**VCE Physics**
**Solutions to the 2017 Paper: Version: November, 2017**
**Suggested Marking Scheme in italics**
**Consequentials are indicated as "Conseq on 1"**

These suggested solutions have been prepared by Vicphysics Teachers' Network. Their purpose is to assist teachers and students when using this exam paper as a revision exercise.

Every effort has been made to check the solutions for errors and typos.

**Section A**

1 D Others are wrong.
2 B Using $F = Eq$, $F = 10^4 \times 9.6 \times 10^{-19} = 9.6 \times 10^{-15}$ N
3 A Using $E = V/d$, $V = E \times d = 1000 \times (5.0/1000) = 5.0$ V
4 D Ratio of turns = Ratio of voltages = 240 / 12 = 20 : 1
5 C Using $P = VI$, $I_{RMS} = P/V = 48 / 12 = 4.0$ A, so $I_{peak} = 4.0 \times \sqrt{2} = 5.7$ A
6 D Graph of induced emf is proportional to the gradient of the magnetic flux graph, so D
7 C Using $F = ma$, $a = F/m = 4.0 / 2.0 = 2.0$ m s$^{-2}$
8 C Using $I = F\Delta t = 4.0 \times 5.0 = 20$ N s
9 C Using $v = u + at$, $v = 0 + 2.0 \times 10 = 20$ m s$^{-1}$ Conseq on Q'n 7 for B and D. Using $\Delta p = m\Delta v = F\Delta t$, $\Delta v = 4.0 \times 10 / 2.0 = 20$ m s$^{-1}$ Conseq on Q'n 8 for D. Note: Consequentials in multiple choice questions are not normally awarded.
10 B A: Wrong, C: results are the same, D: Wrong
11 B Using $E = mc^2$, $m = 3.8 \times 10^{26} / (3 \times 10^8)^2 = 4.2 \times 10^9$ kg
12 C Using $F = kx$, $k = 400 / 1.0 = 400$ N m$^{-1}$
13 B Using Area under graph initial KE = ½ x 200 x 0.50 = 50 J. Or use $\frac{1}{2}kx^2$, consequential on Q'n 12 for B and D using this unlikely method. Note: Consequentials in multiple choice questions are not normally awarded.
14 D A, B: factually wrong, C: wrong explanation
15 A B, C and D: factually wrong
16 B A: does not make sense, C: Properties of slit width don't depend on the electron, D: Approach is head on
17 D A; wrong, electrons have wave properties, B: energy requirements determined by interaction between electrons and the nucleus, C: Energy levels are not diffraction patterns
18 A The use of the phrase 'the true value' is problematic in this question as a definition that might apply in this instance is either '*something measured perfectly*' or '*the value obtained after an infinite series of measurements performed under the same conditions with an instrument not affected by systematic errors*' both of which are obviously unrealistic in a school laboratory. If one assumes that 9.35 mA was the result of such an exercise, then as accuracy means closeness to this reading, Rob is more accurate than Jan. Precision refers to the spread on readings with a range of 0.50 mA for Rob and 0.16 mA for Jan, so Jan is more precise.
19 A B, C and D all wrong
20 A or D It could be argued that the answer to this question could be either A or D, depending on your interpretation of what the random error refers to. Taking repeated readings, means that the resultant average value is more likely to represent the "true value" of the quantity, due to the cancellation of random fluctuations in the measurement process, reducing the uncertainty (sometimes incorrectly referred to as error) in the averaged value, corresponding to answer A. However, each reading is subject to random error, with the same unpredictable contribution each time, so the random error in each measurement is the same, corresponding to answer D. Systematic errors are due to the configuration of the measuring instrument itself and so are not eliminated by repeated readings.

