**VCE Physics**
**Solutions to 2019 NH Physics Exam - Version 2, 31st July**
**Suggested Marking Scheme in italics**
**Consequentials are indicated as "Conseq on 1"**

## Section A

1. B The field at X is the combined effect of the field from the left magnet, which is to the right from the N end, and the field from the right magnet, which is also to the right into the S end. So the combined effect is to the right, B.
2. D Using the hand rule, the magnetic field is to the North, current is East to West, so the magnetic force on the current is downwards, D.
3. C Using $F = BIl$, $F = 5.0 \times 10^{-5} \times 1.0 \times 10^{3} \times 1.0 = 5.0 \times 10^{-2}$ N
4. D Using $GPE = mg\Delta h$, $GPE = 10 \times 3.7 \times 2.0 = 74$ J
5. A Primary = 240 V, secondary = 12 V, so ratio = 240 / 12 = 20:1.
6. A A battery voltage equal to the RMS output voltage will have the same effect on the circuit, so 12V.
7. C The frequency is halved, so the period is doubled, giving either A or C. Because the same change in magnetic flux is occurring in a longer time, the peak induced voltage will be less, so C.
8. C At top Net force = mg = ma = $mv^2/r$, so $g = v^2/r$, $v = \sqrt{gr} = \sqrt{10 \times 1.6} = \sqrt{16} = 4.0$ m $s^{-1}$
9. A At Z the acceleration in inwards and upwards towards to centre of the circle. The resultant force is in the same direction as the acceleration.
10. D A, B and C are unchanged in refraction.
11. A A is correct, B and C are not relevant to whether the wave is transverse or longitudinal, D implies longitudinal.
12. C A, B and D are all wrong, C is correct. EM radiation can be produced by accelerating charges and by atomic energy level transitions.
13. B Mechanical waves produce energy transfer without matter transfer.
14. D : Sound does not travel through a vacuum, B, em waves can, so, C is wrong on both counts. D is correct.
15. B A wider slit narrows the diffraction pattern, so B. D is an interference pattern.
16. A $\gamma = \sqrt{(1/(1- v^2 / c^2)} = \sqrt{(1/(1- 0.2^2)} = = \sqrt{(1/(0.96)} = 1.02$
17. D $\gamma = 16/2.2 = 7.3$
18. C $KE = (\gamma -1)\, mc^2 = 10 \times mc^2$, so $\gamma = 10 + 1 = 11$.
19. B Note: absorption, so only up arrows. Highest frequency means greatest energy (E = hf), so longer arrow, that is B
20. B Precise means measurements are not scattered, so B or D, inaccurate means not close to the teacher's measurement, that is, the 'true value', so B.

## Section B

1a 5000 V Using $Vq = ½ mv^2$ *(1)*, $V = ½ \times 9.1 \times 10^{-31} \times (4.2 \times 10^7)\ 2 / (1.6 \times 10^{-19})$ *(1)*
V = 5016 V = 5000 V *(1)*

1b $3.4 \times 10^{-13}$ N Using $F = Bqv$, $F = 5.0 \times 10^{-2} \times 1.6 \times 10^{-19} \times 4.2 \times 10^7$ *(1)* $= 3.36 \times 10^{-13}$ N
$F = 3.4 \times 10^{-13}$ N *(1)*

1c Circle *(1),* because the magnetic force is always at right angles to the velocity of the electron, as demonstrated, in the hand rule. *(1)*

2a $8.0 \times 10^{-2}$ V Average induced EMF for each turn = change in magnetic flux / time taken. change in magnetic flux = BA - zero = $(4.0 \times 10^{-2} \times 0.010)$ - zero,
change in magnetic flux = $4.0 \times 10^{-4}$ Wb *(1)* .
Average induced EMF for the loop = $20 \times 4.0 \times 10^{-4} / (0.10)$ *(1)* = $8.0 \times 10^{-2}$ V *(1)*

2b At t = 0, the flux through the loop is a maximum, so the induced voltage is zero at t = 0, *(1)* , the period is 0.40 s, so draw 2.5 cycles of either a sine wave or an inverted sine wave over the 1.0 s time scale. *(1)* Figure 2 does not specify the direction of rotation of the loop and also the polarity of the CRO terminals is not defined, so the voltage could go initially go up or down depending on the combination of these two aspects.

