QCAA PHYSICS EXTERNAL ASSESSMENT 2021

ALTERNATIVE SEQUENCE

Worked solutions and explanations to Alternative Sequence Paper 1 Multiple choice

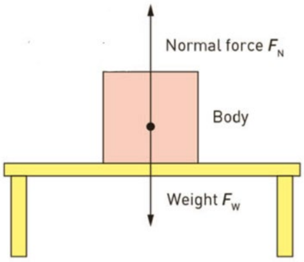
- from Dr Richard Walding, author *New Century Physics for Queensland* (OUP)

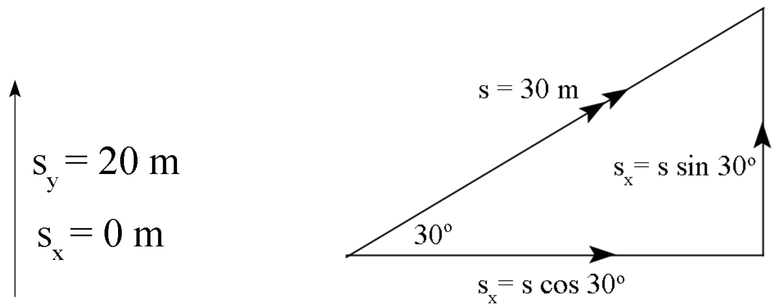
Note: I have included worked solutions and explanations to the multiple choice questions to other QCAA Physics EA papers on my website at seniorphysics.com/ncpq. See the bottom of that page for links.

Option	Solutions and explanations (validity statements and distractor justification)
1	**Leptons do not experience the…etc**
A	Incorrect. Leptons such as electrons and neutrinos do experience the weak force such as in beta decay.
*B	Correct. Quarks, but not leptons, experience the strong (nuclear) force. Even charged leptons such as electrons and positrons do not experience the strong nuclear force. Note that ‘strong force’ in the question is not a syllabus term and represents the syllabus term ‘strong nuclear force’. But we know what QCAA meant.
C	Incorrect. Objects with mass experience the gravitational force, and leptons do have mass. Even neutrinos are NOT massless.
D	Incorrect. Electrically charged particles experience the electromagnetic force, and leptons such as electrons, positrons and muons are electrically charged. However, not all leptons are electrically charged – such as neutrinos – and they will not experience the electromagnetic force.
2	**Calculate the initial horizontal velocity….etc**
A	Incorrect: $38 \times \sin 42° = 25$ m s^{-1}
*B	Correct: $38 \times \cos 42° = 28$ m s^{-1}
C	Incorrect: $42 \times \cos 38° = 33$ m s^{-1} (≈ 34 m s^{-1})
D	Incorrect: has calculated the average of the two values $(38 + 42)/2 = 40$ without any reason.
3	**Identify the correct formula for the mass–energy…etc**
*A	Correct. This is equivalent to the formula in the Formula Book and syllabus $\Delta E = \Delta mc^2$ where E or ΔE represent the change in energy, and m or Δm represent the equivalent change in mass.
B	Incorrect. This is the gravitational potential energy formula which relates the energy of an object of mass m at a position h in a gravitational field of strength g.
C	Incorrect. This formula incorrectly uses the non-relativistic kinetic energy formula $E = \frac{1}{2} mv^2$ to an object travelling at the speed of light where $v = c$, hence $E = \frac{1}{2} mc^2$, without taking into account relativistic effects.
D	Incorrect. This is the kinetic energy formula $E_k = \frac{1}{2} mv^2$ which relates the kinetic energy of an object of mass m travelling at a speed v. It only applies at non-relativistic speeds.
4	**What is the final velocity of a 5 kg...etc**
A	Incorrect. Calculated time of flight but had faulty rearrangement of second formula.