**Section B**

1 ← The field of the - Q charge on the left is to the left, the field of the + Q charge in the middle is also to the left, while the field of the -Q charge on the right is to the right, but weaker by a factor of 9, so the combined effect is a field to the left.*(1)*

2a Using $F = kQq/r^2$, $F = 9.0 \times 10^9 \times (1.6 \times 10^{-19})^2 / (53 \times 10^{-12})^2$ *(1)* $= 8.20 \times 10^{-8}$ N *(1)*

2b $2.2 \times 10^6$ m s$^{-1}$ Using $F = mv^2/r$, $v^2 = Fr/m$ *(1)* $= 8.2 \times 10^{-8} \times 53 \times 10^{-12} / (9.1 \times 10^{-31})$ *(1)*
$v^2 = 4.775 \times 10^{12}$, so $v = 2.2 \times 10^6$ m s$^{-1}$ *(1)*

3a 0.90 N, down Using I = V/R, I = 9.0 / 6.0 = 1.5 A, so using F = nBI*l*, *(1)*
F = 10 x 0.50 x 1.5 x (12/100) = 0.90 N. *(1)* Using the hand rule, the field is to the right, the current is from J to K, so the direction of the force is down. *(1)*

3b Zero The direction of current is parallel to that of the magnetic field *(1)*, so the magnitude of the force is zero. *(1)*

4a 0.60 N/kg Using $g = GM/r^2$, $g = 6.67 \times 10^{-11} \times 1.3 \times 10^{22} /(1.2 \times 10^6)^2$ *(1)* = 0.602 *(1)*
Unit is N kg$^{-1}$. *(1)* Note: an alternative unit is m s$^{-2}$. There should have been a separate box for the unit.

4b $5.2 \times 10^5$ s Using $R^3 / T^2 = GM/4\pi^2$, *(1)* $T^2 = (1.8 \times 10^7)^3 \times 4\pi^2 / (6.67 \times 10^{-11} \times 1.3 \times 10^{22)}$, *(1)*
$T^2 = 2.655 \times 10^{11}$, $T = 5.153 \times 10^5$ s $= 5.2 \times 10^5$ s. *(1)*

4c Rick and Nam are wrong *(1), (1)*, Melissa is correct *(1)*. If the radius of the satellite is to be the same as Charon's, then a greater speed means a shorter period and a slower speed means a longer period. However as the answer to the previous question showed, the period of a satellite depends only on the radius of the satellite's orbit. The other factors are properties of the central body, Pluto.

5a 1.7 T Using Φ = BA, B = 0.20 / (0.30 x 0.40) *(1)* = 1.666 T *(1)*.
The unit is Tesla, symbol T. *(1)* Note the number of turns is not relevant as the same amount of flux passes through each turn. The number of turns only comes into play when calculating the size of the induced emf, when each turn produces a small emf and the total emf is this small emf x number of turns.

5b 32 V The time for a quarter turn = (1/4) x (1/4) = 1/16 s.
Using Total EMF = N ΔΦ / Δt, *(1)*so Total EMF = 10 x (0.20 - 0) / (1/16) *(1)*
Total EMF = 32 V = *(1)*

5c The parts of the voltage graph that are below the time axis will be reflected above the time axis, *(1)* so that the final graph will be a series of four humps in the top half of the graphing space. *(1)*

6a 120 kW Using power loss = $I^2R$, the power loss = $200^2 \times 3.0$ *(1)* $= 1.2 \times 10^5$ W = 120 kW*(1)*

6b 4 As the transformer is ideal, there is no power loss, so if the secondary voltage is halved, the secondary current will be doubled. *(1)* But the power loss ∝ (current)$^2$, so the power loss increases by a factor of 4. *(1)*

7a Net force arrow: horizontal and to the left. *(1)* Other arrows i) a vertically downwards arrow to represent the force by the earth on the rider and bicycle and ii) an upwards arrow angled to the left so that it is at right angles to the track to represent the normal reaction force by the track on the rider and the bicycle. *(1)*

7b $27^0$ Vertically mg = N cos θ , Horizontally net force = $mv^2/r$ = N sin θ, so combining equations, tan θ = $v^2/gr$, so tan θ = 10 x 10 /(9.8 x 20) = 0.510, *(1)*
so θ = $27.03^0$, rounding to θ = $27^0$. *(1)* If g = 10 is used, θ = $26.57^0$

8a 7.9 m s$^{-1}$ At top if n = 0, then $mv^2/r = mg$, $v^2 = gr$, so $v^2 = 9.8 \times 6.4 = 62.72$ *(1)*,
so v = 7.9 m s$^{-1}$ . *(1)* If g = 10 is used, v = 8.0 m s$^{-1}$.

