QCAA PHYSICS EXTERNAL EXAM – 2023

MULTIPLE CHOICE QUESTIONS - SOLUTIONS AND EXPLANATIONS

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Note: *NCPQ* refers to *New Century Physics for Queensland*, U3 & 4, 2020, OUP.
Percentages (%) indicate the overall choice by students (QCAA Subject Report 2024)

Q		**%**	**Reasoning**
1	A	2.07	Incorrect. Length contraction changes the length in the direction of travel.
	B	12.14	Incorrect. As the velocity of an object increases the amount of time dilation also increases. That is, clocks aboard the moving object would appear to slow and as the object approached *c*, the clocks would slow to a standstill. This does not mean the velocity of the object would also slow, only their clocks. That would not prevent the object from attaining a speed of *c*.
	C*	78.88	Correct. Relativistic momentum approaches infinity as the speed approaches *c*. The formula $p_v = \frac{mv}{\sqrt{1-\frac{v^2}{c^2}}}$ shows that as v increases to c, the term below the line decreases to zero thus making p_v infinite.
	D	6.72	Incorrect. The inertia (its mass) will not change with increasing speed. The statement that inertia will decrease would mean that less and less force is required to keep accelerating an object and thus it would not be impossible to reach a speed of *c*.
2	A*	79.39	Correct. Gauge bosons are particles that mediate forces. Photons are gauge bosons that mediate the electromagnetic force. Photons are particles in the model for light but they can behave as a wave (eg diffraction, interference, polarisation) thus giving rise to the concept of ‘wave-particle duality’.
	B	9.91	Incorrect. It is correct to say they are particles, but they don’t need a medium for their propagation (travel).
	C	6.05	Incorrect. Photons are mediators of the electromagnetic force, not the weak nuclear force. Electrons are the mediators of the weak nuclear force.
	D	4.47	Incorrect. This statement is half true. They are not leptons, but it is true that photons have no charge.
3	A*	55.87	Correct. $$B = \frac{\mu_0}{2\pi}\frac{I}{r} = 2\times10^{-7}\times\frac{0.5}{0.020} = 5\times10^{-6}\ \text{T}$$ Using Ampere’s Right Hand Rule, thumb points down and fingers curl <u>out of the page</u> at position X.
	B	24.43	Incorrect. The field strength is correct, but the direction is wrong.
	C	11.15	Incorrect. The distance of 2.0 cm was not converted to 0.020 m. Direction is correct.
	D	8.17	Incorrect. Distance was not converted to 0.020 m and the direction is wrong.
4	A	9.6	Incorrect. This is a part of (Kepler’s) first law of planetary motion.
	B	8.52	Incorrect. This is describing the idea that objects tend to move in a straight line (Nowton’s first law) but when undergoing circular motion, the object needs a force to pull it towards the centre of the circle. This is not (Kepler’s) third law of planetary motion.

	C	18.01	Incorrect. This is (Kepler's) second law of planetary motion.
	D*	63.62	Correct. It equates the gravitational force F_g between objects as described by the Law of Universal Gravitation, $F_g = \frac{GMm}{r^2}$, and the force needed to make an object travel in a circle, $F_c = \frac{mv^2}{r}$.
5	A	11.89	Incorrect. It is true that light behaves differently in different situations, e.g. as a wave in Young's double slit experiment or as a particle in the photoelectric effect, but these situations are not called different frames of reference. A *frame of reference* is just an abstract coordinate system that defines location of the observer.
	B*	67.61	Correct. Light exhibits characteristics such as diffraction, interference and polarisation just as mechanical waves (sound, water, waves on springs and strings) do.
	C	12.38	Incorrect. Light waves exhibit <u>transverse</u> motion, not longitudinal. It is true that longitudinal waves (sound, water waves) can undergo diffraction and interference like light waves, but Young's experiment used light as the wave and that is known to be transverse (oscillations at right angles to the direction of travel).
	D	7.95	Incorrect. Young's experiment could only be explained if light behaved as a wave. It is true that light can behave as a particle as well (wave-particle duality), but the particle model is not consistent with Young's experimental results.
6	A	24.63	Incorrect. Used 160 m as the distance travelled in the 25 s.
	B*	52.67	Correct. The object moves in a circular motion from Y to Z, half the circumference of a circle: $s = 2\pi r/2 = (2 \times \pi \times 80)/2 = 251$ m. Velocity is $v = s/t = 250/25 = 10.1$ m s^{-1}. Centripetal force: $F_c = \frac{mv^2}{r} = \frac{6.0 \times 10^2 \times 10.1^2}{80} = 7.6 \times 10^2$ N.
	C	13.56	Incorrect. Used 160 m for the radius, not 80 m.
	D	8.42	Incorrect. Did not square the velocity.
7	A	8.74	Incorrect. In the way the question is presented there is no change in mass as the products are identical to the reactants. This is enough to say this option is incorrect. However, the option is partially correct. Mass is not always conserved, for example there is often a mass defect in nuclear reactions ($\Delta E = \Delta mc^2$) and this could also be the case here. Thus, while there could be a change in mass, it is unclear, so this option is best considered incorrect.
	B	7.95	Incorrect. Baryons are quark composites and there are no quarks or baryons mentioned in the interaction.
	C*	77.95	Correct. Lepton number is always conserved in a particle interaction. In this case the lepton number L = 0 at the start ($^{+}1 + {}^{-}1 = 0$) and L = 0 at the end ($^{+}1 + {}^{-}1$).
	D	5.23	Incorrect. There are two particles to start with and two at the end.
8	A*	41.34	Correct. $E = hf - W$ $= 6.626 \times 10^{-34} \times 1.7 \times 10^{15} - 1.00 \times 10^{-18}$ $= 1.26 \times 10^{-19} J$ $= \frac{1.26 \times 10^{-19}}{1.6 \times 10^{-19}}$ eV $= 0.79$ eV $(7.9 \times 10^{-1}$eV$)$
	B	9.29	Incorrect.

