ΔR = 0.030 × 10.625 = 0.318 Ω
R = 10.6 ± 0.3 Ω

2 **(a)** Pressure is the normal force acting per unit area;
pressure = $\frac{\text{force}}{\text{area}}$

(b) A force acts on any surface because molecules collide with the surface and rebound. The collision and rebound cause a change in momentum of the molecules and thus a force on the molecules. An equal and opposite force acts on the surface.
At the top of a mountain there are fewer molecules per unit volume and the temperature is lower. This means that the molecules move slower and hit the surface less often, with a smaller rate of change in momentum and less force and pressure.

(c) **(i)** density $\rho = \frac{m}{V}$
mass of liquid $m = \rho V$ = 0.45 × 0.250 ×13600
weight = mg = 0.45 × 0.250 ×13600 × 9.81 = 15009.3 N
(= 15000 N to 2 sig. fig.)
(ii) pressure = $\frac{F}{A} = \frac{15000}{0.45}$ = 3.33×10^4 Pa
(= 3.3×10^4 Pa to 2 sig. fig.)
(iii) The pressure acting on the base of the container also includes the pressure of the air which acts on the surface of the liquid

3 **(a)** The mass has no acceleration. This is because there is no resultant force or torque on the mass as the force acting upwards on the mass caused by the spring is equal to the weight of the mass acting downwards.

(b) **(i)** at either 0.2 s, 0.6 s or 1.0 s
(ii) at either 0 or 0.8 s
(iii) at either 0.2 s, 0.6 s or 1.0 s

(c) **(i)** Hooke's law is obeyed because the graph is a straight line that would pass through the origin if the origin was taken to be at l=20cm with mass = zero. Thus the extension of the spring is proportional to the force applied.
(ii) Force constant = $\frac{\text{force}}{\text{extension}}$ = gradient of graph
$k = \frac{0.4 \times 9.81}{35 \times 10^{-2} - 20 \times 10^{-2}}$ = 26.16 N m^{-1}
(= 26 N m^{-1} to 2 sig. fig.)
(iii) Energy stored can be calculated using the area under the graph
$= 0.5\ x\ (0.40\ x\ 9.81)\ x\ (35 - 20)\ x\ 10^{-2} = 0.2943$ J
(= 0.29 J to 2 sig. fig.)

Examination Questions V

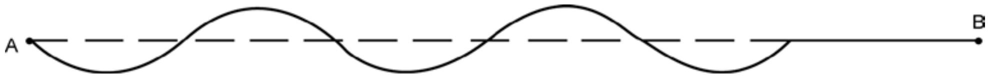
1 **(a)** **(i)** The displacement of a point on the rope is the distance of the point from the equilibrium, or from the original rest position

(ii) **1.** amplitude = $\frac{80}{4}$ = 20 mm

2. $f = \frac{1}{T} = \frac{1}{0.2}$ = 5.0 (Hz)

$v = f\lambda$ = 5.0 × 1.5 = 7.5 m s^{-1}

(b)



(c) **(i)** The wave is progressive as the energy and the peaks move to the right

(ii) The wave is transverse as the particles on the rope move up and down perpendicular to the direction of travel of the wave itself

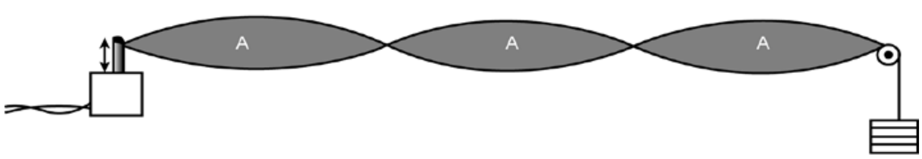
2 **(a)** **(i)** The frequency of a progressive wave is the number of oscillations per unit time of a point in the wave

(ii) The speed of a progressive wave is the distance travelled per second by a wavefront

(b) **(i)** A stationary wave is formed by two progressive waves of the same frequency travelling in opposite directions. There is no net transfer of energy along the wave.

(ii) A point on a stationary wave where the amplitude is a maximum

(iii)



(c) wavelength λ = 2 × 17.8 = 35.6 (cm)

$v = f\lambda$ = 125 × 0.356 = 44.5 (m s^{-1})

$m = \frac{T}{v^2} = \frac{4}{44.5^2}$ = 2.02 × 10^{-3} kg m^{-1}

3 **(a)** Diffraction is the bending or spreading of a wave when it passes through a small aperture or as it passes around a corner or the edge of an object.

(b) **(i)** The apparatus should show, in words or by a diagram, either:

- a source of light and a slit, e.g. a laser and a slit or a point source of light and a slit with a screen to observe the diffraction
- the source of a water wave, e.g. an oscillating bar in a ripple tank and a slit, and a lamp or stroboscope to project the waves on a screen
- a microwave source, a slit and an aerial or probe connected to a receiver to detect the microwaves
- Diffraction is observed as light or the water wave is seen or the microwave signal is detected in what should be the shadow region outside the slit

(ii) Sound is a longitudinal wave. The apparatus to demonstrate diffraction of sound, e.g. a loudspeaker and a slit made from two wooden boards placed close together with a microphone and cathode ray oscilloscope (c.r.o.) placed to detect sound on the other side of the slit to the loudspeaker. Diffraction is observed when the microphone is placed in what should be a quiet region where no sound can come in a straight line from the loudspeaker to the microphone, yet the c.r.o. trace shows a sound signal.

