ACCESS EDUCATION

Access Education

PHYSICS
Unit 3 & 4
Trail examination 2017

Solutions

SECTION A – Multiple-choice questions

Question 1 D

At the atomic level in order to measure the position of a particle we have to interact with it for example by firing photons at it. At this small scale the interaction of the photon with a subatomic particle will cause a change in momentum not applicable to heavier masses and so we cannot determine both its position and momentum at any one time. Heisenberg defined the relationship as $\Delta x \Delta p \ \geq \frac{h}{4\pi}$ where Δ represents the uncertainty so the smaller *Δx* the larger *Δp*

Question 2 A

Net force is vertically downwards so F_{net} = T + mg ⇒ T = F_{net} – mg, T must be positive so T > mg

Question 3 D

Diffraction is proportional to λ/w and λ = h/p and p = mv so only beam intensity will not change the pattern produced.

Question 4 B

5 × 50g masses each with 0.5g uncertainty give ± 2.5g uncertainty in final mass

Question 5 D

Accuracy is defined as half of the smallest scale available

Question 6 B

Relative uncertainty is another name for percentage uncertainty.
Systematic (error) is caused by a fault in the design or operation of a measuring device that is consistent for all measurements ie the scales were reading 0.05 g too high.
Random (error) is the fluctuations between identical measurement processes ie weighing the same mass 3 times and getting 3 different readings 10.01g, 10.00g, 10.02g
Human (error) is a mistake made by the experimentor ie transposing figures when recording data ie writing 45.8 instead of 54.8 etc

Question 7 B

$$k = \frac{F}{\Delta x} = \frac{9.8 \times 5 \times 50}{28.9 - 14.0} = 16.443$$

mass % uncertainty = $\frac{2.5}{250} \times 100 = 1\%$ extension % uncertainty = $\frac{0.0005}{0.149} \times 100 = 0.336\%$
k % uncertainty = 1 + 0.336 = 1.336%
k absolute uncertainty = $\pm\frac{1.336}{100} \times 16.443 = \ 0.2196 = 0.2$
So k = 16.4 ± 0.2 N m^{-1}

Question 8 D

Slide D is closest to angle of polarised light

Question 9 B

Magnetic field lines go from North to south so right hand end is a North pole. AC would change the field direction to often to develo a clear pattern with the compass

Question 10 A

$E_k = \frac{1}{2}mv^2$ at highest point all motion is horizontal (constant velocity) $v = 22\cos40^o = 16.85$ m/s

$E_k = \frac{1}{2} \times 4 \times 16.85^2 = 568\ J$

Question 11 D

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{1}{\sqrt{1 - \frac{(0.8c)^2}{c^2}}} = \frac{1}{\sqrt{1 - 0.8^2}} = 1.67$$

$l_0 = l\gamma = 308 \times 1.67 = 513\ m$

Question 12 A

$$F = \frac{kq_1q_2}{r^2} = \frac{9\times10^9 \times 1.6\times10^{-19} \times 3.2\times10^{-19}}{(4\times10^{-3})^2} = 2.88\times10^{-23}\ N$$

Question 13 B

The interference between the light coming from both slits was a wave characteristic that particles could not produce

Question 14 C

Incandescent light sources produce wide spectrum light and heat

Question 15 C

$E = hf - \phi = 4.14\times10^{-15} \times 6\times10^{15} - 2.3 = 22.54$ eV

Question 16 C

Total internal reflection can only occer when refraction is away from the normal ie when the second media has a lower refractive index thatnthe first medium

Question 17 C

The Doppler effect is caused when the source of the waves is moving relative to the observer. Both sound and light travel via waves.

