Neap

Trial Examination 2023

Suggested Solutions

QCE Physics Units 3&4

Paper 1

SECTION 1 – MULTIPLE CHOICE QUESTIONS

	A	B	C	D
1.	○	○	○	●
2.	○	●	○	○
3.	○	●	○	○
4.	○	○	●	○
5.	○	●	○	○
6.	●	○	○	○
7.	○	●	○	○
8.	●	○	○	○
9.	○	○	●	○
10.	○	○	●	○
11.	○	○	○	●
12.	○	○	●	○
13.	○	○	○	●
14.	○	●	○	○
15.	○	○	●	○
16.	○	○	○	●
17.	●	○	○	○
18.	○	○	●	○
19.	●	○	○	○
20.	○	●	○	○

QUESTION 1 D

D is correct. Hydrogen is comprised of one proton, which is a baryon, and one electron.

A is incorrect. Atoms are not comprised of photons.

B and **C** are incorrect. These options state that a hydrogen atom contains a single quark or a single gluon, respectively, but a proton is comprised of three quarks and three gluons.

QUESTION 2 B

B is correct and **C** is incorrect. A frequency is not the same as a wavelength. The frequency of a wave is inversely proportional to its wavelength; therefore, maximum wavelength can be equated with minimum frequency. As such, threshold frequency is the minimum frequency required for the emission of a photoelectron by a photon incident on a metal.

A is incorrect. This option describes work function.

D is incorrect. This option describes the frequency of a photon.

QUESTION 3 B

B is correct. In this free-body diagram, the forces along the ramp cancel each other out, and the forces perpendicular to the ramp cancel each other out. Therefore, there is no net force, which represents constant motion (that is, zero acceleration).

A is incorrect. This free-body diagram shows a net force down the ramp, which implies that the object is accelerating down the ramp.

C is incorrect. This free-body diagram shows a net force (and thus acceleration) down the ramp and no normal force.

D is incorrect. This free-body diagram shows a net force into the ramp and no normal force.

QUESTION 4 C

C is correct. By doubling the distance between the charges, the electrostatic force between the charges would decrease by a factor of 4.

A is incorrect. The physical size of the charges does not affect the electrostatic force between them; only the magnitude of the charges has an effect.

B is incorrect. Halving the charge value of one of the charges would reduce the electrostatic force between the charges by a factor of 2.

D is incorrect. Doubling the charge value of one of the charges would increase, not reduce, the electrostatic force between the charges.

QUESTION 5 B

B is correct. This is the definition of a meson.

A is incorrect. This is the definition of an elementary particle.

C is incorrect. A quark and its corresponding antiquark would annihilate the particle and produce photons.

D is incorrect. This is the definition of a baryon.

QUESTION 6 A

A is correct. Bohr's model describes angular momentum as $\frac{nh}{2\pi}$, which is constant for each electron energy level.

B is incorrect. This option describes classical momentum.

C is incorrect. This option describes the kinetic energy of photoelectrons.

D is incorrect. This option describes a limitation of Rutherford's model of the atom.

QUESTION 7 B

B is correct.

$$hf = W$$

$$f = \frac{2.2 \times 1.60 \times 10^{-19}}{6.626 \times 10^{-34}}$$

$$= 5.3 \times 10^{14} \text{ Hz}$$

A is incorrect. This option uses 2.0 eV instead of 2.2 eV.

C is incorrect. This option does not convert the work function to joules and uses 2.0 eV instead of 2.2 eV.

D is incorrect. This option does not convert the work function to joules.

QUESTION 8 A

A is correct. This is the definition of Kepler's second law of planetary motion. Kepler's second law explains why the speed of an object in elliptical orbit around a parent body increases when it is closer to the parent body and slower when it is further away.

B is incorrect. This option describes Kepler's third law of planetary motion.

C is incorrect. This option describes Kepler's first law of planetary motion.

D is incorrect. This option describes Newton's second law of motion.

QUESTION 9 C

C is correct. The south poles of the freely rotating compasses would be attracted to Earth's magnetic north pole. The north poles of the compasses would be attracted to the Earth's magnetic south pole. The geographical north pole of Earth is actually a magnetic south pole, which explains why north poles of magnets point north. Thus, diagram C best represents the poles of the compasses and Earth.

