PHYSICS

Unit 3 – Written examination

TSSM™
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2021 Trial Examination

SOLUTIONS

SECTION A

Question 1

Answer: **D, F, J** (2 marks for all three, subtract 1 for any incorrect answers. Minimum zero).

Explanation:
- (**D**) Electric field lines are directed from positive to negative, so X is positive, Y is negative.
- (**F**) The electric field is symmetrical, indicating charges of equal magnitude
- (**J**) The field is curved and spacing between the field lines varies, indicating that strength is variable – this implies a non-uniform field.

Question 2

Answer: **531 km**

Explanation: Use gravitational field strength formula:

$$g = \frac{GM}{R^2}$$

$$0.146 = \frac{6.67\times10^{-11}\times6.17\times10^{20}}{R^2}$$ (1 mark)

$$R = 5.31 \times 10^5 \text{ m}$$

$$R = 531 \text{ km}$$ (1 mark)

Question 3

Answer: $\mathbf{4.6\ T}$, **out of the page**.

Explanation:

$$B = \frac{mv}{qr}$$

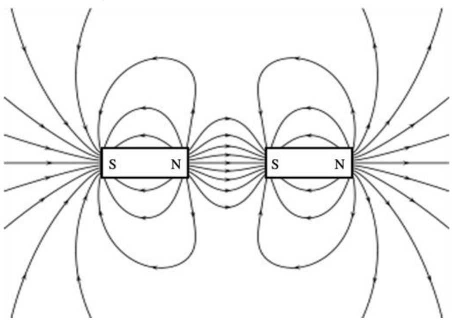
$$B = \frac{6.64\times10^{-27}\times1.6\times10^{7}}{3.2\times10^{-19}\times7.2\times10^{-2}}$$ (1 mark)

$$B = 4.6\ \text{T}$$ (1 mark)

Use RH slap rule (current to the right, force initially down) to show that magnetic field is directed out of the page. (1 mark)

Question 4

Answer:



(1 mark for each correctly labelled magnet)

Explanation: Field lines are directed from North to South externally from the bar magnets.

Question 5

Answer: In order: **M, E, G** (3 x 1 mark)

Explanation: Magnetic fields must be dipole (N & S), Electric fields can be either (single or multiple charges), Gravity fields are monopole (directed towards centre of mass).

Question 6

a.

Answer: $\mathbf{7.84 \times 10^{-14}}$ **N**

Explanation:

$F = qE$
$F = 1.6 \times 10^{-19} \times 490 \times 10^{3}$ (1 mark)
$F = 7.84 \times 10^{-14}$ N (1 mark)

b.

Answer: $\mathbf{0.27}$ **T**

Explanation: Equate electric and magnetic force acting on electron.

$F = qE = qvB$
$7.84 \times 10^{-14} = 1.6 \times 10^{-19} \times 1.8 \times 10^{6} \times B$ (1 mark)
$B = 0.27$ T (1 mark)

c.

Answer:

Electron velocity	Magnetic field	Electric field
Decrease	Decrease	Increase

(3 x 1 mark)

Explanation: In order for the electron to be deflected upwards, the magnetic field (acting down) should be decreased (decrease velocity or magnetic field). Alternatively, the electric field (which leads to an upwards force on the electron) could be increased.

Question 7

a.

Answer: $\mathbf{2.637 \times 10^7}$ **m**

Explanation: Add altitude to Earth radius.

$R = 20{,}000 \times 10^3 + 6.37 \times 10^6 = 2.637 \times 10^7$ m (1 mark)

b.

Answer: $\mathbf{4.3 \times 10^4}$ **s**

Explanation:

$$\frac{GM}{4\pi^2} = \frac{R^3}{T^2}$$

$$T = \sqrt{\frac{R^3 \times 4\pi^2}{GM}}$$ (1 mark)

$$T = \sqrt{\frac{(2.637 \times 10^7)^3 \times 4\pi^2}{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}}$$ (1 mark)

$$T = 4.3 \times 10^4 \text{ s}$$ (1 mark)

c.