8b 11 m s$^{-1}$ Using KE + GPE at P = KE at Q, ½mu$^2$ + mgh = ½mv$^2$. Cancel 'm' and multiply through by 2 to give $u^2 + 2gh = v^2$, so $v^2 = 4.0^2 + 2 \times 9.8 \times 5.0 = 114$, *(1)*
so v = 10.68 m s$^{-1}$, rounding to 11 m s$^{-1}$. *(1)* If g = 10 is used, $v^2 = 116$, v = 10.77 m s$^{-1}$.

9a 4.0 m Horizontal: u = 20 cos $30^0$ = 17.3 m s$^{-1}$, time of travel = dist/speed = 26 / 17.3, time = 1.50 s. *(1)* Vertically with up being positive: u = 20 sin $30^0$ = 10, a = -9.8, t = 1.50, s = ?. So using s = ut + ½at$^2$, s = 10 x 1.50 - ½ x 9.8 x $1.50^2$ *(1)* = 3.97 m, rounding to 4.0 m. *(1)* If using g = 10, s = 3.74 m

9b Controlled: one of the following: angle, mass of the ball, weight of the ball, the type of catapult, factors affecting air resistance *(1)*, Dependent: range *(1)*, Independent: initial speed *(1)*

9c Scales *(1),* units *(1)*, smooth curve through origin: *(2)*,
Uncertainty bars, the data in the question can be used to argue for different sized bars. The tape measure is marked in intervals of 10 cm, which would suggest the bars be drawn as ± 5 cm. However there is a reading of 0.78 m which implies an uncertainty of ± 0.005 m, that is, the value is between 0.775 and 0.785 m.*(1)*, data plotting: *(3)*

10 0.94 c Using length contraction, $L = L_0/\gamma$, so $\gamma = 3$, and $v^2/c^2 = 8/9$ *(1)*, so v = 0.94 c *(1)*

11a $3.05 \times 10^{-13}$ s In the scientists' frame of reference, lifetime = dist / speed
lifetime = $9.14 \times 10^{-5}$ /(0.99875c) *(1)*, lifetime = $3.05 \times 10^{-13}$ s,
rounded to $3.05 \times 10^{-13}$ s. *(1)*

11b Zero As the question is written the answer should be zero because the particle is at rest in its own frame . It may have been the intention of the question to calculate a contracted length. In the particle's frame the laboratory is moving at speed with $\gamma$ = 20, the distance travelled by the laboratory will be contracted by a factor of 20to equal $9.14 \times 10^{-5} / 20$ *(1)* = $4.6 \times 10^{-6}$ m *(1)*

11c In the laboratory frame the particle's lifetime is increased because it is moving relative to the laboratory frame *(1)*. The increased lifetime is called time dilation. *(1)* This time dilation means that the moving particles travel further along the laboratory range before they decay than would be predicted from classical physics, which assumes that the half life is the same in all frames of reference. *(1)*

12 Inelastic. *(1)* By definition, any 'sticky' collision is inelastic, but to confirm this calculate the total KE before and after and compare, and use the conservation of momentum to find the speed after collision. By Cons'n of momentum, (4.0 x 5.0) + (2.0 x 2.0) = (4.0 + 2.0) x v, so v = 4.0 m $s^{-1}$
KE before = ½ x 4.0 x $5.0^2$ + ½ x 2.0 x $2.0^2$ = 50 + 4 = 54 J *(1)*
KE after = ½ x (4.0 + 2.0) x $4.0^2$ = 48 J, *(1)* which is less than 54 J

13a 2.0 m Let $\Delta x$ = the distance the mass falls. Grav PE at the top = spring PE at the bottom, that is, $mg\Delta x = ½ \times k \times (\Delta x)^2$, cancelling $\Delta x$, so $\Delta x = 2\ mg/k$ *(1)*
$\Delta x = 2 \times 2.00 \times 9.8 / 20.0$ *(1)* = 1.96 m, round to 2 sig figs because of the value of g to 2.0 m. *(1)* If g = 10 is used, then $\Delta x$ = 2.0 m.