4 **(a)** **(i)** The waves from the two slits are coherent if there is a constant phase difference between the two waves

(ii) The path difference at P_1 between the waves from the two slits is λ, 2λ, 3λ, etc. This means the waves arriving at P_1 have a phase difference of 360°, 720°, etc. and are in phase. They thus interfere constructively at this point.

(iii) The path difference at P_2 is $\frac{\lambda}{2}$, $\frac{3\lambda}{2}$, $\frac{5\lambda}{2}$, $\frac{7\lambda}{2}$, etc. The waves arriving at P_2 are out of phase (by an odd multiple of 180°) and destructively interfere, cancelling each other out at this point.

(iv) width of fringe, $w = \frac{\lambda D}{a} = \frac{630 \times 10^{-9} \times 1.5}{0.45 \times 10^{-3}} = 2.1 \times 10^{-3}$ m

(b) The position of the pattern does not change, with both dark and bright fringes in the same positions as before. The bright fringes are brighter, more intense and the dark fringes are still completely black, showing no light.

Examination Questions VI

1 **(a)** The p.d. between two points is the energy transformed (from electrical to other forms of energy) in moving a unit positive charge between the points or the work done in transferring a unit positive charge between two points

(b) **(i)** $R = \frac{\rho l}{A} = \frac{18 \times 10^{-9} \times 75}{2.5 \times 10^{-6}} = 0.54\ \Omega$

(ii) $I = \frac{V}{R} = \frac{240}{38 + 2 \times 0.54} = 6.14$ A (= 6.1 A to 2 sig. fig.)

(iii) $P = I^2R = (6.14)^2 \times (2 \times 0.54) = 40.7$ W
(= 41 W to 2 sig. fig.)

(c) The cross-sectional area of the wires is less and their resistance is greater (since resistance $\propto \frac{1}{A}$).
The current in the wires is slightly less but as resistance is five times larger or the p.d. across the wires is much larger, the power loss in the cables increases.

2 **(a)** current = $\frac{\text{power}}{\text{voltage}} = \frac{10500}{230} = 45.7$ A

(b) **(i)** p.d. across cable = 5.0 V
$R = \frac{V}{I} = \frac{230-225}{46} = 0.109\ \Omega$ (= 0.11 Ω to 2 sig. fig.)

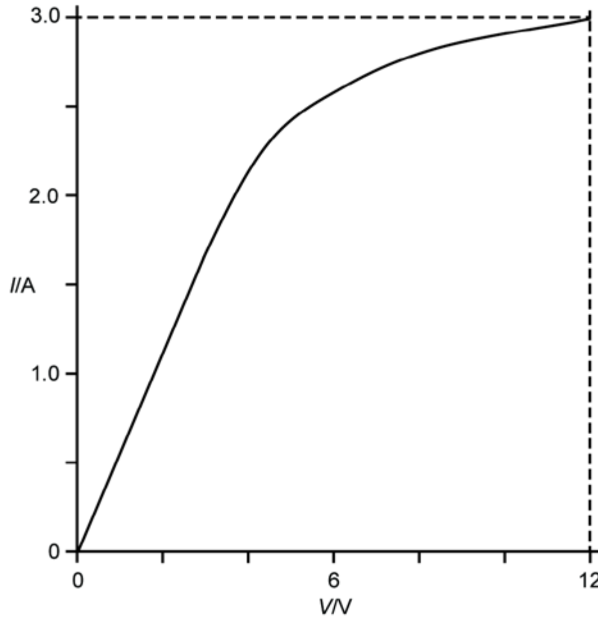
(ii) $R = \frac{\rho l}{A}$
$A = \frac{\rho l}{R} = \frac{1.8 \times 10^{-8} \times 2 \times 16}{0.109} = 5.28 \times 10^{-6}\ \text{m}^2$
(= $5.3 \times 10^{-6}\ \text{m}^2$ to 2 sig. fig.)

(c) **(i)** Power = $\frac{V^2}{R}$ so ratio = $\frac{210^2}{230^2} = 0.834$ (= 0.83 to 2 sig. fig.)

(ii) As the cables have greater resistance, there is more power loss (and the possibility of the cable becoming too hot and the insulation melting)

3 **(a)** **(i)** $P = \frac{V^2}{R}$
$R = \frac{V^2}{P} = \frac{12^2}{36} = 4.0\ \Omega$

(ii)



(b) **(i)** 2.0 kW

(ii) Power = VI and as the resistance of the two heaters in series is twice as large, the current is half and the power $= \frac{1.0}{2}$ = 0.50 kW

(iii) The total resistance $= \frac{3R}{2}$

$P = \frac{V^2}{R} = 1.0 \times \frac{2}{3}$ = 0.67 kW

4 **(a)** **(i)** The sum of the e.m.f.'s around any complete or closed loop in a circuit is equal to the sum of the p.d.'s around the loop

(ii) energy

(b) **(i)** 2.0 = I × (4.0 + 2.5 + 0.5) I = 0.286 A (= 0.29 A to 2 sig. fig.)

(ii) $R_{XJ} = 4 \times \frac{90}{100}$ = 3.6 (Ω)

$V = IR_{XJ}$ = 0.286 × 3.6 = 1.03 V (= 1.0 V to 2 sig. fig.)