Question 18 B

The Proton has a heavier mass and the opposite charge so deflection is in downwards direction but due to its greater inertia the proton will not defelct as quickly as the electron

Question 19 **B**

An independent variable is one which the experimenters choose the value of. The balloon size was the dependent variable

Question 20 **B**

Standing waves only appear stationary. They ae the outcome of constructuve and destructive interfernce between two identical waves travellingin opposite directions ie resonance

SECTION B

Question 1 (13 marks)

a. $\Delta E_p = \Delta E_k$

⇒ $mg\Delta h = ½mv^2$

⇒ $9.8 \times 2 \times 0.4 = ½ \times 2 \times v^2$ ①

⇒ $v^2 = 7.84$

⇒ $v = 2.8$ m/s ①

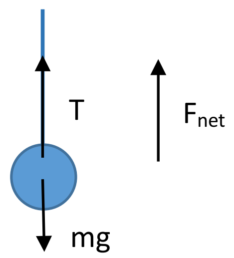
b. $F_{net} = T - mg$

⇒ $T = F_{net} + mg$

$= \frac{mv^2}{r} + mg$

$= \frac{2 \times 2.8^2}{0.5} + 2 \times 9.8$ ①

$= 50.96$ N ①



c. $p_i = p_f$

⇒ $2 \times 2.8 = 3.2v$ ①

⇒ $v = \frac{5.6}{3.2} = 1.75$ m/s ①

d. Initial $E_k = ½mv^2 = ½ \times 2 \times 2.8^2 = 7.84$ J ①

Final $E_k = ½mv^2 = ½ \times 3.2 \times 1.75^2 = 4.9$ J ① *CONSEQUENTIAL on v from part* ***c***

⇒ COLLISION IS INELASTIC ①

e. $\Delta E_p = \Delta E_k$

⇒ $mg\Delta h = ½mv^2$

⇒ $9.8 \times 2 \times \Delta h = ½ \times 2 \times 1.75^2$ ① *CONSEQUENTIAL on v from part* ***c***

⇒ $\Delta h = \frac{1.75^2}{19.6} = 0.15625$ m ① $h = \frac{(\textbf{Answer c})^2}{19.6}$

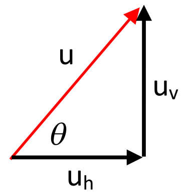
$= 15.6$ cm

f. Work = $F\Delta x = \Delta E_k$

⇒ $1.4F = ½ \times 3.2 \times 1.75^2$ ① *CONSEQUENTIAL on v from part* ***c***

⇒ $F = 3.5$ N ① $F = 1.14 \times (\textbf{Answer c})^2$

Question 2 (7 marks)



a. horizontal velocity $u_h = \frac{x}{t} = \frac{0.8}{1.2} = \frac{2}{3} = 0.667$ m/s ①

Vertically :

x = 0.3m $x = ut + \frac{1}{2}at^2$

t = 1.2 s ⇒ $0.3 = 1.2u + \frac{1}{2}(-9.8)\times 1.2^2$ ①

a = -9.8 ms⁻² ⇒ $u_v = 6.13$ m/s ①

u = ?

$\tan\theta = \frac{u_v}{u_h} = \frac{6.13}{0.667} = 9.195$

⇒ $\theta = \tan^{-1}(9.195) = 83.8^o$ ①

b. At maximum height

v = 0 ⇒ $v^2 = u^2 + 2ax$

x = ? ⇒ $0 = 6.13^2 - 19.6x$ ①

a = -9.8 ms⁻² ⇒ $x = \frac{6.13^2}{19.6} = 1.917$ m ①

$u_v = 6.13$ m/s

height above table = 1.92 – 0.3 = 1.62 ①

*CONSEQUENTIAL on u_v from part **a***

Question 3 (8 marks)

a. F = nBIL = $20 \times 0.02 \times \frac{12}{10} \times 0.04$ ①

⇒ F = 0.0192 N ①

b. anticlockwise ①
since magnetic field is to right and on side KL current is into the page according to the right hand slap rule the force on side KL is down.

c. ① reverses direction of current through loop every 180° (½ cycle)
① does this when plane of loop is perpendicular to the magnetic field
① keeps loop rotating in the same direction

d. (ii) & (iii) ① for each subtract ① for each incorrect answer down to zero

(i) Increase the area of the loop no change in side length L so no effect

(ii) Increase the supply voltage increases current through loop

(iii) Double the magnetic field strength whilst halving the resistance increase B and I in F = nBIL

(iv) Halving the number of turns and doubling the supply voltage. Changes cancel each other out, no overall effect