Answer: $\mathbf{3.9 \times 10^3}$ **m s**$^{-1}$

Explanation: Use equation for orbital velocity.

$$v = \sqrt{\frac{GM}{R}}$$

$$v = \sqrt{\frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{2.637 \times 10^7}}$$ (1 mark)

$$v = 3.9 \times 10^3 \text{ m s}^{-1}$$ (1 mark)

Question 8

a.

Answer: $\mathbf{1.2 \times 10^6}$ **J**

Explanation: GPE is equal to the area under the graph multiplied by the mass.

$E_g = Area \times mass$

$E_g = \left(\left(\frac{0.116+0.101}{2} + \frac{0.101+0.089}{2}\right) \times 2 \times 10^5\right) \times 30$ (1 mark)

$E_g = 1.2 \times 10^6$ J (1 mark)

b.

Answer: $\boldsymbol{E_k}$ **will be constant** (1 mark) This is because E_g will be constant as it is related to the altitude of the satellite, which is also constant. (1 mark).

Question 9

Answer: $\mathbf{7.0 \times 10^{-2}}$ **T**

Explanation: Use Faraday's Law for a quarter rotation.

$\epsilon = N\frac{B\Delta A}{\Delta t}$

$\Delta t = \frac{1/f}{4} = \frac{1/20}{4} = 0.0125$ s (1 mark)

$0.16 = -12\frac{B\times(0.06\times0.04)}{0.0125}$ (1 mark)

$B = 7 \times 10^{-2}$ T (1 mark)

Question 10

a.

Answer: $\mathbf{0.2}$ **m s**$^{\mathbf{-1}}$

Explanation: Use speed equation based on time taken for loop to cross into the field.

$v = \frac{d}{t} = \frac{0.04}{0.2} = 0.2$ m s^{-1} (1 mark)

b.

Answer: $\mathbf{0.5}$ **mT**

Explanation: Use the maximum flux as shown in Fig 6b, knowing this represents the full area of the coil within the field.

$\emptyset = BA$
$1.75 \times 10^{-6} = B \times (0.04 \times 0.08)$
$B = 5 \times 10^{-4}$ T (1 mark)
$B = 0.5$ mT (1 mark)

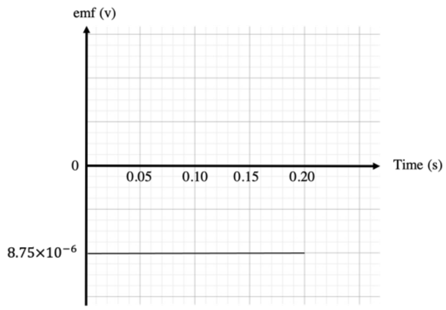
c.

Answer: **Anticlockwise**

Explanation: Initial flux is zero, final flux is directed into the page so change in flux is into the page (1 mark). The induced current must produce a flux out of the page to oppose this (1 mark). Using RH grip rule, current must be anticlockwise (1 mark).

d.

Answer: See diagram. The *emf* is calculated by referring to gradient of flux vs time graph (1 mark). Negative according to convention. (1 mark).



$$\epsilon = -\frac{1.75\times10^{-6}}{0.2} = -8.75 \times 10^{-6}$$

Question 11

a.

Answer: $\mathbf{0.95\ A}$

Explanation:

$I_{PEAK} = \sqrt{2} \times I_{RMS}$

$I_{PEAK} = \sqrt{2} \times 0.67$ (1 mark)

$I_{PEAK} = 0.95\ \text{A}$ (1 mark)

b.

Answer: $\mathbf{1150\ turns}$

Explanation:

$n_{prim} = n_{sec} \times \frac{V_{prim}}{V_{sec}}$

$n_{prim} = 60 \times \frac{230}{12}$ (1 mark)

$n_{prim} = 1150$ (1 mark)

c.