A is incorrect. In this diagram, the north poles of the compasses would repel from Earth's magnetic north pole.

B and **D** are incorrect. The compasses are independent of each other and should therefore have the same orientation to Earth's magnetic field.

QUESTION 10 C

C is correct.

$$L = L_0\sqrt{\left(1-\frac{v^2}{c^2}\right)}$$

$$50 = L_0\sqrt{\left(1-\frac{(0.866c)^2}{c^2}\right)}$$

$$L_0 = 100 \text{ metres}$$

A is incorrect. This option may be reached by rearranging the equation incorrectly.

B is incorrect. This option may be reached by assuming that the speed of the spacecraft is not relativistic.

D is incorrect. This option may be reached by not squaring the velocity.

QUESTION 11 D

D is correct.

$$u_y = 30\sin(30)$$

$$= 15 \text{ m s}^{-1}$$

$$v_y = gt + u_y$$

$$0 = 9.8t + 15$$

$$t = 1.53 \text{ seconds}$$

As 1.53 seconds is the time it takes the projectile to reach its maximum height, the time of flight is $2t = 3.06$ seconds.

A is incorrect. This option may be reached by using cosine instead of sine and not doubling the value of *t*.

B is incorrect. This option is the time it takes the projectile to reach its maximum height, not the time of flight.

C is incorrect. This option may be reached by using cosine instead of sine.

QUESTION 12 C

C is correct. The time of flight of a projectile is related to the vertical component of its motion only.

Since the initial vertical component of the projectile's velocity is zero, the equation relating height above ground, *h*, and time of flight, *t*, is $h = \frac{1}{2}gt^2$. Taking the square root of each side gives $\sqrt{h} \propto t$.

A is incorrect. The relationship between *h* and *t* is not linear.

B is incorrect. This option shows h^2 instead of $\sqrt{h}$.

D is incorrect. The option shows an inverse square relationship; this is a common relationship between variables but is not applicable in this scenario.

QUESTION 13 D

D is correct. In the experiment, light diffracts after passing through each slit, and the resultant wavefronts interfere with each other either constructively or destructively to produce light and dark fringes on the screen.

A, **B** and **C** are incorrect. These wave properties do not explain the observed pattern on the screen.

QUESTION 14 B

B is correct. In positron–electron annihilation, a matter–antimatter corresponding pair comes together and results in the creation of pure energy (a photon). In a Feynman diagram, this is shown by the positron arrowhead pointing toward the left on the time axis, and the electron arrowhead pointing toward the right on the time axis. Note that this diagram represents both positron–electron annihilation and pair production.

A is incorrect. This diagram reverses the positron symbols.

C is incorrect. This diagram represents electron–positron scattering.

D is incorrect. This diagram shows an interaction between an electron and a positron that violates charge conservation at each event. The charge and/or lepton number is not conserved in each interaction.

QUESTION 15 C

C is correct, and **A** and **B** are incorrect. A particle with a composition of uud is made up of three quarks (two up and one down). A particle with three quarks is a baryon, and the quarks combine with the strong nuclear force, which is mediated by gluons.

D is incorrect. The uud particle itself is a proton, not a neutron.

QUESTION 16 D

D is correct. A step-down transformer has fewer loops of wire in its secondary coil, resulting in a lower voltage in the secondary coil. Per conservation of energy, if the voltage is decreased, the current will increase.

A is incorrect. This combination of coils would increase the voltage and thus decrease the current.

B and **C** are incorrect. These combinations will not transform the voltage or the current as the number of loops are equal.

QUESTION 17 A

A is correct.

$$|F_c| = |F_g|$$

$$\left|\frac{mv^2}{r}\right| = |mg|$$

$$\left|\frac{v^2}{r}\right| = |g|$$

$$v = \sqrt{gr}$$

$$= \sqrt{9.8 \times 0.30}$$

$$= 1.7 \text{ m s}^{-1}$$

B is incorrect. This option may be reached by calculating $2\pi r$; that is, $2\pi \times 0.30$ m.

C is incorrect. This option may be reached by using 0.6 m as the radius.

D is incorrect. This option may be reached by not calculating the square root.

QUESTION 18 C

C is correct. Wavelength is inversely proportional to the difference in electron energy levels. Therefore, a shorter photon wavelength results in a larger electron energy level transition.

