PHYSICS

Unit 1 – Written examination 1

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SOLUTIONS

SECTION A
Area of Study 1 – Nuclear Physics and Radioactivity

Question 1
Gamma radiation is massless and travels at the speed of light, so it is able to penetrate matter far more easily than the relatively heavy alpha particles (helium-4 nuclei).

Question 2
The two primary forces are electrostatic repulsion (between protons in the nucleus) and the strong nuclear force (between nucleons at very close range only). The balance between these forces plays a significant role in determining how certain combinations of protons and neutrons (ie. Isotopes) remain stable or otherwise.

Question 3
Answer: **24 Protons. 33 Neutrons.**
Explanation: The lower number in the symbolic notation of Cr-57 is the atomic number. The atomic mass is equal to the total number of nucleons, so Neutrons = 57 – 24 = 33.

Question 4
$${}^{57}_{24}Cr \rightarrow {}^{57}_{25}Mn + {}^{0}_{-1}\beta$$

Question 5
Answer: 2 x 57 = **114 mins**
Explanation: 1.25/5 = ¼. Thus there is one quarter of the original activity rate, so two half-lives must have elapsed.

Question 6
Geiger counter.

Question 7
Mica is more suitable as any alpha radiation which could be detected would otherwise be blocked by aluminium and the counter would only record beta or gamma decay.

Question 8

Incoming gamma radiation will pass through the mica (or indeed walls of the counter) and ionize an atom of argon. The positive argon ion will be attracted to the negative walls of the counter and any free electrons will be attracted to the central, positive electrode. As the charged particles meet the electrodes, a spike of current will be detected and recorded by the counter.

Question 9

Answer: **2 x 10^{-4} Gy**

Explanation: $AD = \frac{DE}{QF} = \frac{0.004}{20} = 2 \times 10^{-4}\, Gy$

Question 10

Answer: **0.015 J**

Explanation: $E = AD \times mass = 2 \times 10^{-4} \times 75 = 0.015\, J$

Question 11

Alpha radiation has a very high ionizing ability, making it particularly dangerous when in contact with human tissue.

Question 12

Effects, ranked in approximate order of severity.

Short Term	Long Term
Nausea, vomiting, rashes, convulsions	Inherited birth defects due to abnormal egg, sperm
Hair loss	Tumours caused by DNA mutations
Bone marrow damage	Leukaemia
Damage to reproductive organs	Death due to cancer
Death due to severe short-term symptoms	

Question 13

Sources of background radiation

Sources of background radiation	
Atmospheric – eg. Radon, fallout	Buildings – concrete
Food and drink- e.g K-40	TV – low level x-rays
Sun and space	Medical procedures
	Rocks and soil

Question 14

Answer: **Alpha**

Explanation: A decrease of 4 nucleons is most likely due to the ejection of an alpha particle – helium nucleus.

Question 15

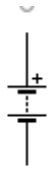
Answer: **Helium nucleus – 2 protons, 2 neutrons**. Relatively low speed and heavy, but energy of ~ 5 MeV, affording them high ionizing ability, but low penetration.

Question 16
Answer: $^{222}_{86}Rn \rightarrow {}^{218}_{84}Po + {}^{4}_{2}\alpha$
Explanation: .

Question 17
Answer: **200 sec.**
Explanation: 5/40 = 1/8, which means 3 half-lives (0.5)3 = 0.125. So 10/3 = 3.33 mins = 200 sec.

SECTION A
Area of Study 2 – Electricity

Question 1
Answer: **Clockwise**
Explanation: Current flows from the positive terminal of the battery to the negative terminal through the circuit. The positive terminal is shown with the longer side of the battery symbol (below).