	$v = u + at$ $= 0 + \frac{1}{2} \times 9.8 \times 1.8$ $= 9\, m\, s^{-1}$
B	Incorrect. Faulty rearrangement of the formula. $s = ut + \frac{1}{2}at^2$ $v = \left(\frac{2s}{a}\right)^2$ $= \left(\frac{2 \times 16}{9.8}\right)^2$ $= 11\, m\, s^{-1}$
C	Incorrect. Faulty substitution into formula. $v^2 = u^2 + 2as$ $v = \sqrt{0 + 9.8 \times 16}$ $= 13\, m\, s^{-1}$
*D	Correct. $v^2 = u^2 + 2as$ $v = \sqrt{0 + 2 \times 9.8 \times 16}$ $= 18\, m\, s^{-1}$
5	**Mesons are …etc**
*A	Correct. Mesons are subatomic (but not elementary as they can be further subdivided into smaller particles: quarks and antiquarks). Only quarks and leptons are considered elementary. Mesons are composed of two particles only: a quark and an antiquark. By the way: the quark and antiquark don’t have to be the same flavour, eg up and antiup.
B	Incorrect. They are not elementary as they are a composite of two elementary particles (quark and antiquark). It is true that they are subatomic as they are smaller than an atom.
C	Incorrect. They are not elementary as they are a composite of two elementary particles (quark and antiquark). The particle exchanged between quarks is the gluon, not a meson. However, the gluon is also exchanged between mesons.
D	Incorrect. It is true that mesons are subatomic, but they are composed of two particles - a quark and an anti-quark. A composite particle composed of three quarks, such as a proton or a neutron, is known as a *baryon*. However, a meson and a baryon are different, but both belong to the group known as hadrons because they are quark composites.
6	**The mass defect is the difference...etc**
A	Incorrect. The mass of a proton is slightly heavier than a neutron but the difference is not called mass defect. It is to do with the extra energy needed to keep the proton together compared to a neutron.
B	Incorrect. It is true to say the mass of a parent nucleus is different to the mass of the daughter nucleus after radioactive decay, but this is not 'mass defect'. It is similar to mass defect but is just the mass carried off by the emitted particles and the mass equivalence of energy released.

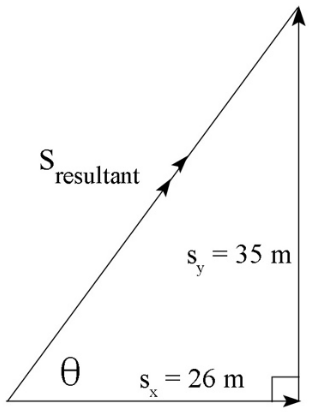
<table>
<tr><td>*C</td><td>Correct. Mass defect is defined as the mass of an intact nucleus and the sum of the masses of the individual nucleons of which it is made. See NCPQ U1&2 p 142.</td></tr>
<tr><td>D</td><td>Incorrect. There is no such quantity as relativistic mass, only relativistic momentum. The only mass dealt with in Special Relativity is rest mass, m_o.</td></tr>
<tr><td></td><td></td></tr>
<tr><td>7</td><td>Normal force is the force acting...etc</td></tr>
<tr><td>A</td><td>Incorrect. This would be an applied force or friction, or some component of the weight or normal force.</td></tr>
<tr><td>*B</td><td>Correct. The normal force acts perpendicular to the surface such as in this case here where the tabletop is horizontal, and the normal force is vertical.


</td></tr>
<tr><td>C</td><td>Incorrect. The gravitational force is equal in magnitude and opposite in direction to the normal force on an object, if the object is not accelerating, and is on a horizontal surface. On an inclined plane, for instance, the gravitational force acts vertically down, whereas the normal force acts in an upwards direction (that is, opposite) but is perpendicular to the incline, and thus at an angle to the vertical.</td></tr>
<tr><td>D</td><td>Incorrect. When there is no acceleration, the forces are balanced, so the normal force and the force due to gravity are equal <u>but opposite</u>. As a side-note, they are not a Newton's 3rd law action-reaction pair.</td></tr>
<tr><td></td><td></td></tr>
<tr><td>8</td><td>The diagram shows two displacement vectors… etc</td></tr>
<tr><td>A</td><td>Incorrect. Calculated the complement of the angle (90° – 53.4° = 36.6°)</td></tr>
<tr><td>*B</td><td>Correct.
1. Decomposition method.
The two vectors can be decomposed (resolved) into two vectors at right angles; one in the y-direction (or vertical), and one in the x-direction (horizontal):