3a 4.0 x $10^{-3}$ N Using F = nBI*l*, F = 10 x 2.0 x $10^{-3}$ x 2.0 x 0.10 *(1)* = 4.0 x $10^{-3}$ N *(1)*

3b The commutator reverses the current *(1),* twice every rotation *(1),* when the loop is at right angles to the field. *(1)*

4a 160 W Using P = VI, the current through the globe and the wires is 480 / 240 *(1)*
P = 2.0 Amp. *(1)* The Power loss in the connecting wires is give by $P_{loss}$ = $I^2R$
$P_{loss}$ = 2.02 x 40 = 160 W. *(1)*

4b 320 V The voltage drop across the connecting wires is given by V = IR = 2.0 x 40 = 80 V, *(1)* so the farmhouse needs to supply 240 + 80 *(1)* = 320 V. *(1)*

4c 2.5 W With a 8:1 step down transformer the current in the connecting wires will reduce by a factor of 8 to 2.0 / 8 = 0.25 A. *(1)* The power loss will be now 0.252 x *40 (1),* power loss = 2.5 W, or 160 / $(8)^2$ = 2.5 W. *(1)* Conseq on 4a

5a 0.20 m For extension, y, mg = ky, y = 2.0 x 10 /100 *(1)* = 0.20 m. *(1)*

5bi 0.40 m Using conservation of energy, the gravitational PE at release position = spring potential energy at lowest point, so mgΔh = ½$kx^2$*, (1)* where Δh = 'x'. So cancelling and rearranging, 2 x mg = kx, giving x = 2 x 2.0 x 10 / 100 = 0.40 m, *(1)* which the equation above shows is always twice the equilibrium extension.

5bii 1.4 m $s^{-1}$ Maximum speed will occur as the mass passes through the equilibrium position because above that point, the net force is down as the weight force > the spring force, and below that point, the net force is up as the weight force < the spring force. So KE = total energy - grav PE at equilibrium position - spring PE at equilibrium position.
KE = 2.0 x 10 x 0.40 - 2.0 x 10 x 0.20 - ½ x 100 x $0.20^2$ *(1)*
KE = 4.0 - 2.0 = 2.0 J *(1)*
KE = ½$mv^2$, so v = √(2.0 x 2/2.0) *(1)* = 1.4 m $s^{-1}$ *(1)* Conseq on 5bi

6a 20 m Vertical: u = 40 sin $30^0$ = 40 x 0.5 = 20, v = 0, a = -9.8, s = ?. Use $v^2 = u^2 + 2as$
s =(0 - $20^2$ ) /(2 x -9.8) *(1)* = 20.4 m = 20 m. *(1)*
Note: using g = 10, gives $20^2$ / 20 = 20m.

6b 16 m Find time to travel a horizontal distance of 104 m.
Horizontal: v = 40 cos $30^0$ = 34.6 m $s^{-1}$, d = 104 m, t = ? Use v = d/t.
t = 104 / 34.6 *(1)* = 3.00 s. *(1)*
Vertical find height when t = 3.00 s, using s = ut +½$at^2$
s = 20 x 3.00 - ½ x 9.8 x $(3.00)^2$ *(1)* = 60 - 44.2 = 15.8 = 16 m *(1)*

7a 20 Ns Impulse by bat on ball = change in momentum of the ball *(1)*
Impulse = 0.20 x(40 - -60) *(1)*
Impulse = 20 Ns or kg m $s^{-1}$, *(1)* taking direction to the right as positive.

7b 2000 N Force by the bat on the ball = Change in momentum of the ball / time taken
Force = 20 / 0.010 *(1)* = 2000 N. *(1)* Conseq on 7a
Alternatively Force = Impulse on ball / time taken.

7c Inelastic KE before = ½ x 2.0 x $10^2$ + ½ x 0.20 x $60^2$ = 100 + 360 = 460 J *(1)*
KE After = = ½ x 0.20 x $40^2$ = 160 J, *(1)* which is less than 460 J and so inelastic.

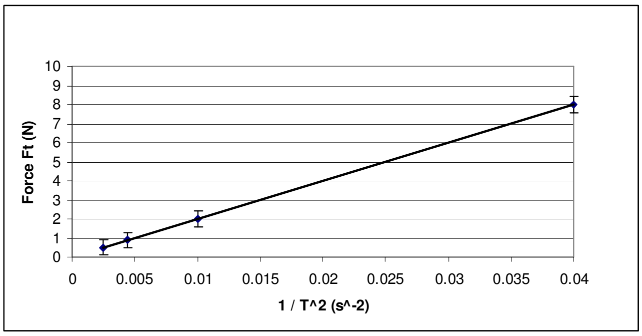
8a Uncertainty represents the range of values that can be reasonably attributed to the quantity being measured. The value of ± 0.4 N means that for a reading of say, 5.2 N, then this is the best estimate and the actual value might be anywhere between 5.2 - 0.4, 4.8 N and 5.2 + 0.4, 5.6 N. *(1).* The experimental uncertainty can be reduced by using a more precise sensor. Additional readings of the force by the sensor will not reduce the uncertainty below the value of ± 0.4 N *(1)*