Question 2
Answer: **0.9 A**
Explanation:
$$I = \frac{V_{total}}{R_{total}} = \frac{9}{10} = 0.9A$$

Question 3
Answer: **162 C**
Explanation: Note that units of time must be seconds.
$$Q = It = 0.9 \times 180 = 162C$$

Question 4
Answer: **3.6 V**
Explanation: Use the voltage divider formula.
$$V_4 = \frac{4}{4+6} \times 9 = 3.6V$$

Question 5
Answer: **583 J**
Explanation:
$$E = VIt = 3.6 \times 0.9 \times 180 = 583.2J$$

Question 6
Answer: **2.5 A**
Explanation:
$$R_{total} = \frac{6 \times 12}{6+12} = 4\Omega$$
$$I = \frac{V_{total}}{R_{total}} = \frac{10}{4} = 2.5A$$

Question 7
Answer: **10 V**
Explanation: Components in parallel with the supply experience the same voltage drop as the supply.

Question 8
Answer: **8.3 W**
Explanation:
$$P = \frac{V^2}{R} = \frac{10^2}{12} = 8.33W$$

Question 9
Answer: **Increase**
Explanation:
Adding an additional resistor in parallel will reduce the overall resistance and thus increase the total current in the circuit: $I = \frac{V_{total}}{R_{total}}$

Question 10
In the event of a short circuit or similar failure, there may be a large surge in current which could take the path of relatively low resistance to the ground (0 V) via a user. To avoid this potential for shock, many appliances connect their outer casing to an earth wire which is connected directly to the stake in the ground via the switchboard. This provides a lower resistance path for the current in preference to the user.

Question 11
A fuse is a piece of wire designed to heat, melt and thus break the circuit at a pre-determined current value. When placed in series with an appliance, this prevents the device from experiencing high currents that may damage it or shock users. A circuit breaker operates in the same way as a safety device, but as it is a resettable, electromagnetic device, it acts faster and can easily be reset unlike the fuse which must be physically replaced.

Question 12
Students using power packs in a laboratory must remember they are connected to mains power and thus the current available is far greater than with a 9 V battery. Thus, potential for dangerous shocks is increased.

Question 13
Answer: **93 Ω**
Explanation:
$$V_R = 12 - V_{diode} = 12 - 0.8 = 11.2V$$
$$R = \frac{V}{I} = \frac{11.2}{0.12} = 93.3\Omega$$

Question 14
Answer: **No change**
Explanation:
Increasing the resistance will decrease the current in the circuit (including the diode), but not enough to change the voltage across the diode (refer to Fig 4). So V_R =11.2 V as before.

Question 15

If the resistance is reduced to 20 Ω, the current in the diode will increase considerably (to 560 mA), which is beyond the capacity of the diode – causing it to burnout.

Question 16
Answer: **14000 kWh**
Explanation:
$E = Pt = 3.5kW \times 16 \times 5 \times 50 = 14000kWh$

Question 17
Answer: **5.04×10^{10} J**
Explanation:
$E = 14000 \times 60 \times 60 \times 1000 = 5.04 \times 10^{10} J$

Question 18
Answer: **$ 3220.00**
Explanation:
$Cost = 0.23 \times 14000 = \$3220$

SECTION B – Detailed Studies

Detailed Study 1 – Astronomy

Question 1
Answer: **A**
Explanation: Ptolemy's Earth centric, circular orbits were in contrast to more modern such as thos of Galileo and Copernicus.

Question 2
Answer: **B**
Explanation: Observing the motion of Jupiter's moons enabled Galileo to conclude that they were indeed moons of Jupiter and not the Earth.

Question 3
Answer: **B**
Explanation: Azimuth is measured as the clockwise angle from due North.

Question 4
Answer: **A**
Explanation: Altitude is the angle of elevation from the horizon for the given star.

Question 5
Answer: **B**
Explanation: The stars would appear to rotate clockwise about the South Celestial Pole.

Question 6
Answer: **A**
Explanation: Zenith is a point with an altitude of 90^{o}.

Question 7
Answer: **C**
Explanation: The diurnal motion of the stars is their apparent motion about the celestial poles due to the rotation of the Earth about its own axis.