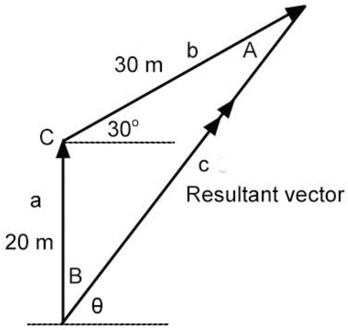
The two components in each direction can now be added:

<table>
<tr><th></th><th>y-direction</th><th>x-direction</th></tr>
<tr><td>Vector A (m)</td><td>20</td><td>0</td></tr>
<tr><td>Vector B (m)</td><td>30 sin 30° = 15</td><td>30 cos 30° = 26</td></tr>
<tr><td>Addition $\vec{A} + \vec{B}$ (m)</td><td>35</td><td>26</td></tr>
</table></td></tr>
</table>



$$s_{resultant} = \sqrt{26^2 + 35^2}$$
$$= 43.6\ m$$
$$\theta = tan^{-1}\frac{35}{26}$$
$$= 53.4°$$

2. Cos/sin method



Cosine rule:

$$c^2 = a^2 + b^2 - 2ab\cos c$$
$$= 20^2 + 30^2 - 2\times 20\times 30\times \cos(90+30)$$
$$= 1300 - (-600)$$
$$= 1900$$
$$c = \sqrt{1900} = 43.6\,m$$

Sin rule:

$$\frac{b}{\sin B} = \frac{c}{\sin C}$$
$$\frac{30}{\sin B} = \frac{43.6}{\sin 120^\circ}$$
$$\sin B = \frac{30\times 0.866}{43.6} = 0.596$$
$$B = \sin^{-1} 0.566 = 36.6^\circ$$
$$\therefore \theta = 90^\circ - 36.6 = 53.4^\circ$$

C	Incorrect. Used *cos* in vertical and *sin* in horizontal; and stated the complement of the angle.

D	Incorrect. Used *cos* in vertical and *sin* in horizonal. Angle correctly calculated for these wrong vectors.
9	**Alpha radiation is defined as…**
A	Incorrect. It is release of energy from an unstable nucleus but not in the form of electromagnetic radiation (gamma rays) but in the form of discrete particles.
B	Incorrect. The radiation emitted from a blackbody is in the form of electromagnetic radiation or photons. See NCPQ U3&4 p305.
C	Incorrect. This is the property for electromagnetic radiation. See NCPQ U1&2 p 114, or U3&4 p 231 and p 302.
*D	Correct. See NCPQ U1&2 p 166.
10	**Proper length is the length measured…etc**
*A	Correct. *Proper length* is the length as measured by an observer at rest to the object being measured.
B	Incorrect. If the object appears to be moving to an observer, that observer will measure dilated (or relativistic) length but will also agree that the observer moving with the object will measure proper length.
C	Incorrect. The term 'accelerating' implies that an object is in motion, and thus measurement of the length of the object by an observer who sees the object accelerating will not be the *proper length*. You could also argue that Special Relativity applies only to objects moving at constant velocity relative to one another, and so the idea of *proper length* is not covered by the theory.
D	Incorrect. If the object appears to be moving to an observer, that observer will measure dilated (or relativistic) length – irrespective of whether the object is at constant velocity or is accelerating.
11	**Uniform circular motion occurs…etc**
A	Incorrect. The force has to be perpendicular not parallel. The first part 'constant speed, due to a force of constant magnitude', however, is correct.
B	Incorrect. The force has to be perpendicular not parallel, and has to refer to velocity (which is a vector so has a direction) and not speed (which is a scalar and has no direction).
*C	Correct. Must have a constant *speed* (not velocity) because its direction of motion is always changing so the velocity is changing. Also, the force must be *perpendicular* to the direction of the *velocity* vector.
D	Incorrect. The answer has to refer to *velocity* (which is a vector so has a direction) and not to *speed* (which is a scalar and has no direction).
12	**Calculate the maximum height…etc**
*A	Correct. The initial velocity of the projectile in the vertical direction is: $u_y = u\sin\theta$ $= 15\sin 30^\circ$ $= 7.5\, m\, s^{-2}$ At the top of it's flight the projectile has zero velocity (v_y = 0 m s^{-1})