A is incorrect. Neither photon would produce a photoelectron.

B is incorrect. Frequency is proportional to the difference in electron energy levels. Therefore, a higher frequency results in a larger electron transition. Photon 2 had a larger energy level transition, so its frequency is greater than the frequency of photon 1.

D is incorrect. Angular momentum increases with electron energy levels, so the angular momentum of the electron that absorbed photon 1 is less than that of the electron that absorbed photon 2.

QUESTION 19 A

A is correct and **C** is incorrect. Gravity is always an attractive force. Therefore:

$$F = \frac{GMm}{r^2}$$

$$= \frac{\left(6.67\times10^{-11}\right)\times\left(7.3\times10^{22}\right)\times\left(5.97\times10^{24}\right)}{\left(3.844\times10^{8}\right)^2}$$

$$= 2.0\times10^{20} \text{ N attraction}$$

B and **D** are incorrect. These options may be reached if the distance is not converted to metres.

QUESTION 20 B

B is correct.

$$n = \frac{N}{L}$$

$$= \frac{150}{0.50}$$

$$= 300 \text{ coils per metre}$$

$$I = \frac{B}{n\mu_0}$$

$$= \frac{750\times10^{-6}}{300\times\left(4\pi\times10^{-7}\right)}$$

$$= 2.0 \text{ A}$$

A is incorrect. This option may be reached by using $L = 0.10$ m.

C is incorrect. This option may be reached by using $n = 150$.

D is incorrect. This option may be reached by using 4 instead of 4π.

SECTION 2

QUESTION 21 (3 marks)

To move with uniform circular motion, an object must move with constant speed (uniform speed) in a circular path. The object experiences a constant acceleration inward along the radius of motion.

[3 marks]
1 mark for describing constant speed.
1 mark for describing a circular path.
1 mark for referring to constant acceleration inwards. Note: Responses must state the direction of the acceleration, as well as the fact that the acceleration is constant. Accept responses that refer to 'force' instead of 'acceleration'.

QUESTION 22 (2 marks)

Postulate 1: The laws of physics are the same in all inertial (uniformly moving) frames of reference.

Postulate 2: The speed of light in a vacuum has the same value, c, in all inertial frames of reference.

[2 marks]
1 mark for each postulate stated.

QUESTION 23 (3 marks)

a)
$$t = \frac{L_0}{v}$$
$$= \frac{26\,659}{0.99999 \times 3 \times 10^8}$$
$$= 8.8864 \times 10^{-5} \text{ s}$$
$$= 88\,864 \text{ ns}$$

[1 mark]
1 mark for calculating the time of travel.

b) $L = L_0\sqrt{\left(1-\frac{v^2}{c^2}\right)}$

$= 26\,659\times\sqrt{1-0.99999^2}$

$= 119.2224$ m

$v = \frac{L}{t_0} = \frac{L_0}{t}$

Therefore:

$t_0 = \frac{L}{v}$

$= \frac{119.2224}{0.99999\times 3\times 10^8}$

$= 3.97\times 10^{-7}$ s

$= 397$ ns

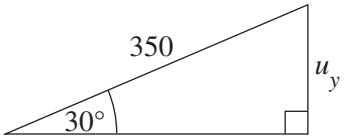
[2 marks]
1 mark for calculating the length of the Large Hadron Collider in the frame of reference of the proton.
1 mark for calculating the time of travel.

QUESTION 24 (6 marks)

Muons are created in the upper atmosphere. They are unstable particles *(that is, they decay)*, have a short half-life *(that is, they decay fast)*, and travel at nearly the speed of light *(that is, at relativistic speeds)*. According to Newtonian physics, this means that almost all muons should have decayed by the time they reach Earth's surface. However, it has been observed that very few muons actually decay by the time they reach Earth's surface. Since this observation does not align with Newtonian physics, Newtonian physics cannot account for the phenomenon.

[6 marks]
1 mark for stating that muons are created in the upper atmosphere.
Note: To obtain this mark, responses must refer to the upper region of the atmosphere by using terms such as 'upper atmosphere', 'high in the atmosphere', or 'of cosmic origin'.
1 mark for stating that muons are unstable and have a short half-life.
1 mark for stating that muons travel near the speed of light.
1 mark for explaining what Newtonian physics predicts regarding muons.
1 mark for outlining the real observations of muons.
1 mark for stating that Newtonian physics and real observations do not align.