Question 4 (9 marks)

a. $E_k = qV$

$\Rightarrow$ $\frac{1}{2}mv^2 = qV$

$\Rightarrow$ $\frac{1}{2} \times 9.1\times10^{-31} \times (4.6\times10^6)^2 = 1.6\times10^{-19} \times V$ ①

$\Rightarrow$ $V = 60.17$ V ①

b. $F = qvB = mg$

$\Rightarrow$ $B = \frac{mg}{qv} = \frac{9.1\times10^{-31}\times9.8}{1.6\times10^{-19}\times4.6\times10^6}$ ①

$= 1.21 \times 10^{-17}$ T ①

Direction: out of page ①

c. $\lambda = \frac{h}{p} = \frac{6.63\times10^{-34}}{9.1\times10^{-31}\times4.6\times10^6}$ ①

$= 1.584 \times 10^{-10}$ ①

$= 0.158$ nm ①

d. X-ray ① X rays are the region is from 0.1 to 10 nm

Question 5 (2 marks)

① for correct field direction in each region

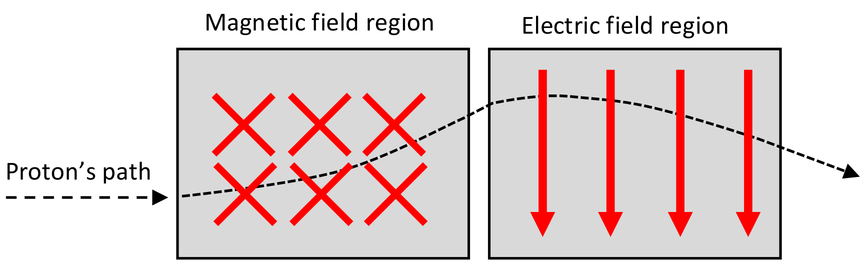


Figure 4

Question 6 (10 marks)

a. $V_R = 2V \Rightarrow$ only 4V across globe ①

$P = VI \Rightarrow P_{globe} = 4 \times 1 = 4$ W not 6 W as rated so globe is not as bright ①

OR

6 V supplied is being shared by globe and resistor ①

thus $V_{globe} < 6V \Rightarrow P_{globe} < 6$ W ①

b. ① per correct table entry

Transformer T_1 $N_p : N_s$	Transformer T_2 $N_p : N_s$	Globe brightness compared to Figure 5 circuit
20 : 200	200 : 20	brighter
200 : 20	20 : 200	dimmer

c. $\frac{N_p}{N_s} = \frac{I_s}{I_p}$

$\Rightarrow$ $I_s = \frac{N_p I_p}{N_s} = \frac{1 \times 20}{200} = 0.1\ A$ ①

$P_{loss} = I^2R = 0.1^2 \times 2$ ①

$= 0.02$ W ①

d. $V_{out\ T1} = 60$ V

$V_{in\ T2} = 60 - IR = 60 - 0.1 \times 2 = 59.8$ V ①

$V_{globe} = V_{out\ T2} = \frac{V_{in\ T2} \times N_2}{N_1} = \frac{59.8 \times 20}{200} = 5.98$ V ①

$V_{peak} = V_{globe} \times \sqrt{2} = 5.98 \times \sqrt{2} = 8.46$ V ①

OR

$P_{globe} = V_{out\ T2} \times I_{out\ T2}$ $I_{out\ T2} = I_{in} = 1$ A

$P_{globe} = P_{in} - P_{loss} = 6 - 0.02 = 5.98$ W ①

$\Rightarrow$ $V_{out\ T2} = \frac{P_{globe}}{I_{out\ T2}} = \frac{5.98}{1} = 5.98\ V_{rms}$ ①

$V_{peak} = V_{globe} \times \sqrt{2} = 5.98 \times \sqrt{2} = 8.46$ V ①

Question 7 (6 marks)

a. $T = \frac{1}{f} = \frac{1}{50} = 0.02$ s ①

b. $EMF = n\frac{\Delta\phi_B}{\Delta t}$ Δt = ¼ of period = ¼ × 0.02 = 0.005 ①

$\Rightarrow$ $EMF = 100\frac{0.04 \times 0.5}{0.005}$ ① $\Delta\phi_B = BA = 0.5 \times 0.04 = 0.02$ Wb

= 40 V ①

c.