13b Note: the question actually asks about the 'total energy of the mass', whereas what was presumably intended was the 'total energy of the system, that is, the mass and the spring'. The answer below assumes this interpretation.
Gravitational potential energy decreases steadily from top to bottom reaching zero at the bottom (GPE $\propto$ height) *(1)*
Spring potential energy increases from a value of zero as the mass falls from top to bottom, but it increases more rapidly as the stretching increases (Spring PE $\propto$ $(\text{extension})^2$) *(1)*
Kinetic energy is initially zero increases, reaching a maximum and coming back to zero at the bottom. *(1)*
The total energy of the system is the sum of all three and it remains constant. *(1)*

14a $44.0^0$ Using $n_g \sin\theta_c = 1$, $\sin\theta_c = 1/1.44 = 0.6944$, so $\theta_c = 43.983^0$, rounded to three sig figs to give $44.0^0$ *(1)*

14b There will be a refracted ray travelling into the air at an angle of refraction greater than the angle of incidence. *(1)* There will also be a reflected ray back into the glucose. *(1)* The incident ray should be drawn between the original position of the laser beam and the normal.

14c Because the angle is greater than the critical angle, *(1)* all the light from the laser will be reflected at the surface back into the glucose. *(1)* Note: This experimental set up is unsafe. Also a person at X as drawn in the diagram would never actually see the light, no matter what the relative refractive index, because the beam would either diverge towards or away from the normal when it crossed the boundary

15a 0.500 m Using $v = f\lambda$, $\lambda$ = 340 / 680 = 0.500 m *(1)*

15b Elli is wrong, Sam is right. *(1)* For each of the students at positions, 1 - 3 and 5 - 7, the sound from one speaker will travel a different distance to the sound form the other speaker. *(1)* Because sound is a wave, when sound from two sources meet the waves, they interfere producing either cancellation (destructive interference) or reinforcement (constructive interference). Destructive interference produces less intense or softer sound, while constructive interference produces a louder sound. *(1)*

15c Student 2 will hear a louder sound than student 5. *(1)* Using $\Delta x = \lambda L/d$, where $\Delta x$ is the spacing between maxima, $\Delta x = 0.500 \times 24 / 4.0 = 3.0$ m. Student 4 is at the central maximum. Student 2 is 3.0 m away so is also at a maximum, while student 5 is 1.5 m away and so is at a minimum.

16a 8.0 m — For the lowest frequency, the wavelength = twice the length *(1)*= 2 x 4.0
wavelength = 8.0 m. *(1)*

16b 60 Hz — For the next lowest frequency the wavelength = the length = 4.0 m. *(1)*
Using $v = f\lambda$, $f = 240 / 4.0 = 60$ Hz *(1)*

16c A standing wave on a string is a stationary pattern with some parts of the string undergoing large oscillation, these are called antinodes, while nearby, other parts are still, these are called nodes. *(1)* A standing wave is formed on a string when two travelling waves of the same wavelength move in opposite directions, passing through each other. *(1)* If the ends are fixed, when a wave meets an end, it undergoes a change of phase upon reflection, that is a crest is reflected as a trough and vice versa. *(1)*

At a node the crest of one wave is cancelled by the trough of the other. A moment later the null points of the two waves meet at the node, then another moment the trough of the first wave cancels with the crest of the second. So the part of the string at the node does not move.

At an antinode the crest of one wave is reinforced by the crest of the other producing a large deflection. A moment later the null points of the two waves meet and the string is momentarily straight, then another moment the trough of the first wave meets the trough of the second producing a large deflection in the opposite direction,. So this part of the string experiences large oscillations.