Question 8
Answer: **A**
Explanation: The annual revolution of the Earth about the Sun causes a secondary apparent motion of the stars due to the varying position of the observer.

Question 9
Answer: **A**
Explanation: The use of mirrors avoids error associated with the different rate of refraction through of various colours through lenses (chromatic aberration).

Question 10
Answer: **B**
Explanation: Apparent magnitude, with smaller or even negative numbers indicating increasing brightness, describe the brightness of a star when viewed from Earth. Absolute magnitude is a standardized brightness – when viewed as though 33 light years away.

Detailed Study 2 – Astrophysics

Question 1
Answer: **C**
Explanation: White Dwarf stars are hot, but very small and not bright compared to our Sun.

Question 2
Answer: **C**
Explanation: Red Giants are much larger and therefore emit more light, even though they are cooler than White Dwarfs.

Question 3
Answer: **D**
Explanation: Given our Sun will NOT end in a supernova due to its relatively small size, the only viable option is White Dwarf (remnant of a Red Giant and planetary nebula).

Question 4
Answer: **A**
Explanation: In a red supergiant, the hydrogen fuel has been exhausted and the star is now seeing fusion of heavier elements, such as carbon to oxygen. Iron is larger than boron, so this is not a viable option.

Question 5
Answer: **A**
Explanation: The image is of a typical spiral galaxy.

Question 6
Answer: **D**
Explanation: These are the accepted, approximate dimensions of the Milky Way galaxy.

Question 7
Answer: **B**
Explanation: Hubble used similar data to conclude that, as distant galaxies are receding faster, there must have been a fixed starting point and subsequent expansion – the Big Bang.

Question 8
Answer: **B**
Explanation: As above. Red shift is due to an object moving away from an observer (Doppler Effect on the frequency of light), so more distant galaxies will be moving more rapidly and thus be more red-shifted.

Question 9
Answer: **B**
Explanation: $d = \frac{1.9 \times 10^{`14}}{3.09 \times 10^{13}} = 6.2\ pc$

Question 10
Answer: **A**
Explanation:
$\theta = \frac{1}{d} = \frac{1}{6.2} = 0.16$

Detailed Study 3 – Energy from the nucleus

Question 1
Answer: **D**
Explanation: The strong nuclear force acts over very short distances as is necessary to overcome the electrostatic repulsion of like charges (protons) in the nucleus.

Question 2
Answer: **A**
Explanation: The difference in mass is due to binding energy differences.

Question 3
Answer: **D**
Explanation: The largest element to undergo fusion is Iron.

Question 4
Answer: **D**
Explanation: The material that slows the fast neutrons released during fission is called a moderator.

Question 5
Answer: **A**
Explanation: Total number of nucleons must remain constant.

Question 6
Answer: **C**
Explanation:
$E = 215\times10^{6}\times1.6\times10^{-19}\,J$

$E = 3.44\times10^{-11}\,J$

Question 7
Answer: **B**
Explanation:
$E = mc^2$

$$m = \frac{E}{c^2} = \frac{3.44\times10^{-11}}{\left(3\times10^{8}\right)^2} = 3.8\times10^{-28}\,kg$$

Question 8
Answer: **A**
Explanation: Fission products are regarded as high level radioactive waste as they are usually unstable and will decay.

Question 9
Answer: **D**
Explanation: Reducing the surface area will aid absorption of neutrons and increase the rate of reaction. Cadmium rods (used as control rods in a reactor) will absorb free neutrons and slow the reaction.

Question 10
Answer: **A**
Explanation: Moderator can be heavy water, graphite or other materials which slow, but do not readily absorb neutrons.

Detailed Study 4 - Flight

Question 1
Answer: **C**
Explanation:
$Q = Av = 2.5 \times 21 = 52.5 m^3 s^{-1}$

Question 2
Answer: **B**
Explanation:
$v = \frac{Q}{A} = \frac{52.5}{\pi \times 0.6^2} = 46.4 ms^{-1}$

Question 3
Answer: **D**
Explanation: Lift must exceed weight, given that the craft is accelerating and ascending after takeoff. Weight = 3 x10^6 x 10 = 3 x 10^7 N. So 3.4 x 10^8 N is the most sensible option.