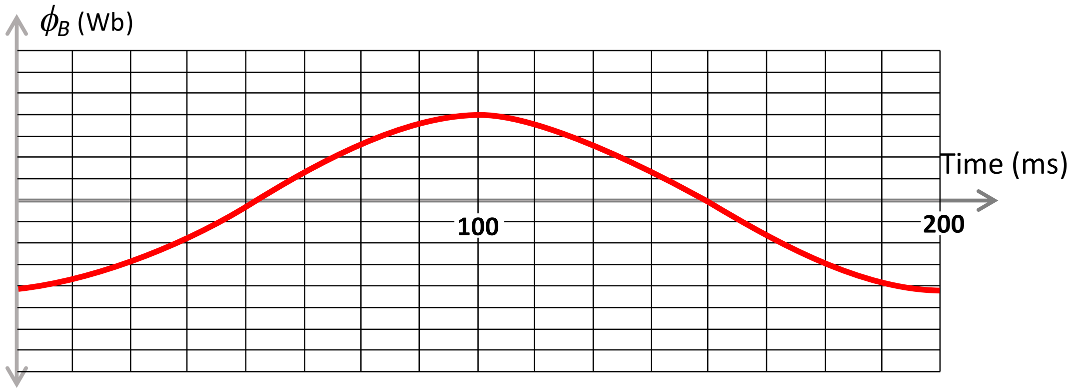
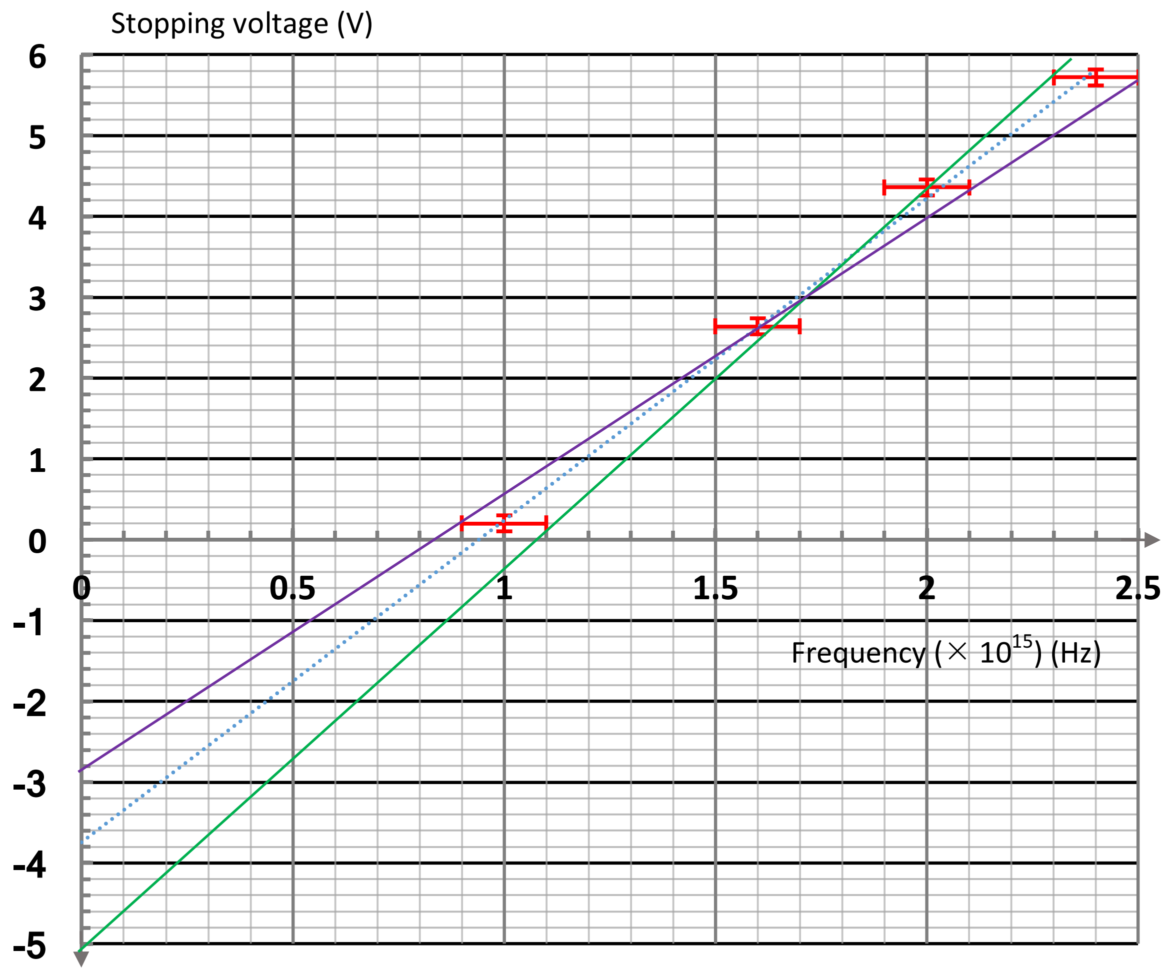