QUESTION 25 (2 marks)



$$u_y = 350\sin(30)$$
$$= 175 \text{ m s}^{-1}$$
$$s_y = \frac{1}{2}gt^2 + u_y t$$
$$0 = \frac{1}{2} \times (-9.8)t^2 + 175t$$
$$0 = -4.9t + 175$$
$$t = \frac{175}{4.9}$$
$$= 35.7 \text{ s}$$

[2 marks]
1 mark for calculating the vertical component of the bullet's velocity.
1 mark for determining the time of travel.

QUESTION 26 (3 marks)

According to Lenz's law, when an induced current flows through a solenoid, the magnetic field produced by the solenoid has a polarity that repels the incoming magnetic pole. Work/energy must be done/used to overcome this repulsion. If work/energy is not done/used, then the induced electrical energy would be produced out of nothing, which is impossible. Thus, Lenz's law is consistent with the principle of conservation of energy.

[3 marks]
1 mark for explaining the polarity of the magnetic field.
1 mark for explaining the role of work done/energy used.
1 mark for explaining what would occur if work was not done/energy was not used.

QUESTION 27 (4 marks)

Gluons mediate the strong nuclear force.

W and Z bosons both mediate the weak nuclear force.

Photons mediate the electromagnetic force.

[4 marks]
1 mark for each force identified.
Note: Accept W^+ or W^- for W bosons, and Z^0 for Z bosons.

QUESTION 28 (7 marks)

$F_{C(net)} = F_{A \text{ on } C} + F_{B \text{ on } C} + F_{D \text{ on } C}$

$$F_{A \text{ on } C} = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{\text{A}\cdot\text{C}}{\left(\sqrt{0.1^2+0.1^2}\right)^2}$$

$$= 9\times10^9 \times \frac{\left(2\times10^{-6}\right)^2}{0.02}$$

$= 1.8$ N (repulsion) 45° below the horizontal to the right from charge C

(This is due to the angles in an isosceles right-angled triangle.)

$$F_{B \text{ on } C} = \frac{1}{4\pi\varepsilon_0}\frac{B\cdot C}{0.1^2}$$

$$= 9\times10^9 \times \frac{\left(2\times10^{-6}\right)^2}{0.01}$$

$= 3.6$ N (repulsion) downwards from charge C

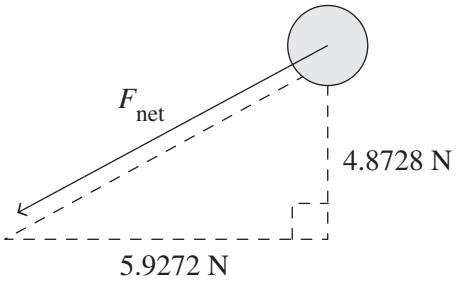
Since the magnitude of charge D is twice that of charge B, and the distance of charges B and D from charge C is equal:

$2\left(\left|F_{B \text{ on } C}\right|\right) = \left|F_{D \text{ on } C}\right|$

$F_{D \text{ on } C} = 2\times3.6$

$= 7.2$ N (attraction) to the left of charge C

Therefore, the free-body diagram for charge C is:



Net horizontal force on charge C:

$F_{horizontal} = -7.2 + 1.8\sin(45)$

$= 5.9272$ N to the left of charge C

Net vertical force on charge C:

$F_{vertical} = -3.6 + \left(-1.8\sin(45)\right)$

$= 4.8728$ N downwards from charge C

Net force on charge C:

$F_{net} = \sqrt{4.8728^2 + 5.9272^2}$

$= 7.7$ N

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(continued)

[7 marks]

1 mark for recognising that the net force is the vector sum.

1 mark for calculating the magnitude of $F_{A \text{ on } C}$.

1 mark calculating the magnitude of $F_{B \text{ on } C}$.

1 mark calculating the magnitude of $F_{D \text{ on } C}$.

1 mark for determining the direction of all the forces from charges A, B and D.

1 mark for calculating both the horizontal and vertical components of the net force on charge C. Note: Directions are not required to obtain this mark.

1 mark for calculating the magnitude of the net force on charge C. Note: Direction is not required to obtain this mark.

Note: Diagrams are not required to obtain full marks. Accept follow-through errors.