8b Independent: Period, *(1)* Dependent: Tension, *(1)* Controlled variables: radius, mass of car, direction of travel, radial friction. *(1)*

8ci *(1)*

| **Period T (s)** | **$1/T^2$ ($s^{-2}$)** | **Force $F_T$ (N)** |
|---|---|---|
| 5.00 | 4.00 x $10^{-2}$ | 8 |
| 10.0 | 1.00 x $10^{-2}$ | 2 |
| 15.0 | 4.44 x $10^{-3}$ | 0.9 |
| 20.0 | 2.50 x $10^{-3}$ | 0.5 |

8cii




Plotting of data *(2)*, Uncertainty bars *(1)*, Correct labels *(2)*, Line of best fit *(1)*

8d 5.1 kg — Gradient = 200 ± 10 N $s^2$ *(1)* . m = 200 / ($4\pi^2 r$) = 200 / (4 x $\pi^2$ x 1.0) *(1)*
Gradient = 5.07 kg. m = 5.1 kg *(1)*

9 98 N upwards — Forces on Mass A: weight force = mg = 10 x 9.8 = 98 N an Force on Mass A by Mass B , $F_{on\ A\ by\ B}$ . Net force on Mass A = zero, $F_{on\ A\ by\ B}$ = 98 N. *(1)*
Weight force is down, so this force acts upwards. *(1)*

10a $1.1 \times 10^4$ s — Using $GMm/r^2 = m\, 4\pi^2\, r/T^2$, *(1)*, $T = \sqrt{(4\pi^2 r^3 / GM)}$ *(1)* , r = (3.4 + 1.6) x $10^6$ m *(1)*,
T = 10727 sec = 1.1 x $10^4$ s *(1)*

10b Lower — Speed = $2\pi r/T$, if the radius is increased by a factor of k (k>1), then, because $R^3/T^2$ is constant, T is increased by a factor of $k^{3/2}$, so the speed is reduced by a factor of $k^{1/2}$. *(1)* So the speed is lower . *(1)*

11a Electrons and X-ray photons of the same energy will have different wavelengths, because electrons have mass and photons do not. *(1)* For electrons $E = p^2 /2m$, where $p = h/\lambda$, so $E = (h/\lambda)^2/2m$, whereas for photons, $E = hf = hc/\lambda$. For photons their energy is inversely proportional to the wavelength, whereas for electrons, their energy is inversely proportional to the square of their wavelength. *(1)*

11b 72 keV — For an electron with energy of 5000 eV, first convert to energy in joule by multiplying by q, the charge on the electron, then find its wavelength from rearranging the above 1st expression to give $\lambda = h / \sqrt{(2mqE)}$. *(1)* For this wavelength, find the photon energy in joules using the above second expression $E_{photon} = hc/\lambda = c \times \sqrt{(2mqE_{electron})}$, then convert the energy back to eV. *(1)*
$E_{photon} = 3.0 \times 10^8 \times \sqrt{(2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19} \times 5000)}$ Joules *(1)* = 71545 eV
E (in eV) = 72 keV *(1)*

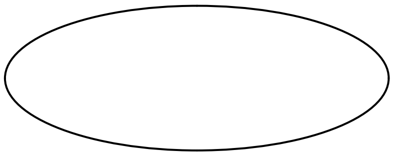
12a core — Because you want total internal reflection as light travels from within the core to the core - cladding boundary, so core. *(1)*

12b 1.55 — $n_{core} \times \sin 66.0^0 = n_{cladding} \times \sin 90^0$,
$n_{core} = 1.42 / \sin 66^0$ *(1)* = 1.55 = 1.55 *(1)* to 3 sig figs.

13a Large waves — Because C is equidistant from S1 and S2, this means the waves from S1 and S2 constructively interfere, producing reinforcement when the crest from S1 meets the crest from S2. *(1)* Large waves. *(1)*

13b 6.0 m — The separation of the nodal points is 42 m, which is given by the expression, $\Delta l = \lambda L/d$ where $\lambda$ = wavelength, L = distance from the two gaps, 420 m and d is their separation, 60 m. So the wavelength, $\lambda$ = 42 x 60 / 420 *(1)* = 6.0 m *(1)*

14a — Node at each end *(1)*, antinode in middle *(1)*



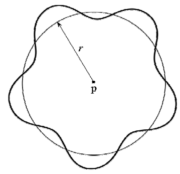
14b 1.8 m — The distance between adjacent nodes = $\lambda/2$, so the wavelength $\lambda$ = 2 x 0.92 *(1)*
$\lambda$ = 1.84 m = 1.8 m *(1)* rounded to 2 sig figs.