Figure 8

① for shape
① for orientation and period both correct
NOTE: No need to calculate the magnitude of the flux.

Question 8 (8 marks)

a. ① For correct data point locations
① for correct size of error bars



b. Blue line shows line of best fit through data
Use this to calculate gradient (planck's constant)
Purple line shows line of least fit. Use this to calculate least gradient
Green line shows line of maximum fit. Use this to calculate maximum gradient

Sample calculations:

$$h_{blue} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{5.4-0.6}{(2.3-1.2)\times 10^{15}} = 4.4 \times 10^{-15} \text{ eVs}$$

$$h_{purple} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{5.4-(-1.2)}{(2.4-0.5)\times 10^{15}} = 3.5 \times 10^{-15} \text{ eVs}$$

$$h_{blue} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{6.0-(-0.8)}{(2.3-0.9)\times 10^{15}} = 4.9 \times 10^{-15} \text{ eVs}$$

Biggest deviation from 4.4×10^{-15} is 3.5×10^{-15} of 0.9×10^{-15}
So h = 4.4 $\pm$ 0.9 $\times 10^{-15}$ eVs

Mark allocation:
① for method finding 3 gradients
① for uncertainty answer
① for planck's constant value close to 4.4×10^{-15} eVs

c.

Wave model predicts any frequency of light will produce the photoelectric effect, but there is a minimum (threshold) frequency for every metal ①

Wave model predicts a delay in the photoelectric effect with low intensity light of any frequency. Results show if frequency is above threshold then the effect is immediate. If frequency below threshold no effect at any intensity. ①

Higher intensity light should produce more energetic photoelectrons than low intensity light of the same frequency according to wave model. Results show higher intensity light produces more photoelectrons of the same maximum E_k not more energetic ones ①

Question 9 (9 marks)

a. $E = \frac{hc}{\lambda}$ ⇒ shortest wavelength will have the largest energy so largest transition is n = 3 to n =1 of 10.4 – 3.7 = 6.7 eV

$\Rightarrow \lambda = \frac{hc}{E} = \frac{4.14\times10^{-15} \times 3\times10^{8}}{6.7}$ ①

⇒ $\lambda = 1.8537 \times 10^{-7}$ m

= 185.4 nm ①

b. 6 lines. ①

Transition from n = 4 to n = 1 is across 4 – 1 = 3 levels so total number of possible transitions is given by the arithmetic sum formula $S_n = \frac{n}{2}[2a - (n-1)d]$ where *n* is the difference between the transition levels and *a* and *d* are always equal to 1

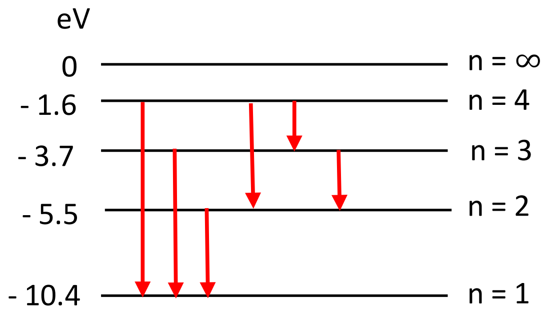


Figure 9

c. $1.68\times10^{-18}\,J = \frac{1.68\times10^{-18}}{1.6\times10^{-19}} = 10.5\,eV$ ①

This is greater than 10.4 eV so electron will escape the mercury atom ①

The atom becomes an ion ①

d.