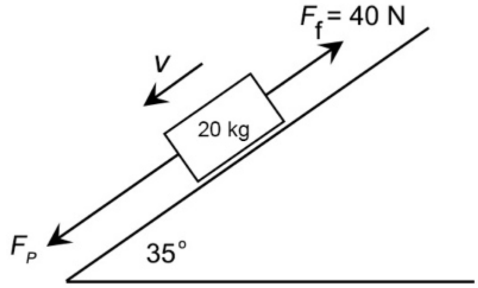
	C	41.9	Incorrect. This is the answer in joule (J) not eV.
	D	7.23	Incorrect. Multiplied the energy in joule (J) by 1.6×10^{-19} instead of dividing by it. $E = 1.26 \times 10^{-19} J$ $E = 1.26 \times 10^{-19} \times 1.6 \times 10^{-19}\text{eV}$ $= 2.0 \times 10^{-38}\text{eV}$ (wrong)
9	A	6.75	Incorrect. This solution would have had the equation upside down: $$emf(new) = \frac{2}{3 \times 0.75} = 0.89\ V$$
	B*	67.85	Correct. We assume the field is <u>uniform</u> since the question doesn't state anything about the type of magnet or the shape of the field. We can just apply (Faraday's) law of electromagnetic induction: $$emf = \frac{n\ \Delta B \times A_{\perp}}{\Delta t} = 0.75\ V$$ $$emf(new) = \frac{3n\ \Delta B \times \frac{A_{\perp}}{2}}{\Delta t} = \frac{3}{2} \times \frac{n\ \Delta B \times A_{\perp}}{\Delta t} = \frac{3}{2} \times 0.75 = 1.1\ V$$ Alternatively: First scenario: $$emf = \frac{n\ \Delta B \times A_{\perp}}{\Delta t}$$ $$0.75 = \frac{5 \times\ \Delta B \times 0.60}{\Delta t}$$ Second scenario: $$emf = \frac{n\ \Delta B \times A_{\perp}}{\Delta t}$$ $$0.75 = \frac{3 \times 5 \times\ \Delta B \times \frac{0.6}{2}}{\Delta t}$$ $$\Delta t = \frac{5 \times\ \Delta B \times 0.60}{0.75} = \frac{3 \times 5 \times\ \Delta B \times \frac{0.6}{2}}{emf}$$ $$\frac{5 \times\ 0.60}{0.75} = \frac{3 \times 5 \times\ \frac{0.6}{2}}{emf}$$ $$emf = \frac{3 \times 5 \times\ \frac{0.6}{2}}{5 \times\ 0.60} \times 0.75$$ $$= 1.1\text{ V}$$ **As a matter of interest:** fields from magnets are rarely uniform. An experiment conducted as described in the question does not provide a similar result. The relationship in practice is $emf \propto \frac{1}{A}$ where A is the area of the coil. The result would be $emf = 0.75 \times 3 \times 2 = 4.5$ V. However, option (B) is still correct based on the information provided. Remember, it's about selecting the best answer, not the one that is possible.
	C	8.55	Incorrect. Didn't halve the area:

			$$mf(new) = \frac{3n\,\Delta B \times A_\perp}{\Delta t} = 3 \times \frac{n\,\Delta B \times A_\perp}{\Delta t} = 3 \times 0.75 = 4.0\text{ V}$$
	D	16.13	Incorrect. Doubled the area instead of halving: $$mf(new) = \frac{3n\,\Delta B \times 2A_\perp}{\Delta t} = 6 \times \frac{n\,\Delta B \times A_\perp}{\Delta t} = 6 \times 0.75 = 4.5\text{ V}$$
10	A*	48.42	Correct. $$\lambda = \frac{b}{T} = \frac{2.898 \times 10^{-3}}{6040} = 4.798\ \times 10^{-7}\text{m}$$ $$f = \frac{c}{\lambda} = \frac{3 \times 10^{8}}{4.798\ \times 10^{-7}} = 6.3 \times 10^{14}\text{ Hz}$$
	B	10.4	Incorrect. Used formula as: $$\lambda = bT$$ $$= 2.898 \times 10^{-3} \times\ 6040 = 2.1\ \times 10^{6}$$
	C	29.56	Incorrect. This is the wavelength in metres, not the frequency in Hz.
	D	10.9	Incorrect. Had frequency formula upside down: $$f = \frac{\lambda}{c} = \frac{4.798\ \times 10^{-7}}{3 \times 10^{8}} = 1.6 \times 10^{-15}$$
11	A	19.27	Incorrect. This is true but is about electromagnetic induction.
	B	31.8	Incorrect. This is true but is about the force on a moving charge ($F = qvB$).
	C	3.22	Incorrect. This is more about Lenz's law.
	D*	45.5	Correct. Coulomb's law describes the strength of the force between changes as a function of the quantity of charge and separation distance. The direction of the force depends on the nature (+/-) of the charges.
12	A*	47.1	Correct. In all particle interactions momentum is conserved. This must occur when a symmetry operation is performed.
	B	12.89	Incorrect. Only in some symmetry operations are charges different. They don't necessarily have to be.
	C	31.94	Incorrect. Antiparticles are shown with their arrow pointing in the opposite direction to time, but this is not a consequence of symmetry but just a convention.
	D	7.82	Incorrect. Mass could be converted to energy, but it doesn't have to be such that the mass of products is less than the mass of reactants.
13	A	14.53	Incorrect. Would be at right angles to the electric field.
	B*	63.0	Correct. The change in flux due to the induced current must oppose the change in flux due to the magnet. Thus, it is in the opposite direction.
	C	18.22	Incorrect. Voltage and current are directly proportional ($V \propto I$) when resistance is constant.
	D	3.96	Incorrect. An *emf* is generated only when there is a change in magnetic flux. Once the magnet is removed there is no change in flux.
14	A	25.49	Incorrect. It is a lepton but has same mass as a positron.
	B	10.31	Incorrect. Is not a baryon but does have smaller mass than a proton.
	C	5.42	Incorrect. Is not a meson and does not experience the strong nuclear force.
	D*	58.57	Correct. Is electrically charged so interactions mediated by the electromagnetic force whose particles are photons.

<table>
<tr><td>15</td><td>A</td><td>9.22</td><td>Incorrect. Mass not doubled.</td></tr>
<tr><td></td><td>B*</td><td>58.79</td><td>Correct. Doubling the distance decreases the force by ¼. Increasing the mass of one object doubles the force. Result: $(\frac{1}{4} \times 2)F = \frac{1}{2}F$</td></tr>
<tr><td></td><td>C</td><td>20.9</td><td>Incorrect. $(2 \times r)$ not squared so force only halved due to doubling distance.</td></tr>
<tr><td></td><td>D</td><td>10.91</td><td>Incorrect. Says doubling the distance increases force by 4 and says that doubling the mass decreases force by 2. Result (4/2) $F = 2F$.</td></tr>
<tr><td>16</td><td>A</td><td>13.83</td><td>Incorrect. To a stationary observer at the tunnel, the train is less than 95 m so would not see both ends of the train at both ends of the tunnel at the same time. See Option D.</td></tr>
<tr><td></td><td>B</td><td>.86</td><td>Incorrect. Mass is invariant (not changing), thus there is no change in mass at any place.</td></tr>
<tr><td></td><td>C</td><td>5.41</td><td>Incorrect. There is no mention of the train changing speed. The question just says ‘relativistic speed’ and this is common (same value) to both observers.</td></tr>
<tr><td></td><td>D*</td><td>78.79</td><td>Correct. The (first) observer on the train is at rest (stationary) to the train so measures the length of the train to be the proper length: L_0 (train) = 95 m. The same observer on the train is moving relative to the tunnel so measures the relativistic (contracted) length of the tunnel: L (tunnel) = 95 m.