(iii) E = 1.03 V (or 1.0 V to 2 sig. fig.)

(iv) There is no current in cell B and thus no p.d. across the resistor r

Examination Questions VII

1 **(a)** **(i)** The direction of the electric fields is the same (or they are both uniform or they both have a constant electric field strength)

(ii) Reduce the p.d. across the plates or increase the separation of the plates

(iii)

- β particles have the opposite charge to α particles (negative rather than positive) and are deflected in the opposite direction
- β particles have less mass than α particles so the deflection is more for the same field strength
- β particles have a range of velocities and are deflected at different angles

(b) W = 234; X = 90; Y = 4; Z = 2

(c) A = 32; B = 16; C = 0; D = -1

2 **(a)** The nucleus at the centre of the atom contains 92 protons and 143 neutrons. There are 92 electrons in orbit around the nucleus.

(b) **(i)** α particles can be absorbed by substances in its path. α-particles only travel a few cm (about 6 cm) in air and so may not reach the detector if air is present.

(ii) Large reading when D is near X as most α-particles pass through the metal with no or small deflections. Most pass straight through because most of an atom is empty space. There is a small but not a zero reading when D is near Y or W, since a small proportion of the α-particles are deflected backwards at large angles as they pass through an atom. This is because most of the mass of the atom is concentrated in a very small volume, the nucleus which is charged positive and repels the α-particles.

(c) $Q = It = 1.5 \times 10^{-12}$

number of particles $= \frac{1.5 \times 10^{-12}}{2 \times 1.6 \times 10^{-19}} = 4.69 \times 10^{6}\ \text{s}^{-1}$

$(= 4.7 \times 10^{6}\ \text{s}^{-1}$ to 2 sig. fig.)

Examination Questions VIII

1 **(a)** The work done in bringing a unit mass from infinity to the point

(b) At infinity the gravitational potential is zero. Gravitational force attracts two masses. Thus as a unit mass moves from infinity to a point work is done by the gravitational force. Hence, the gravitational potential energy at that point is lower.

(c) Force on mass = *mg* (where *g* is the gravitational field strength)
$g = \frac{GM}{r^2}$ and if *h* is small then *r* = *h* + radius of planet changes very little. Thus *g* is constant and ΔE_P = force × distance moved = *mgh*
alternatively,
$\Delta E_P = m\Delta\phi = GMm\left(\frac{1}{r_2} - \frac{1}{r_1}\right) = \frac{GMm\Delta r}{r_1 r_2}$
$\Delta r = h$ and $r_1 \approx r_2 \approx r$, Since $GM = gr^2$, $\Delta E_P = mgh$

(d) $m\Delta\phi = \frac{1}{2}mv^2$
$v^2 = 2 \times \frac{GM}{r} = \frac{2 \times 4.3 \times 10^{13}}{3.4 \times 10^6}$
$v = 5.03 \times 10^3$ m s^{-1} (= 5.0×10^3 m s^{-1} to 2 sig. fig.)

2 **(a)** **(i)** The radian is the angle subtended at the centre of a circle by an arc of length equal to the radius of the circle
(ii) The angular speed of the mass is the angle swept out per unit time by the string (= $\frac{\text{change in angle}}{\text{time taken}}$)

(b) The centripetal force is provided by the frictional force *F*
$F = 0.72\,W = 0.72\,mg = md\omega^2$
$\omega^2 = \frac{0.72 \times 9.81}{0.35}$
$\omega = 4.49$ rad s^{-1}
number of revolutions per minute = $60 \times \frac{\omega}{2\pi}$ = 42.9 min^{-1}
(= 43 min^{-1} to 2 sig. fig.)

(c) Mud flies off at the edge first because the centripetal force needed for any given angular speed increases as radius *r* increases since $F = mr\omega^2$

3 **(a)** A gravitational field exists in a region if a mass experiences a force

(b) **(i)** Two point masses attract each other with a force that is directly proportional to the product of the two masses and inversely proportional to the square of their separation
(ii) gravitational field strength $g = \frac{GM}{R^2}$
required ratio $= \left(\frac{7.78 \times 10^{11}}{1.5 \times 10^{11}}\right)^2$ = 26.9

(c) **(i)** gravitational force = centripetal force

$\frac{GMm}{R^2} = mR\omega^2$ or $\frac{mv^2}{R}$

$\omega^2 = \frac{GM}{R^3} = \left(\frac{2\pi}{T}\right)^2$ or $v^2 = \frac{GMm}{R} = \left(\frac{2\pi R}{T}\right)^2$

$M = \frac{4\pi^2 R^3}{GT^2}$

(ii) $M = \frac{4\pi^2 \times (1.5 \times 10^{11})^3}{6.67 \times 10^{-11} \times (3.16 \times 10^7)^2} = 2.00 \times 10^{30}$ kg

4 **(a)** Two point masses attract each other with a force that is directly proportional to the product of the two masses and inversely proportional to the square of their separation

(b) **(i)** Geostationary orbit is the orbit of a satellite around the equator with a period of 24 hours. The satellite rotates in the same direction as the Earth and stays over the same point on the equator

(ii) gravitational force on satellite = centripetal force

$\frac{GMm}{x^2} = mx\omega^2$

At the Earth's surface $g = \frac{GM}{R^2}$ or $GM = gR^2$

So $gR^2 = x^3\omega^2$

(iii) $\omega = \frac{2\pi}{24 \times 3600} = 7.27 \times 10^{-5}$ (rad s^{-1})

$x^3 = \frac{9.81 \times (6.4 \times 10^6)^2}{(7.27 \times 10^{-5})^2} = 7.60 \times 10^{24}$

$x = 4.24 \times 10^7$ m (= 4.2×10^7 m to 2 sig. fig.)