Answer: $\mathbf{3.48 \times 10^{-2}}$**A**

Explanation: Use $P = VI$ based on ideal transformer.

$P = VI$
$8 = 230 \times I$
$I = 3.48 \times 10^{-2}$ A (1 mark)

Question 12

a.

Answer: $\mathbf{2.2}$ **m s**$^{\mathbf{-1}}$

Explanation:

Vertically: $mg = T\cos\theta$, so $T = \frac{mg}{\cos\theta}$.
Horizontally: $T\sin\theta = \frac{mv^2}{r}$.

Combining: $\frac{mg}{\cos\theta} \times \sin\theta = \frac{mv^2}{r}$
$\tan\theta = \frac{v^2}{rg}$ (1 mark)
$v = \sqrt{rg\tan\theta}$
$v = \sqrt{0.6 \times 9.8 \times \tan(40)}$ (1 mark)
$v = 2.2 \text{ m s}^{-1}$ (1 mark)

b.

Answer: $\mathbf{716.4}$ **N**

Explanation:

Vertically: $T = \frac{mg}{\cos\theta}$
$T = \frac{56 \times 9.8}{\cos(40)}$ (1 mark)
$T = 716.4$ N (1 mark)

c.

Answer: The radius will not change (1 mark) as it depends on the speed and the angle, not the mass. (1 mark)

Question 13

Answer: $\mathbf{3.8\ m}$

Explanation: To find maximum height, equate elastic potential energy (E_s) at the lowest point with gravitational potential energy (E_g) at the highest point.

$E_s = E_s$
$0.5 \times 250 \times 0.2^2 = 0.15 \times 9.8 \times \Delta h$ (1 mark)
$\Delta h = 3.4$ m (1 mark)
$h = 3.4 + 0.4 = 3.8$ m above bench. (1 mark)

Question 14

a.

Answer: $\mathbf{6.53\ s}$

Explanation: Use constant horizontal velocity.

$t = \frac{d}{v}$
$t = \frac{300}{60 \times \cos(40)}$ (1 mark)
$t = 6.53$ s (1 mark)

b.

Answer: **Brandon is correct as the projectile falls too short to reach *X*.** (1 mark)

Explanation: Use the kinematics equations to determine the height of the projectile as it arrives at 300 m at 6.53 sec.

$s = ut + 0.5at^2$
$s = 60 \times \sin(40) \times 6.53 + 0.5 \times -9.8 \times (6.53)^2$ (1 mark)
$s = 42.9$ m (1 mark)
Clearly, this is below the 53 m cliff height, meaning that the projectile has fallen short.

Question 15

a.

Answer: $\mathbf{1921\ g}$

Explanation: Use conservation of momentum to find unknown mass, *m*.

$$\sum p_i = \sum p_f$$
$4.9m = 2.6(m + 1700)$ (1 mark)
$m = 1921$ g (1 mark)

b.

Answer: $\mathbf{36.8\ N, left}$

Explanation: Use impulse equals to change in momentum. Note positive is to the right. Mass needs to be in kg.

$$F_{B\ on\ A} = \frac{\Delta p_A}{\Delta t}$$
$$F = \frac{1.921 \times (2.6 - 4.9)}{0.12}$$
$F = -36.8$ N (1 mark)

Negative force indicates it is directed left. (1 mark)

c.

Answer: An elastic collision is where kinetic energy is conserved (1 mark). An isolated collision is where momentum is conserved (1 mark).

Question 16

a.

Answer: $\mathbf{2.3\ m\ s^{-2}}$

Explanation: Use Newton's Second Law for the net force and acceleration of the combined mass.

$$F_{NET} = ma$$
$2 \times 9.8 - 3 \times 9.8 \times \sin(8) - 4 = (2 + 3)a$ (2 marks)
$a = 2.3\ \text{m s}^{-2}$ (1 mark)

b.