	$v_y{}^2 = u_y{}^2 + 2gs_y$ $0 = 7.5^2 + 2\times(-9.8)\times s_y$ $s_y = \frac{-56.25}{19.6}$ $= 2.87\,m$
B	Incorrect – used 35° for the angle instead of 30°
C	Incorrect – used 15 × cos30° for u_y instead of 15 × sin30°
D	Incorrect – used 15 m s^{-1} for u_y instead of 15 × sin30°
13	**Calculate the orbital period…etc**
A	Incorrect – used r^2 instead of r^3 in the first equation $\frac{T^2}{r^2} = \frac{4\pi^2}{GM_e}$ $\frac{T^2}{(4.00\times10^8)^2} = \frac{4\pi^2}{6.67\times10^{-11}\times5\times10^{24}}$ $T^2 = 1.58\times10^4$ $T = 1.26\times10^2\,s$ $= 3.49\times10^{-2}\,h$
B	Incorrect – used 4π instead of 4π^2 in the equation $\frac{T^2}{r^3} = \frac{4\pi}{GM_e}$ $\frac{T^2}{(4.00\times10^8)^3} = \frac{4\pi}{6.67\times10^{-11}\times5\times10^{24}}$ $T^2 = 2.02\times10^{12}$ $T = 1.42\times10^6\,s$ $= 3.94\times10^2\,h$
*C	Correct. $\frac{T^2}{r^3} = \frac{4\pi^2}{GM_e}$ $\frac{T^2}{(4.00\times10^8)^3} = \frac{4\pi^2}{6.67\times10^{-11}\times5\times10^{24}}$ $T^2 = 6.34\times10^{12}$ $T = 2.519\times10^6\,s$ $= 6.99\times10^2\,h$
D	Incorrect – used the T^2 value as seconds and then converted this to hours: $T^2 = 6.34\times10^{12}$ $T \neq \frac{6.34\times10^{12}}{60\times60} = 1.76\times10^9\,h$ [incorrect]
14	**Which example describes one of Newton's laws of motion…etc.**
A	Incorrect. Acceleration will depend on the mass and the force applied (2nd law)

*B	Correct.
C	Incorrect. This is a correct statement related to Einstein's Theory of Special Relativity but not to Newton's laws.
D	Incorrect. This is a correct statement related to Newton's law of universal gravitation but now to Newton's laws of motion.
15	**Which Feynman diagram shows an electron**
*A	Correct. See *New Century Physics for Queensland* (Walding) Units 3&4, page 384, or the QCAA booklet *Feynman diagrams: representing particle interactions.* https://www.qcaa.qld.edu.au/downloads/senior-qce/sciences/snr_physics_19_Feynman_diagrams.pdf
B	Incorrect. The lower left particle is a positron, e+. This is an example of electron-positron *scattering*.
C	Incorrect. The lower left particle is a positron, e+. This is an example of electron-positron *annihilation*.
D	Incorrect. This is an example of a neutron decaying into a proton (beta negative decay).
16	**The weight of a 5 kg object on Earth is…etc**
A	Incorrect. This option wrongly assumes g = 9.8 cm/s^2 (in centimetres, not metres) so the result has to be divided by 100 to get it to metres. F_g = 5 × 9.8/100 = 0.49 N
B	Incorrect. This option is the result of incorrectly writing the formula as $F_g = m/g$ = 5/9.8 = 0.51 N.
*C	Correct. Weight is a measure of the gravitational force on an object: $F_g = mg$. On the surface of the Earth g = 9.8 m s^{-2}. Thus F_g = 5 × 9.8 = 49.0 N
D	Incorrect. This option wrongly assumes g = 9.8 cm/s^2, and incorrectly transcribes the formula as F_g = m/g, so the result had to be divided by 100 to get it to metres: F_g = 5/(9.8/100) = 51 N
17	**Which fundamental force is mediated by photons…etc**
A	Incorrect. The gravitational force is mediated by the gravitational field and its mediating particles are tentatively called 'gravitons', but yet to be confirmed.
B	Incorrect. The weak nuclear force's mediating particles are W+, W-, and Z^0 gauge bosons.
C	Incorrect. The strong nuclear force is mediated by gluons.
*D	Correct. Photons mediate the electromagnetic force. See NCPQ U3&4 p361 for table.
18	**A gravitational field is the…etc**
A	Incorrect. This is the definition of the *gravitational field strength, g,* which is given by the formula: $F_g = mg$, hence $g = F_g/m$. That can be stated as net gravitational force per unit mass.
B	Incorrect. This is the definition of *gravitational potential energy*: $E_P = mgh$.
*C	Correct. A gravitational field is a *region of space* around a mass in which a gravitational force can be experienced by another mass.
D	Incorrect. It is true that it is a region of space, but it could apply to the force needed to move a charged particle in a magnetic field, or a gravitational field, not just an electric field. Work will be done in all cases.
19	**A spaceship with a velocity of 9.0**
A	Incorrect. The 125 m is incorrectly designated as *proper length* L_0 because the question uses the term 'measured …to an observer at rest'. However, the observer is at rest relative to the spaceship – which is moving. The question does not say the observer is at rest relative to the spaceship. This option uses this calculation (which is wrong):