5 **(a)** gravitational force on moon = centripetal force

$\frac{GMm}{r^2} = mr\omega^2$

$r^3\omega^2 = GM$

Since GM is a constant so is $r^3\omega^2$

(b) **(i)** **1.** Phobos, $\omega = \frac{2\pi}{7.65 \times 3600} = 2.281 \times 10^{-4}$ (rad s^{-1})

$M = \frac{r^3\omega^2}{G} = \frac{(9.39 \times 10^6)^3 \times (2.281 \times 10^{-4})^2}{6.67 \times 10^{-11}} = 6.46 \times 10^{23}$ kg

2. Deimos $\omega^2 = \frac{GM}{r^3} = \frac{6.67 \times 10^{-11} \times 6.46 \times 10^{23}}{(1.99 \times 10^7)^3}$

$\omega = 7.39 \times 10^{-5}$ (rad s^{-1})

$T = \frac{2\pi}{\omega} = \frac{2\pi}{7.39 \times 10^{-5}} = 8.49 \times 10^4$ s = 23.6 hours

(ii) The orbit of Deimos is almost geostationary. When viewed from Mars it almost appears stationary, moving slowly across the sky compared to Phobos

Examination Questions IX

1 **(a)** **(i)** The molecules move at random with constant velocity until they hit the walls of the container or the molecule collides with another molecule

(ii) The volume of the molecules themselves is negligible compared to the volume of the container

(b) If the components of velocity in the other two directions are c_y and c_z.

$c^2 = c_x^2 + c_y^2 + c_z^2$

on average, since the molecules move at random and there is no preferred direction, $\langle c_x^2 \rangle = \langle c_y^2 \rangle = \langle c_z^2 \rangle = \frac{1}{3} \langle c^2 \rangle$

so $pV = \frac{1}{3}Nm\langle c^2 \rangle$

(c) K.E. = $\frac{1}{2}m\langle c^2 \rangle$ is proportional to absolute temperature

the temperatures are 300 K and 373 K

$\langle c^2 \rangle = 520^2 \times \frac{373}{300}$

$c_{rms} = 580 \text{ m s}^{-1}$

2 **(a)** Specific latent heat of fusion is the energy required to change unit mass of a substance from solid to liquid, without any change in temperature

(b) **(i)** Thermal energy (heat) is gained by the ice from the atmosphere. This can be taken account of by measuring the mass of water with the heater switched off.

(ii) The same mass of water is collected in the same time period, e.g. 5 minutes

(iii) Mass of ice melted by heater in 5 minutes

= 64.7 − ½ × 16.6 = 56.4 (g)

$L = \frac{E}{m} = \frac{18}{56.4 \times 10^{-3}}$ = 319 kJ kg^{-1} (= 320 kJ kg^{-1} to 2 sig. fig.)

3 **(a)** **(i)** Internal energy is the sum of the random distribution of potential energy and kinetic energy of the atoms/molecules in a substance

(ii) In an ideal gas there are no forces between the molecules, (except repulsion during collision) and so there is no potential energy. The internal energy is thus only the kinetic energy of random motion of the molecules.

(b) Kinetic energy is proportional to the absolute or thermodynamic temperature. The temperature in kelvin goes from 273 K to 373 K. It does not double so the student is incorrect.

4 **(a)** A gas that obeys the equation *pV* = constant × *T* or *pV* = *nRT* for a fixed mass of gas, where *p* is the pressure, *V* is the volume, *T* is the absolute or thermodynamic temperature in kelvin, *n* is the number of moles and *R* is the gas constant

(b) **(i)** $n = \frac{pV}{RT} = \frac{3.4 \times 10^5 \times 2.5 \times 10^3 \times 10^{-6}}{8.31 \times 300}$ = 0.34 moles

(ii) $T = \frac{pV}{nT}$ for combined amount of gas

$T = \frac{3.9 \times 10^5 \times (2.5+1.6) \times 10^{-3}}{(0.34+0.20) \times 8.31}$ = 356 K (= 360 K to 2 sig. fig.)

(c) When the tap opens, gas passes into cylinder A from cylinder B. Work is done on the gas in cylinder A as it decreases in volume. Since no heat enters of leaves A, the internal energy of the molecules in A rises and thus temperature increases.

5 **(a)** **(i)** *N* is the (total) number of molecules in the gas

(ii) $<c^2>$ is the mean square speed of the molecules

(b) $pV = ⅓Nm<c^2> = NkT$

mean kinetic energy = ½ $m<c^2>$

$⅓Nm<c^2> = NkT$

$m<c^2> = 3kT$

½ $m<c^2> = \frac{3kT}{2}$

(c) **(i)** energy per molecule = $\frac{3 \times 1.38 \times 10^{-23} \times 1.0}{2} = 2.07 \times 10^{-23}$

total energy = $2.07 \times 10^{-23} \times 6.02 \times 10^{23}$ = 12.46 J

(= 12J to 2 sig. fig.)

