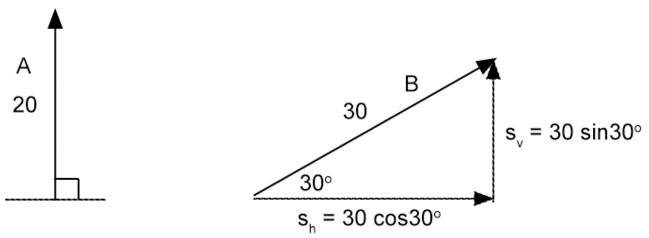
QCAA PHYSICS EXTERNAL ASSESSMENT 2021

Worked solutions and explanations to Paper 1 Multiple choice

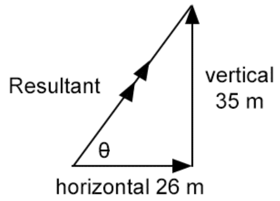
- from Dr Richard Walding, author *New Century Physics for Queensland* (OUP)

Note: I have included worked solutions and explanations to the multiple choice questions of the QCAA Physics 2020 EA and the 2019 Sample EA in the *Oxford Study Buddy* Vol. 1 (Walding & O'Callaghan, 2021). See: oup.com.au/studybuddy

Q	Option	Solutions and explanations (validity statements and distractor justification)
1	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	A	Correct: 38 × cos 42° = 28 m s^{-1}
	B	Incorrect: 38 × sin 42° = 25 m s^{-1}
	C	Incorrect: 42 × 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	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 $E = ½\ mv^2$ to an object travelling at the speed of light where $v = c$, hence $E = ½\ mc^2$, without taking into account relativistic effects.
	D	Incorrect. This is the kinetic energy formula $E_k = ½\ mv^2$ which relates the kinetic energy of an object of mass m travelling at a speed v. It only applies at non-relativistic speeds.
4	A	Incorrect. It is true that if one of the charges is doubled the force will double, but if the separation distance is halved the force will increase, so they are both increasing and so the force will not stay the same (1F).
	B	Incorrect. It is true that if the separation distance is halved the force will increase fourfold (as it is an inverse square relationship). But if one of the charges is doubled the force will double. For the answer to be 2F, this force would have to halve (not double) so that the product of 4× and ½ × will be 2× (or 2F).
	C	Incorrect. Both changes result in an increase in the force. Doubling the charge will amount to 2F, but halving the distance will amount to $(2d)^2$ or 4F. This option does not take into consideration that the distance is an inverse squared relationship.
	D	Correct. $F = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}$ $F = \frac{k\,q_1q_2}{d^2}(initial\ force)$ $F' = \frac{k\,q_1 \times 2q_2}{\left(\frac{d}{2}\right)^2} = \frac{8 \times k\,q_1q_2}{d^2} = 8F$

5	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	A	Incorrect. *Electromagnetic radiation (emr)* applies to all frequencies of wave-based radiation not just high frequency. It is true that extremely high-frequency radiation, such as gamma radiation, is emitted from the nucleus of some radionuclides during nuclear reactions, but this is irrelevant.
	B	Incorrect. It is true that *emr* can display wave or particle properties, but it doesn't have to be in the form high energy ionising particles. This option is only partly true.
	C	Incorrect. It is true that *emr* is a wave of energy produced by an oscillating electric charge. However, the mutually perpendicular electric (E) and magnetic (B) fields <u>are</u> the wave of energy, and not <u>resulting from</u> the wave of energy. The E and B fields are also synchronised as well as being mutually perpendicular. A correct statement would be 'Emr is a wave of energy consisting of mutually perpendicular synchronised electric and magnetic fields produced by an oscillating electric charge.' In summary, this option is partly true.
	D	Correct. Although this option has omitted the term 'mutually perpendicular' – all parts of it are correct, nonetheless. Note that the condition 'in a vacuum' is correctly appended to 'propagated at the speed of light'. Without a mention of a vacuum, this statement would be incorrect. Be warned!
7	A	Incorrect. The statement 'parallel to the surface' refers to one of the common components used in incline plane questions, and this option is designed to trick you by seeming familiar. It is correct for inclines but irrelevant for this question.
	B	Correct. 'Normal' means perpendicular to the surface, even if the surface is not horizontal. It from the Latin *norma* meaning a 'carpenter's square'.
	C	Incorrect. This statement is partially correct for objects on a horizontal surface where the only applied force acting is gravity. At other angles such as on an incline, or an object being pushed or pulled at an angle to the surface, this statement is incorrect. It is also incorrect when the force is due to a magnetic or electric field for example.
	D	Incorrect. It is neither just for gravitational force, nor in the direction of the applied (gravitational, magnetic, electric) force, but would be in the opposite direction if anything.
8	A	Incorrect. The magnitude of the resultant vector is correct but the interior opposite angle (90° – 54.4°) is given in the answer.
	B	Correct. **1. Decomposition (components) method** Firstly, determine the horizontal and vertical components of the two vectors: 