The second observer is stationary relative to the tunnel so measures the proper length of the tunnel: L_0 (tunnel), but observes the train to be moving, so would measure the relativistic (contracted) length of the train: L (train).

If the proper length of the train is 95 m, the second observer would measure this length contracted and thus shorter than 95 m. The second observer knows the proper length of the tunnel is 95 m, so the train, which appears shorter than 95 m, is thus shorter than the tunnel. Here is an example if the speed was 0.8 c.
<table>
<tr><td></td><td>1st observer on train</td><td>2nd observer at tunnel</td></tr>
<tr><td>Velocity</td><td>v = 0.8 c</td><td>v = 0.8 c</td></tr>
<tr><td>Train</td><td>L_0 (train) = 95 m</td><td>L (train) = 76 m (< 95 m)</td></tr>
<tr><td>Tunnel</td><td>L (tunnel) = 95 m</td><td>L_0 (tunnel) = 120 m (> 95 m)</td></tr>
</table></td></tr>
<tr><td>17</td><td>A</td><td>16.53</td><td>Incorrect. The particle has to be stationary in its own frame of reference (by definition). It is moving relative to the detector’s frame of reference.</td></tr>
<tr><td></td><td>B</td><td>3.45</td><td>Incorrect. The particle is moving relative to the detector so is moving relative to the detector’s frame of reference.</td></tr>
<tr><td></td><td>C*</td><td>74.78</td><td>Correct. The time of an event is longer (dilated) if the event occurs in a frame of reference moving relative to the observer. The detector sees the particle as moving so measures time in the particle’s frame as being dilated (longer).</td></tr>
<tr><td></td><td>D</td><td>5.06</td><td>Incorrect. The detector signals the detection of the particle irrespective of its speed. If the particle strikes the detector it is ‘present’; if it has already decayed it will not strike the detector.</td></tr>
<tr><td>18</td><td>A*</td><td>65.54</td><td>Correct.</td></tr>
</table>

			18.47  $F_p = $ mg sinθ $= 20 \times 9.8 \times \sin 35°$ $= 112$ N $F_{net} = 112 - 40$ $= 72$ N $a = \frac{F_{net}}{m} = \frac{72}{20} = 3.6$ m s^{-2} 8.04
	B	18.47	Incorrect. Did not subtract friction.
	C	8.04	Incorrect. Used cosθ instead of sinθ
	D	7.61	Incorrect. Added the forces instead of subtracting them.
19	A	10.05	Incorrect. Used *r* instead of r^2.
	B	19.69	Incorrect. Used *r* instead of r^2, and four protons (4+).
	C*	58.92	Correct. $E = \frac{kQ}{r^2} = \frac{9 \times 10^9 \times (2 \times 1.6 \times 10^{-19})}{(2.8 \times 10^{-11})^2} = \frac{2.88 \times 10^9}{7.84 \times 10^{-22}} = 3.7 \times 10^{12}$ N C^{-1}
	D	10.72	Incorrect. Treated the nucleus as having four protons (4+) instead of two protons (2+). A helium nucleus has 4 nucleons (2 protons, 2 neutrons) and a charge of 2+.
20	A	12.19	Incorrect. $n_1 \rightarrow n_3 = 48.4$ eV
	B	7.74	Incorrect. $n_1 \rightarrow n_4 = 51.4$ eV
	C	16.58	Incorrect. $n_2 \rightarrow n_3 = 7.6$ eV
	D*	63.21	Correct. $E = hf$ $= 6.626 \times 10^{-34} \times 6.3 \times 10^{14}$ $= 4.17 \times 10^{-19}$ J $E = \frac{4.17 \times 10^{-19}\text{ J}}{1.6 \times 10^{-19}\text{ J/eV}} = 2.6$ eV $n_3 \rightarrow n_4 = 6.0 - 3.4 = 2.6\ eV$

Whew! For other worked solutions to EA past papers see seniorphysics.com/ncpq