(ii) The energy required to heat the gas at constant pressure is greater, since some energy is required to do work against the atmosphere outside the cylinder as the gas expands

Examination Question X

1 **(a)** Two point masses attract each other with a force that is directly proportional to the product of the two masses and inversely proportional to the square of their separation

(b) **(i)** gravitational force on satellite = centripetal force

$\frac{GMm}{r^2} = \frac{mv^2}{r}$ so $mv^2 = \frac{GMm}{r}$

$E_K = ½mv^2 = \frac{GMm}{2r}$

(ii) 1. $\Delta E_K = \frac{1}{2} \times 4.00 \times 10^{14} \times 620 \times \left(\frac{1}{7.30 \times 10^6} - \frac{1}{7.34 \times 10^6}\right)$

$= 9.26 \times 10^7$ J

2. $\Delta E_P = \frac{GMm}{r}$

$= 4.00 \times 10^{14} \times 620 \times \left(\frac{1}{7.30 \times 10^6} - \frac{1}{7.34 \times 10^6}\right)$

$= 1.85 \times 10^8$ J

(iii) The linear speed increases as E_K increases as the radius decreases. An increase in K.E. is associated with an increases in speed as $E_K = ½mv^2$

2 **(a)** **(i)** 1. 1.7 cm

2. period $T = 0.36$ s

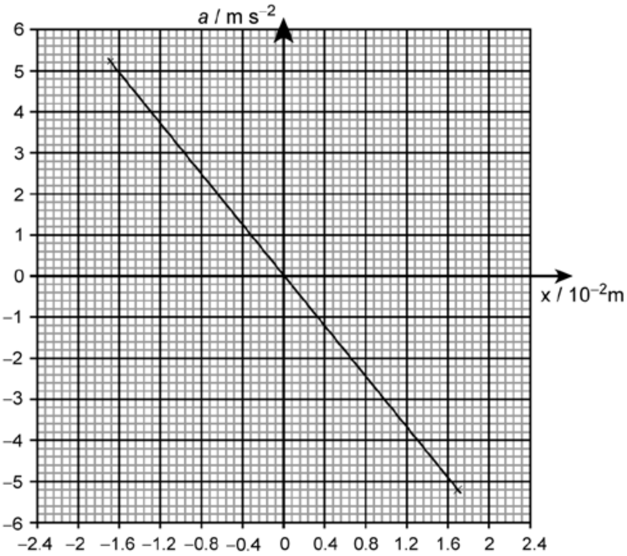
frequency $= \frac{1}{T} = \frac{1}{0.36} = 2.78$ (= 2.8 Hz to 2 sig. fig.)

(ii) acceleration $= -\omega^2 x = -\left(\frac{2\pi}{T}\right)^2$

maximum acceleration $= \left(\frac{2\pi}{0.36}\right)^2 \times 1.7 = 517.8$ cm s^{-2}

$= 5.2$ m s^{-2}

(b)



(c) kinetic energy $= ½mv^2 = ½m\omega^2(x_0^2 - x^2)$

$0.5 \times ½m\omega^2 \times 1.7^2 = ½m\omega^2(1.7^2 - x^2)$

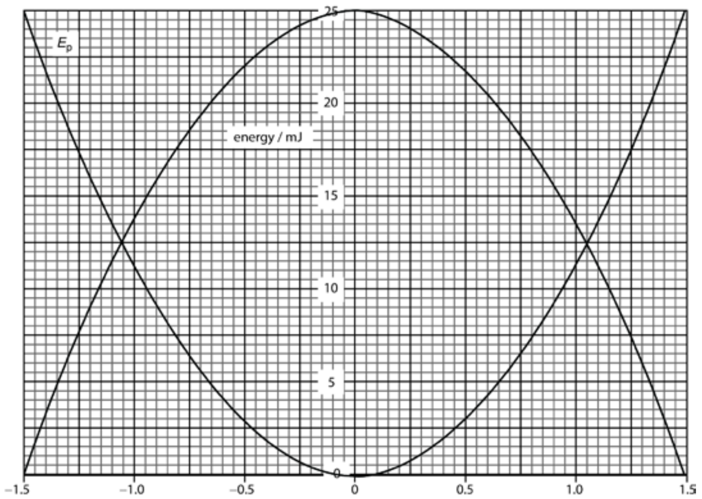
$x^2 = 1.445$

$x = 1.20$ (= 1.2 cm to 2 sig. fig.)

3 **(a)** **(i)** 0.30 s, 0.90 s, 1.50 s

(ii) maximum velocity = $\omega x_0 = \left(\frac{2\pi}{T}\right) x_0 = \left(\frac{2\pi}{1.2}\right) \times 1.5 \times 10^{-2}$
= 0.0785 m s^{-1} (= 0.079 m s^{-1} to 2 sig. fig.

(b) **(i)** Graph:
Correct shape drawn with a maximum at zero displacement.
Kinetic energy E_k as the inverse of the potential energy E_p curve.
(Maximum E_k of 25mJ at zero displacement and 0mJ at displacements of +/- 1.5cm)



(ii) The total energy is E_P at maximum displacement (the amplitude) = 4.0 mJ

4 **(a)** **(i)** The amplitude is constant, it does not change

(ii) The damping is light as the amplitude decreases only a small amount in the time shown and the decrease is gradual

(iii) period T = 0.80 s
frequency = $\frac{1}{T}$ = 1.25 Hz (= 1.3 Hz to 2 sig. fig.)