	Vertical component (m)	Horizontal component (m)
Vector A	20	0
Vector B	30 sin30° = 15	30 cos30° = 26
Sum	35	26

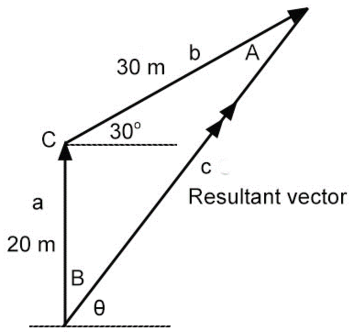


$$\text{resultant} = \sqrt{35^2 + 26^2} = 43.6\,m$$

$$\tan^{-1}\theta = \frac{35}{26}$$

$$\theta = 53.4^{\circ}$$

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. For vector B, answer incorrectly used *sin* for horizontal and *cos* for vertical, and incorrectly gave the interior opposite angle (90° – 71.9°) based on this result.
	D	Incorrect. For vector B, answer incorrectly used *sin* for horizontal and *cos* for vertical, however, gave the correct angle of 71.9° based on this result.

9	A	Incorrect. This is Dalton's 'billiard ball' model from 1808. Because Dalton thought atoms were the smallest particles of matter, he envisioned them as solid, hard spheres, like billiard balls, so he used wooden balls to model them.
	B	Incorrect. This is a part of Rutherford's model in which he said negatively charged electrons orbit the nucleus, but he didn't say they were in fixed orbits like Bohr said later.
	C	Incorrect. This is Thomson's 'plum pudding' model in which electrons were scattered in a sphere of a positively charged substrate (or 'fluid') like raisins in a plum pudding. The Bohr model proposed that the electrons were in fixed orbits or 'stationary states' around a small dense positively charged nucleus, and not just scattered throughout the atom.
	D	Correct. The Bohr model still uses the Rutherford model of a *small positive nucleus surrounded by negative electrons* but also states that the electrons orbit the nucleus in *particular circular orbits* with *fixed* angular momentum and *energy*.
10	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	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	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	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 $4\pi^2$ 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	A	Incorrect. There is no change to the magnitude of the charge but there may be separation of the charges.
	B	Incorrect. Similar to Option A: there is no change to the magnitude of the charge but there may be separation of the charges.
	C	Incorrect. The force is perpendicular, not parallel to the field.
	D	Correct. A moving charge experiences a force perpendicular to the direction of the magnetic field. This is usually demonstrated using Fleming's LH Rule, or the Right-hand Palm (Slap) rule. In both cases, the force is at right angles to the field. See *New Century Physics for Queensland* (Walding) Units 3&4, page 195 (see diagram opposite):