14c 122 Hz — Using $v = f\lambda$, f = 224 / 1.84 *(1)* = 121.7 Hz rounded to 122 Hz. *(1)*

Conseq on 14b

15a 5 The energy of the transition (in eV) = $hc/\lambda$
$E = 4.14 \times 10^{-15} \times 3 \times 10^{8} / 1242 \times 10^{-9}$. *(1)*. E (in eV) = 1.0 eV. *(1)*
The higher energy level = 1.0 + 12.1 eV = 13.1 eV, which is n = 5. *(1)*

15b Electrons have a wavelength determined by their energy and momentum. *(1)* In the closed system inside the atom they form a two dimensional standing wave pattern around the nucleus, the dimensions of which depend on the wavelength of the electron. *(1)* Only specific modes of standing waves fit around the nucleus meaning that only certain wavelengths are allowed and so only certain energy values are allowed. *(1)* This is illustrated in the energy level diagram in this question.



16a 1.00 V Using E = hf – Work function *(1)*, E (in eV) = $4.14 \times 10^{-15} \times 7.13 \times 10^{14} - 1.95$ *(1)*
E = 1.00 V *(1)*

16b 290 nm Threshold frequency is the lowest frequency that will eject electrons, so the maximum wavelength = $3.0 \times 10^{8} / 1.04 \times 10^{15}$ *(1)* = $2.88 \times 10^{-7}$ m
Max wavelength = $288 \times 10^{-9}$ m = 288 nm = 290 nm *(1)* rounded to two sig figs.

16c The wave model argues that the energy is in the amplitude of the wave. *(1)* So with continued exposure to light of low energy, enough energy can be accumulated to eject an electron. This is not observed. *(1)* Similarly an intense light source regardless of frequency should eject an electron. This is not observed. *(1)*
Whereas the particle model argues the light travels as discrete particles called photons, each with a packet of energy determined by its frequency. Further that each photon interacts with only one electron. So with continued exposure to light of low energy means photons with insufficient energy regularly hitting electrons, but with not enough energy to eject them. *(1)* Similarly a high intensity burst of low energy photons will have the same effect.

17 6.5 years $\gamma = 1.90$.
The astronauts will observe a contracted distance of $10.5 \times 9.46 \times 10^{15}/ 1.90$. *(1)*
Time to cross this distance = Dist/speed .
Time (in sec) = $(10.5 \times 9.46 \times 10^{15}/ 1.90) / (0.85 \times 3.0 \times 10^{8}) = 2.05 \times 10^{8}$ sec *(1)*
Time (in years) = 6.5 years *(1)*

18 Length contraction is only in direction of travel *(1)*, so x: $3.20 \times 10^{3} / 7.09 = 451$ m. *(1)*
$y = z = 3.20 \times 10^{3}$ m *(1)*

19. $3.7 \times 10^{-12}$ J Using $E = \Delta mc^2$, Energy released = $(2 \times 3.3436 - 6.6465) \times 10^{-27} \times (3.0 \times 10^{8})^{2}$ *(1)*
$E = 3.66 \times 10^{-12}$ J = $3.7 \times 10^{-12}$ J to 2 sig figs. *(1)*

**Extra Revision questions based on the stem of the questions**

**Section A**

1. Mark on the diagram points where the magnetic field is in direction i) A, ii) C and iii) D. Also mark other points where the field is in the direction of B.
4. Determine the kinetic energy and speed of the mass just before impact.
7. For the alternator in the question, which two answers are impossible. Explain how you produce the remaining graph.
9. Calculate the speed at Z assuming no energy loss. Determine the magnitude and direction of the force on the toy truck by the track at position Z.

**Section B**

1. Determine the strength of the electric field.

2b Assume the coil turns clockwise as viewed from the slip rings and the left terminal of the CRO is connected to ground, redraw the voltage graph and explain.

3a What is the direction of the force on EF?

7b i) Calculate the distance travelled by the ball
ii) Determine the force by the ball on the bat.
iii) Calculate the distance travelled by the bat.
iv) Explain any difference between your answers to i) and iii)
v) How does your answer to iv) relate to working for question 7c?

8d Use the uncertainty bars to determine the uncertainty in the value of the mass of the car.
9 Determine the magnitude and direction of the force on the table by Mass B.
10b Calculate the speed of the satellite at the two altitudes to confirm your answer to 10b.
15a Calculate the wavelength of the photon emitted when an electron drops from n = 6 to n = 2.
16a Calculate the threshold frequency of Caesium.
16b Calculate the work function of Zinc.