(b) **(i)** Whenever there is a change in the magnetic flux linking a circuit an e.m.f. is induced and the magnitude of the induced e.m.f. is proportional to the rate of change of flux linkage

(ii) As the magnet moves within the coil, there is a change in magnetic flux linkage within the coil and this induces an e.m.f. in the coil. As the switch is closed, this e.m.f. causes a current in the coil which creates thermal energy in the resistor and coil. Any induced current that flows in the coil itself creates a magnetic field within the coil that opposes the movement of the magnet, e.g. if a N- pole approaches the coil then a N-pole is formed near the approaching magnet; the repulsion slows down the magnet. The production of thermal energy reduces the energy of oscillation of the magnet.

Examination Questions XI

1 **(a)** Specific acoustic impedance is the product of the density of the substance and the speed of sound in the substance

(b) The amount of reflection at the boundary depends on the difference in the specific acoustic impedance of the two media. A large difference means that a large percentage of the incident intensity is reflected.

(c) A pulse of ultrasound is sent into the body from a transmitter on the skin. The pulse reflects from any boundary between different tissues or materials. The reflected pulses are detected on the surface of the body and the pulses are analysed to determine the time taken for the echo to travel and return. This time t is used, with the speed c of the ultrasound, to determine the distance from the transmitter to the boundary, the depth of any boundary = ct/2. The strength of the reflected signal is analysed to give information on the difference in the specific acoustic impedances at the boundary and gives some idea of the material on either side of the boundary. The transmitter and detector can be moved across the body of the patient to build up a picture of the structures within the body.

2 **(a)** **(i)** When a signal transmitted on one channel or cable is picked up and has an effect on another channel or cable
(ii) Noise is an undesirable and usually random electrical signal, which distorts or interferes with the original (or desired) signal

(b) 30 = $10 \log \frac{P}{6.5 \times 10^{-6}}$, where *P* is the signal input power to the receiver
P = 6.5×10^{-3} W
attenuation produced by the cable = $10 \log \frac{26 \times 10^{-3}}{6.5 \times 10^{-3}}$ = 6.02 (dB)
length = $\frac{6.02}{0.20}$ = 30.1 km (= 30 km to 2 sig. fig.)

3 **(a)** Any aerial or transmitting dish pointed at the satellite does not have to be moved because the satellite remains fixed above the same point on the equator and orbits Earth with a period of one day. A carrier wave is transmitted from Earth up to the satellite (the uplink) at a frequency of, for example, 6 or 15 GHz. The signal received is much smaller in intensity (attenuated) and is amplified and transmitted back to Earth on a different frequency (the downlink), for example, 4 or 12 GHz. Using a different frequency ensures that the downlink signal does not swamp the signal received from Earth.

(b) Advantages of a polar-orbiting satellite (*Any one of the following options):*

- they are at a smaller (lower) height above Earth and may need less transmission power
- there is a smaller delay in time between sending and receiving a signal than for a geostationary satellite
- they can have greater resolution when taking photographs
- one polar satellite can transmit to the whole Earth, particularly the polar regions, during several orbits, which one geostationary satellite cannot do. Polar satellites move across the sky and are not fixed above the same point on Earth.

Disadvantages of a polar-orbiting satellite: (*Any one of the following options):*

- satellite dishes must be rotated to keep pointing at the polar-orbiting satellite as it moves across the sky (tracking)
- satellites cannot be contacted for part of their orbit when they are in the shadow of Earth. For continuous communication many satellites are needed.

Examination Questions XII

1 **(a)** Capacitors store energy in an electric field or provide smoothing in a power supply

(b) **(i)** charge = current × time

(ii) Area under graph is approximately 21 large squares
One large square represents (1.25 × 0.125) = 0.156 mC
charge = 21 × 0.156 = 3.28 mC = 3280 μC
(= 3300 μC to 2 sig. fig.)

(iii) capacitance = $\frac{Q}{V} = \frac{3300 \times 10^{-6}}{15}$ = 220 × 10^{-6} F = 220 μF

(c) final energy = half initial energy
$\frac{1}{2}CV^2 = \frac{1}{2} \times \frac{1}{2} \times C \times 15^2$
V = 10.6 V (= 11 V to 2 sig. fig.)

2 **(a)** The work done in bringing unit positive charge from infinity to the point

(b) **(i)** 18 cm

(ii) Combined potential of two charges V_A and V_B is zero.

$$\frac{Q_A}{4\pi\varepsilon_0 r_A} + \frac{Q_B}{4\pi\varepsilon_0 r_B} = 0$$

$$\frac{3.6 \times 10^{-9}}{4\pi\varepsilon_0 \times 18 \times 10^{-2}} + \frac{Q_B}{4\pi\varepsilon_0 \times 12 \times 10^{-2}} = 0$$

$Q_B = -2.4 \times 10^{-9}$ C

(c) Force on charge = charge × electric field strength. The force is largest where the field strength is largest. Since the field strength = the gradient of the graph, then the force is largest where the magnitude of the gradient is largest, at x = 27 cm. Since the charge on B is numerically greater than the charge on A then the force on any test charge will be largest closer to B.