① Standing waves are stable due to resonance

① If an electron's de Broglie wavelength is such that its orbit about the nucleus equals a whole number of wavelengths then the added stability of the standing wave formed will allow the electron to stay at that energy level for some time. ie 2πr = nλ

① Electron energy $E = \frac{hc}{\lambda}$ so at these wavelengths the energy is also exact and thus the electrons are found only at specific energy levels.

Question 10 (5 marks)

a. 0^{o} ② Sides of prism are parallel so rays will only be translated parallel to origin rays

b. $n_1 sin\theta_1 = n_2 sin\theta_2 \Rightarrow \theta_2 = sin^{-1}\left(\frac{n_1 sin\theta_1}{n_2}\right)$

$\theta_{red} = sin^{-1}\left(\frac{1 \times sin30^o}{1.5}\right) = 19.47^o$ ①

$\theta_{green} = sin^{-1}\left(\frac{1 \times sin30^o}{1.58}\right) = 18.44^o$ ①

① for red arrow less refracted than green arrow on diagram

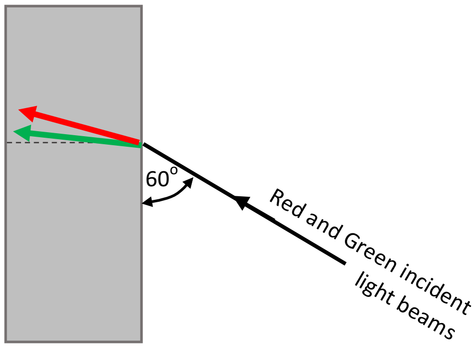


Figure 11

Question 11 (7 marks)

a. $\Delta x = \frac{\lambda L}{d} = \frac{620\times10^{-9} \times 0.8}{0.04\times10^{-3}} = 1.24\times10^{-3}$ m ①

distance to 3rd dark band = 2.5 Δx = 2.5 × 1.24×10^{-3} ①

= 3.1×10^{-3} m

= 3.1 mm ①

b. 2 keV electrons have wavelength $\lambda = \frac{hc}{E} = \frac{4.14\times10^{-15} \times 3\times10^{8}}{2000}$ = 6.21×10^{-10} m

6.21×10^{-10} m = 0.621 nm ①

this is ~ 1000 times smaller than the laser wavelength of 620 nm ①

diffraction is proportional to $\frac{\lambda}{w}$ (maximum when $\frac{\lambda}{w}$ =1) so no diffraction ①

only two lines detected in line with the slits (no interference pattern) ①

Question 12 (5 marks)

a. $g = \frac{GM}{r^2} = \frac{6.67\times10^{-11} \times 6.4\times10^{23}}{(9400\times10^3)^2}$ ①

= 0.483 N/kg ①

b. Roughly 100 squares each is 0.2 × 400×10^3 = 8×10^4 J/kg ①

Total ΔE_k = 100 × 8×10^4 × 2 (mass of meteor) = 1.6 × 10^7 J ①

Energy at surface = ΔE_k + original E_k of meteor = 1.6 × 10^7 + ½ × 2 ×3^2 = 1.6 × 10^7 + 9