17a 0.31 V — Using $V_0 = hf - hf_0$ with Planck's constant as eV s,
so $V_0 = 4.14 \times 10^{-15} \times (6.25 \times 10^{14} - 5.50 \times 10^{14})$ *(1)* $= 4.14 \times 10^{-15} \times 0.75 \times 10^{14}$
$V_0 = 0.3105$ V *(1)*

17b Higher flat region to the right of the y - axis *(1)* and an x-intercept further to the left on the voltage axis. *(1)*

17c Existence of a threshold frequency, *(1)* that is, there is a frequency below which no electrons are emitted regardless of the intensity of the light. *(1)* The wave model predicts that because an increased intensity is equivalent to a larger wave amplitude and a larger wave should produce more electrons regardless of the wavelength of the wave. *(1)*

Electron energy increases with frequency. *(1)* The wave model predicts that the changing wavelength should not affect the energy of the emitted electrons. *(1)*

18a An arrow from n = 5 to n = 2 *(1)*

18b 331 nm — Shortest wavelength = highest frequency = greatest energy = 3.75 eV.
Using $E = hc/\lambda$, $\lambda = hc/E = 4.14 \times 10^{-15} \times 3.0 \times 10^{8} / 3.75$ *(1)*
$\lambda = 3.312 \times 10^{-7}$ m = 331.2 nm *(1)*

18c None of the energy levels nor the differences between any pairs of levels *(1)* equals 2.5 eV. *(1)*

19 Mary is correct *(1)* and Roger is wrong. *(1)*

Electrons fired at a crystal produce a diffraction pattern similar to that produced by X-rays. *(1)*

Electrons fired at an electrical equivalent of either a single slit or a double slit produce evidence of diffraction in pattern similar to light. *(1)*

Electrons fired at such a double slit, but at such a frequency that there is only one electron in the apparatus at a time, still over time produce the same pattern as a high intensity electron beam.

Additional Questions using the stem in the exam questions

Section A

Q'n 1: Describe the magnetic field produced in each of the answers, A, B and C

Q'n 3: What would be the size of the electric force on an electron between the plates? In which direction would the force act? What would be the gain in speed of an electron by the time it reached a plate if it was released in the middle?

Q'n 6: Draw the equivalent flux graphs for each of the answers, A, B and C

Q'n 9: It could be argued that loss of exhaust gases from the rocket has made the model car lighter. Explain what impact this would have on the final speed.

Section B

Q'n 1: If the three charges are equidistant and X is in the middle of the two on the left, determine the size of the electric field at X as a multiple of the contribution from +Q.

Q'n 2b: Calculate the period of the electron's circular path

Q'n 3: The coil does a half rotation, what is the size and direction of the force acting on the side JK

Q'n 6a: What is the voltage across the input to the step down transformer?

Q'n 6b: What is the voltage now across the input to the step down transformer?

Q'n 9a: Calculate the speed with which the ball hits the wall

Q'n 9a: Calculate the maximum height reached by the ball

Q'n 9b Redo the question the following data, constructing the uncertainty bars from each set of data values. The measurements were taken with a tape measure with mm markings.

| Initial speed | Range measurements | Average range |
|---|---|---|
| 1.0 | 0.095, 0.10, 0.11, 0.105, 0.10 | 0.10 |
| 2.0 | 0.325, 0.34, 0.355, 0.36, 0.36 | 0.35 |
| 3.0 | 0.77, 0.78, 0.80, 0.78, 0.79 | 0.78 |
| 4.0 | 1.38, 1.42, 1.41, 1.40, 1.39 | 1.40 |
| 5.0 | 2.17, 2.14, 2.14, 2.16, 2.16 | 2.15 |

Q'n 12: The trolleys each have springs which engage, then lock. Assume the duration of the impact was 0.020 s.

a) Calculate the change of momentum of each trolley
b) Calculate the force each trolley exerts on the other
c) Calculate the distance travelled by each trolley during the collision
d) Explain why the answers in a) and b) are the same, while in c) they are different.

Q'n 13a Determine the maximum speed of the mass