3 **(a)** **(i)** Capacitance is the ratio of the charge on one plate of a capacitor to the potential difference across the plates, the charge per unit potential difference

(ii) The capacitor has positive charge on one plate and an equal amount of negative charge on the other plate. Thus the total charge on the capacitor can be said to be zero. However to achieve positive charge on one plate and negative charge on the other work is done to separate the charge or work will be done if this charge recombines and so energy is stored.

(b) **(i)** $C_Y + C_Z = 24$ (μF)

$$\frac{1}{C_{tot}} = \frac{1}{24} + \frac{1}{12}$$

$C_{tot} = 8.0$ μF

(ii) Charge given by one terminal of supply when p.d. applied = $C_{tot}V$

$= 8.0 \times 10^{-6} \times 9.0 = 72$ μC

This charge flows onto one plate of X and the same amount of charge flows off the other plate onto one plate each of capacitors Y and Z, which share this charge.

(iii) 1. $V = \frac{Q}{C} = \frac{72 \times 10^{-6}}{12 \times 10^{-6}} = 6.0$ V

2. p.d. across capacitor Y = 9.0 − 6.0 = 3.0 (V)

$Q_Y = 12 \times 10^{-6} \times 3.0 = 3.6 \times 10^{-5}$ C = 36 μC

4 **(a)** **(i)** The continuous core ensures that most of the flux in the primary passes to the secondary coil and there is a minimum loss of magnetic flux. Having a complete iron core, rather than an air gap, increases the amount of flux within the coils and means the flux linkage in the secondary coil is larger.

(ii) Laminations reduce unwanted eddy currents in the core and thus reduce the production of thermal energy in the core by these currents

(b) **(i)** Whenever there is a change in the magnetic flux linking a circuit an e.m.f. is induced and the magnitude of the induced e.m.f. is proportional to the rate of change of flux linkage’

(ii) An alternating current in the primary causes a changing magnetic flux in the core. The core passes this flux to the secondary coil where the changing flux linkage induces an e.m.f. because of Faraday's law.

(c) Alternating voltages can be stepped up and down easily. Stepping up the voltage to a high level for transmission reduces the current in the transmission lines and reduces power losses in the transmission lines making transmission more efficient.

5 **(a)** The work done in bringing unit positive charge from infinity to the point

(b) **(i)** An α-particle and a gold nucleus are both positive and repel each other. This slows the α-particle down and all its kinetic energy is converted into electric potential energy.

(ii) **1.** Assuming the gold nucleus is fixed and does not recoil, kinetic energy lost = potential energy gained

$4.8 \times 10^{6} \times 1.6 \times 10^{-19} = \frac{79 \times 1.6 \times 10^{-19} \times 2 \times 1.6 \times 10^{-19}}{4\pi \times 8.85 \times 10^{-12} \times r}$

$r = 4.74 \times 10^{-14}$ m (= 4.7×10^{-14} m to 2 sig. fig.)

2. $F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2} = \frac{79 \times 1.6 \times 10^{-19} \times 2 \times 1.6 \times 10^{-19}}{4\pi \times 8.85 \times 10^{-12} \times r^2}$

= 16.19 N (= 16 N to 2 sig. fig.)

6 **(a)** The direction of any induced current or induced e.m.f. is such as to oppose the flux change that causes it

(b) **(i)** **1.** Using iron increases the flux and the flux linkage within the core. This is because iron is easily magnetised and demagnetised, producing stronger magnetic fields than are produced in air.

2. Laminations reduce unwanted eddy currents in the core and thus reduce the production of thermal energy in the core by these currents

(ii) An alternating current in the primary causes a changing magnetic flux in the core. The core passes this flux to the secondary coil where the changing flux linkage induces an e.m.f.

7 **(a)** **(i)** 4.0 V

(ii) r.m.s. voltage = $\frac{4}{\sqrt{2}}$ = 2.83 V (= 2.8 V to 2 sig. fig.)

(iii) period T = 20 ms (full wave rectification)

frequency = $\frac{1}{T} = \frac{1}{20 \times 10^{-3}}$

frequency = 50 Hz

(b) **(i)** change in voltage = 4.0 − 2.4 = 1.6 V

(ii) $\Delta Q = C\Delta V = 5.0 \times 10^{-6} \times 1.6 = 8.0 \times 10^{-6}$ C

(iii) current = $\frac{\Delta Q}{t} = \frac{8 \times 10^{-6}}{7.0 \times 10^{-3}} = 1.14 \times 10^{-3}$ A

(= 1.1×10^{-3} A to 2 sig. fig.)

(c) resistance = $\frac{\text{average p.d.}}{\text{average current}} = \frac{(4.0 + 2.4) \div 2}{1.14 \times 10^{-3}}$

= 2807 Ω (= 2800 Ω to 2 sig. fig.)

Examination Questions XIII

1 **(a)** **(i)** The minimum frequency of electromagnetic radiation that causes the emission of electrons from a surface

(ii) threshold frequency = $\frac{E}{h} = \frac{\text{work function energy}}{h}$

$= \frac{9.0 \times 10^{-19}}{6.63 \times 10^{-34}} = 1.36 \times 10^{15}$ Hz (= 1.4×10^{15} Hz to 2 sig. fig.)