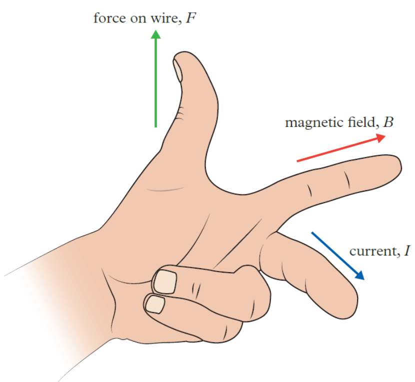


FIGURE 1 Fleming's left-hand rule

15	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	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. $F_g = 5 \times 9.8/100 = 0.49$ 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 $F_g = 5 \times 9.8 = 49.0$ N
	D	Incorrect. This option wrongly assumes g = 9.8 cm/s^2, <u>and</u> 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	A	Incorrect. This is the definition of *electric field strength*, *E*.
	B	Incorrect. This is the definition of *electric potential difference*, ΔV.
	C	Correct. Energy is defined as the capacity to do work. Hence, *electrical potential energy is the capacity of electric charge carriers*, such as electrons, *to do work*. They owe their energy to their *position in an electrical circuit* which is an arbitrary measure of the electric field strength at that point in the circuit.
	D	Incorrect. This is partly true, but it only requires the electron to be moved though an electrical potential difference and this could be at either a constant speed or accelerating. Also, it doesn't have to be one volt as the options says. It may be, but it could be any electrical potential difference.
18	A	Incorrect. This is the definition of the *gravitational field <u>strength,</u> 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	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 <u>does not</u> say the observer is at rest relative to the spaceship. This option uses this calculation (which is wrong): $L = L_0\sqrt{1-(v/c)^2}$ $= 125 \times \sqrt{1-(\frac{9\times10^7}{3\times10^8})^2} = 125 \times 0.9539$ $= 119\,m$
	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.

		$L = L_0\sqrt{1-(v/c)^2}$ $L_0 = \dfrac{L}{\sqrt{1-(v/c)^2}} = \dfrac{125}{\sqrt{1-(\frac{9\times10^7}{3\times10^8})^2}} = \dfrac{125}{0.9539}$ $= 131\,m$
	C	Incorrect. The *relativistic length L* is correctly identified, but the square root in the denominator has been omitted. This option uses the calculation: $L_0 = \dfrac{L}{1-(v/c)^2} = \dfrac{125}{1-(\frac{9\times10^7}{3\times10^8})^2} = \dfrac{125}{0.910}$ $= 137\,m$
	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: $L = L_0\sqrt{1-(v/c)^2}$ $L_0 = \dfrac{L}{\sqrt{1-(v/c)^2}} = \dfrac{125}{\sqrt{1-(\frac{9\times10^8}{3\times10^8})^2}} = \dfrac{125}{\sqrt{-2}} = \dfrac{125}{1.414}$ $= 177\,m\,(\approx 178\,m)$
20	A	Incorrect. This option has calculated the energy of the photon at the threshold frequency in joule (J) but has not converted it to a frequency in Hz. In effect, the answer is just the work function (hf_0) in joule, but is stated as a frequency in Hz. $E = hf - hf_0$ $2.5\times10^{-19} = h\times1.3\times10^{15} - hf_0$ $= (6.625\times10^{-34}\times1.3\times10^{15}) - hf_0$ $hf_0 = 8.6\times10^{-19} - 2.5\times10^{-19}$ $= 6.1\times10^{-19}\ J\ [= work\ function, W]$
	B	Incorrect. This option uses the equation $E = hf$ to calculate the frequency, but this is just the energy of the ejected electron and can not be applied to a photon to determine its frequency. $E = hf$ $f = \dfrac{E}{h} = \dfrac{2.5\times10^{-19}}{6.625\times10^{-34}}$ $= 3.77\times10^{14} Hz$
	C	Correct. $E = hf - hf_0$ $2.5\times10^{-19} = h(1.3\times10^{15} - f_0)$ $\dfrac{2.5\times10^{-19}}{6.625\times10^{-34}} = 1.3\times10^{15} - f_0$ $f_0 = 1.3\times10^{15} - 3.77\times10^{14}$ $= 9.2\times10^{14}\ Hz$
	D	Incorrect. Rearranging Equation 1 below is incorrect. The sign in Equation 2 should be a negative (–).

		$E = hf - hf_0$ $2.5\times10^{-19} = h(1.3\times10^{15} - f_0)$ $\frac{2.5\times10^{-19}}{6.625\times10^{-34}} = 1.3\times10^{15} - f_0$ [Equation 1] $f_0 = 1.3\times10^{15} + 3.77\times10^{14}$ [Equation 2] $= 1.7\times10^{15}\ Hz$

All the best for the 2022 EA.