	$L = L_0\sqrt{1-(v/c)^2}$ $= 125\times\sqrt{1-(\frac{9\times10^7}{3\times10^8})^2} = 125\times0.9539$ $= 119\,m$
*B	Correct. The observer is at rest and sees a spaceship moving at a relativistic speed and measures the spaceship's length to be 125 m. This is the *relativistic length L*. It is not the proper length L_0 as the observer is not at rest to the spaceship which is moving. I found it very tricky. $L = L_0\sqrt{1-(v/c)^2}$ $L_0 = \frac{L}{\sqrt{1-(v/c)^2}} = \frac{125}{\sqrt{1-(\frac{9\times10^7}{3\times10^8})^2}} = \frac{125}{0.9539}$ $= 131\,m$
C	Incorrect. The *relativistic length L* is correctly identified, but the square root in the denominator has been omitted. This option uses the calculation: $L_0 = \frac{L}{1-(v/c)^2} = \frac{125}{1-(\frac{9\times10^7}{3\times10^8})^2} = \frac{125}{0.910}$ $= 137\,m$
D	Incorrect. This answer has used a wrong value for speed (9.0×10^8 instead of 9.0×10^7) and then ignored the subsequent negative in the square root. That is: $L = L_0\sqrt{1-(v/c)^2}$ $L_0 = \frac{L}{\sqrt{1-(v/c)^2}} = \frac{125}{\sqrt{1-(\frac{9\times10^8}{3\times10^8})^2}} = \frac{125}{\sqrt{-2}} = \frac{125}{1.414}$ $= 177\,m\,(\approx 178\,m)$
20	**To determine a value for acceleration due to gravity…etc**
A	Incorrect. Acceleration is independent of mass so will have no effect on any measurement. However, if the increased mass meant a larger surface area then there may be some additional drag forces but that would make the result less accurate. There was no mention of any other changes to the object except mass anyway.
B	Incorrect. More trials would reduce the measurement uncertainty so would reduce the random error. The experiment would be more precise, but the accuracy would not change. That is, the percentage error, E%, would be the same.
*C	Correct. Increased height would result in a longer flight time so any errors in the human count time would have a proportionally smaller effect on the actual time. This would be considered a systematic error as you would expect the student to overestimate the actual time or underestimate the actual by the same amount each time. A reduction in systematic error would make the observed result closer to the actual result and hence improve the accuracy by reducing the percentage error.
D	Incorrect. This would not necessarily improve the accuracy of the result as there would still be the human reaction time involved. That is, judging the moment at the start when the ball was dropped and the moment when the ball struck the ground. Each measurement required a press to the stopwatch and would involve human reaction time.

	This could be a delay of up to 0.2 s for each event so it is not certain that use of the stopwatch would definitely improve accuracy.