(b) Energy of a 300 nm photon = $hf = 6.63 \times 10^{-34} \times \frac{3 \times 10^{8}}{300 \times 10^{-9}}$

= 6.63×10^{-19} J

Energy of a 600 nm photon = 3.32×10^{-19} J

So, Sodium and zinc will emit electrons.

(c) A photon of higher frequency has larger energy and so electrons are still emitted. As the intensity of the light is the same, fewer photons per second strike the metal surface and so fewer electrons are emitted per second, the rate of emission decreases.

2 **(a)** **(i)** The decay constant is the probability that a nucleus will decay per unit time

(ii) $N = N_0 e^{-\lambda t}$

In one half-life, N changes from N_0 to ½ N_0 so the time for one half-life $t_{½}$ is given by

$½ N_0 = N_0 e^{-\lambda t_{½}}$

ln (½) = $-\lambda t_{½}$

$-0.693 = -\lambda t_{½}$

$\lambda t_{½} = 0.693$

(b) $228 = 538 e^{-8\lambda}$

$\lambda = 0.107$ hours^{-1}

$t_{½} = \frac{0.693}{0.107}$ = 6.476 hours (= 6.5 hours to 2 sig. fig.)

(c)

- Radioactive decay is random. Some of the measured count rate may be due to background radiation, which may not have been taken into account.

- The radioactive isotope may be decaying into another isotope which is itself radioactive and which may contribute to the final count rate.

3 **(a)** loss in kinetic energy of both nuclei = gain in electric potential energy

$2 \times \frac{1}{2}mv^2 = \frac{Q^2}{4\pi\varepsilon_0 r}$

$v^2 = \frac{(1.6 \times 10^{-19})^2}{4\pi \times 8.85 \times 10^{-12} \times 1.1 \times 10^{-14} \times 2 \times 1.67 \times 10^{-27}}$

$v = 2.50 \times 10^6\ \mathrm{m\,s^{-1}}$ (= $2.5 \times 10^6\ \mathrm{m\,s^{-1}}$ to 2 sig. fig.)

(b) $pV = \frac{1}{3}Nm\langle c^2\rangle = NkT$

$T = \frac{2 \times 1.67 \times 10^{-27} \times (2.5 \times 10^6)^2}{3 \times 1.38 \times 10^{-23}}$

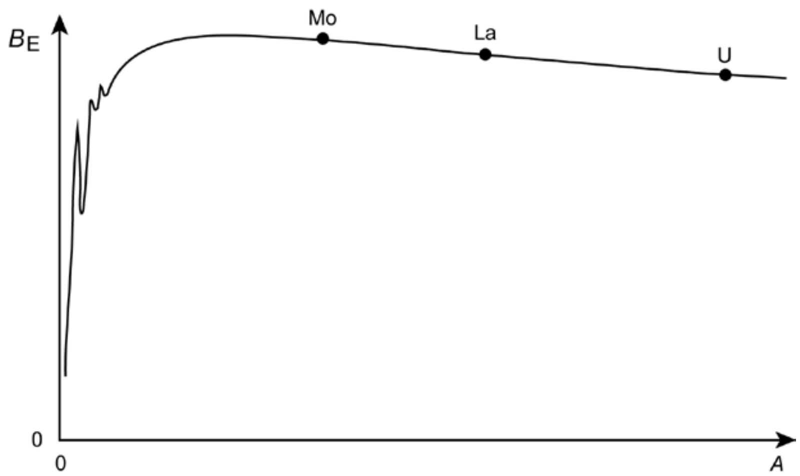
$T = 5.04 \times 10^8$ K (= 5.0×10^8 K to 2 sig. fig.)

(c) This temperature is found at the centre of star where new elements are formed by nuclear fusion

4 **(a)** Binding energy is the minimum energy needed to separate a nucleus into its separate nucleons, with the nucleons moved far apart, to infinity

(b) **(i)** nuclear fission

(ii) Graph:



(iii) **1.** left-hand side of equation, mass = 236.132 u
right-hand side of equation, mass = 235.9219 u
mass change = 0.210 u
2. energy = $mc^2 = 0.210 \times 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$
$= 3.1374 \times 10^{-11}$ J $= \frac{3.1374 \times 10^{-11}}{1.6 \times 10^{-19}}$ eV
= 196.1 MeV
= 196 MeV to 3 sig. fig.

5 **(a)** A photon is an elementary particle, a quantum or packet of energy of electromagnetic radiation. The energy, *E,* of a photon is related to the frequency, *f,* of the radiation by $E = hf$, where *h* is the Planck constant.

(b) Evidence for the particulate nature of e.m. radiation:

- The existence of a threshold frequency, below which no emission occurs whatever the intensity of the radiation
- The maximum kinetic energy of the emitted photoelectrons depends only on the frequency of the radiation and does not depend on the intensity of the radiation. If the frequency of the radiation increases, the max K.E. of the photoelectrons increases.
- The rate of emission of the photoelectrons is proportional to the intensity of the radiation. Doubling the intensity or brightness causes twice as many photoelectrons per second to be emitted but has no effect on the maximum K.E. of the photoelectrons.

(c) Energy of photon = $hf = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{450 \times 10^{-9}} = 4.42 \times 10^{-19}$ J
work function energy = 3.5 eV = $3.5 \times 1.6 \times 10^{-19} = 5.6 \times 10^{-19}$ J
As the work function is larger than the energy of the photon there is no emission of electrons.