½mv^2 = 1.6 × 10^7

$\Rightarrow$ v = $\sqrt{1.6\times10^7}$

= 4000 m/s ①

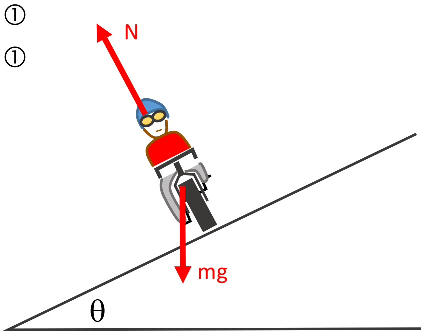
Question 13 (8 marks)

a. $v = \frac{72}{3.6} = 20$ m/s ①

$F_{net} = F_c = \frac{mv^2}{r} = \frac{60 \times 20^2}{20}$ ①

= 1200 N ①

b. ① for each vector



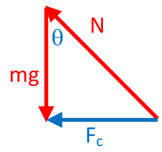
c. $F_c = mg\tan\theta$ CONSEQUENTIAL on part **a**

$\Rightarrow$ $1200 = 60 \times 9.8\tan\theta$ ① or diagram

$\Rightarrow$ $\theta = \tan^{-1}\left(\frac{1200}{60 \times 9.8}\right)$ ① $\theta = \tan^{-1}\left(\frac{Answer\ \boldsymbol{a}}{60 \times 9.8}\right)$

$= 63.895^o$

$= 63.9^o$ ①



Question 14 (7 marks)

a. lines must not cross or touch

① for correct direction

① for around solenoid not magnet

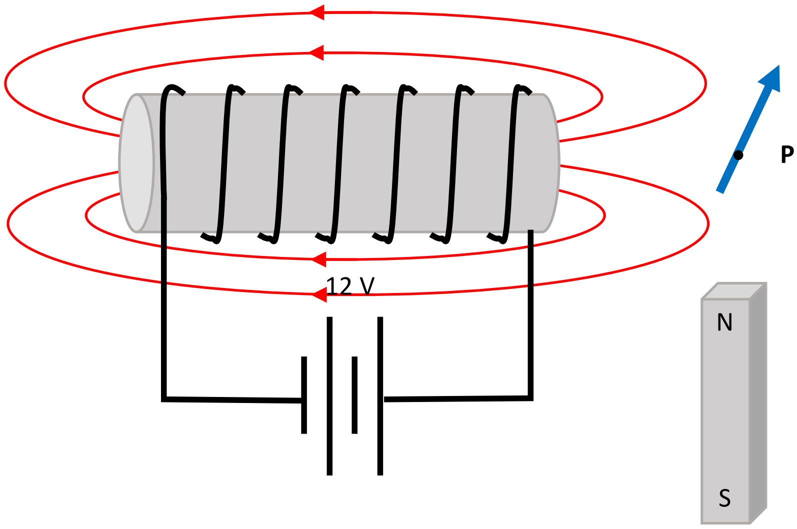
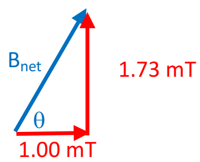


Figure 14

b. $B_{net} = \sqrt{1.73^2 + 1^2}$ ①

$= \sqrt{4} = 2$ mT ①



c. $\tan\theta = \frac{1.73}{1} = 1.73$ ①

$\Rightarrow$ $\theta = 59.97 = 60^o$ ①

d. see blue arrow in above diagram ① for correct direction

(0 marks if angle is 45°)

(0 marks arrow is not through or touching point **P**)

Question 15 (6 marks)

a. $\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{1}{\sqrt{1-\frac{(0.9c)^2}{c^2}}} = \frac{1}{\sqrt{1-0.9^2}} = \frac{1}{\sqrt{0.19}} = 2.294$ ①

$L = \frac{L_0}{\gamma} = \frac{2.4}{2.294} = 0.872$ m ①

b. Timer is in the observer' frame of reference so no relativistic effects on time or distance

$v = \frac{d}{t} \Rightarrow t = \frac{d}{v} = \frac{2.4}{0.9c}$ ①

$\Rightarrow t = \frac{2.4}{2.7 \times 10^8} = 8.89 \times 10^{-9}$ s ①

c. $E_k = (\gamma - 1)m_0c^2 = (2.294 - 1) \times 9.1 \times 10^{-31} \times (3 \times 10^8)^2$ ①

$= 1.294 \times 8.19 \times 10^{-14}$

$= 1.0598 \times 10^{-13}$

$= 1.06 \times 10^{-13}$ J ①