Question 4
Answer: **A**
Explanation: Thrust must exceed drag as the craft should be accelerating forwards as well as upwards after takeoff.

Question 5
Answer: **D**
Explanation: Newtonian lift is generated perpendicular to the sloping aerofoil surface of the wing, directing it up and backwards (partly). The backwards component is induced drag.

Question 6
Answer: **A**
Explanation: Increasing the angle of attack can increase the lift, but will ultimately lead to more turbulence and a stall (no lift).

Question 7
Answer: **B**
Explanation: Ailerons – roll, elevator – pitch, air brake – stop.

Question 8
Answer: **C**
Explanation: 800 x 1.5 = 1200 Nm. The force must be directed upwards on the left wing to counteract the torque on the right.

Question 9
Answer: **C**
Explanation: The air pressure on the top side is less due to the increased speed of the airflow.

Question 10
Answer: **B**
Explanation: Newtonian lift requires the air to be deflected down, thus forcing the wing up.

Detailed Study 5 – Sustainable energy sources

Question 1
Answer: **D**
Explanation: Natural gas, although plentiful, is not replaceable.

Question 2
Answer: **A**
Explanation: Light to electrical energy (at about 15-20% efficiency).

Question 3
Answer: **D**
Explanation: Thermal energy is generally considered low grade, although applications such as geothermal power generations do make use of it.

Question 4
Answer: **B**
Explanation: Potential energy could also include some kinetic due to the motion of the mass.

Question 5
Answer: **A**
Explanation: $E = VIt = 6 \times 1.3 \times 0.6 = 4.68\,J$

Question 6
Answer: **C**
Explanation: $\%Eff = \frac{E_{out}}{E_{in}} = \frac{mgh}{4.68} = \frac{0.25 \times 10 \times 1.4}{4.68} = 75\%$

Question 7
Answer: **B**
Explanation:
$$E = 860 \times 8 \times 7 \times 7 \times 60 \times 60 = 1.2 \times 10^9\,J$$
$$E = 1.2 \times 10^3\,MJ$$

Question 8
Answer: **B**
Explanation: $E = \frac{1.2 \times 10^9 \times 16\%}{24 \times 60 \times 60 \times 1000} = 53.9\,kWh$

Question 9
Answer: **B**
Explanation: More constant solar insolation gives a more manageable output.

Question 10
Answer: **A**
Explanation: The majority of the electrical energy is wasted as heat.

Question 1
Answer: **C**
Explanation: Gamma radiation has the highest penetration power, but lowest ionization ability, so will penetrate from within a patient to detection equipment without causing unwanted ionization of internal structures.

Question 2
Answer: **B**
Explanation: 220 mins is equivalent to two half lives, so the 64 mg will become a quarter of the original value.

Question 3
Answer: **C**
Explanation: 8 mg is an eighth of the original sample, so 3 half lives are required.

Question 4
Answer: **C**
Explanation: The total number of nucleons must be retained.

Question 5
Answer: **D**
Explanation: Alpha particles are "heavy" helium nuclei which have low penetration but high ionization ability.

Question 6
Answer: **B**
Explanation: Shorter half-lives mean higher intensity, but shorter duration.

Question 7
Answer: **A**
Explanation: A coherent bundle will retain the relative position of various pixels and thus deliver an image. An incoherent bundle would lead to a scrambled image.

Question 8
Answer: **A**
Explanation: Lasers are very intense, coherent sources.

Question 9
Answer: **A**
Explanation: X-rays are absorbed by bone and will thus end there, forming a shadow on the film behind the patient.

Question 10
Answer: **A**
Explanation: MRI scans produce higher resolution images of soft tissue such as the brain.