Answer: **15 N**

Explanation: Use Newton's Second Law for the net force and acceleration of the 5 kg mass, using the acceleration from Q16a.

$F_{NET} = ma$
$2 \times 9.8 - T = 2 \times 2.3$ (1 mark)
$T = 15$ N (1 mark)

Question 17

a.

Answer: $\mathbf{5.025}$

Explanation: Use the Lorentz factor calculation.

$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$
$\gamma = \frac{1}{\sqrt{1-\frac{(0.98c)^2}{c^2}}}$
$\gamma = 5.025$ (1 mark)

b.

Answer: $\mathbf{377\ ns}$

Explanation: Use the time dilation as the particle half-life will be longer when they are observed by an observer at rest to the apparatus (ie. Moving relative to the particles).

$t = t_0\gamma$
$t = 75 \times 5.025$ (1 mark)
$\gamma = 377\ \text{ns}$ (1 mark)

c.

Answer: $\mathbf{139\ m}$

Explanation: Use the length contraction as the particles are moving relative to the measuring station.

$l = \frac{l_0}{\gamma}$
$t = \frac{700}{5.025}$ (1 mark)
$\gamma = 139\ \text{m}$ (1 mark)

d.

Answer: $\mathbf{7.25 \times 10^{-9}\ J}$

Explanation: Use the length contraction as the particles are moving relative to the measuring station.

$E_k = (\gamma - 1)m_0c^2$
$E_k = (5.025 - 1) \times 2 \times 10^{-26} \times (3 \times 10^8)^2$ (1 mark)
$E_k = 7.25 \times 10^{-9}\ \text{J}$ (1 mark)

Question 18

Answer: $\mathbf{3.69 \times 10^{26}}$ **W**

Explanation: Use the mass-energy equivalence, then convert to power.

$E = mc^2$
$E = 2.46 \times 10^{11} \times (3 \times 10^8)^2$
$E = 2.21 \times 10^{28}$ J (1 mark)

$P = \frac{E}{t}$
$P = \frac{2.21 \times 10^{28}}{60}$
$P = 3.69 \times 10^{26}$ W (1 mark)

Question 19

a.

Answer: **Right to left** (1 mark)

Explanation: The solenoids wrapped around the iron core both create a magnetic field from right to left, as per the RH grip rule. This means that the coil experiences a right-to-left magnetic field.

b.

Answer: **0.135 N, anticlockwise**.

Explanation: Use Lorentz force calculation and then the RH slap rule.

$F = nBIL$
$F = 10 \times 0.3 \times 0.3 \times 0.15$ (1 mark)
$F = 0.135$ N (1 mark)
RH slap rule gives upwards force on CD so rotation is anticlockwise (1 mark).

c.

Answer: **Same.**

Explanation: Although there is some rotation, the current inside AB remains perpendicular to the magnetic field (1 mark), so the magnitude of the force remains constant (1 mark).

Question 20

a.

Answer: $\mathbf{8.80 \times 10^4}$ **J**

Explanation: The kinetic energy at B is equal to the total energy of the cart at A (E_g), less any work done by friction.

$E_k = mgh - Fx$ (1 mark)
$E_k = 360 \times 9.8 \times 26 - 80 \times 47$ (1 mark)
$E_k = 8.8 \times 10^4$ J (1 mark)

b.

Answer: **Heavier** (1 mark)

Explanation: The rider is in a state of vertical circular motion, with net force towards the centre (ie. up) The reaction force of the cart seat on the rider (*N*) which the rider feels as their apparent weight, will be greater than their "regular" weight (*mg*).

$F_{NET} = N - mg$
$N = \frac{mv^2}{r} + mg$ (1 mark)

c.

Answer: **204 N**

Explanation: The rider is in a state of vertical circular motion, with net force towards the centre (ie. down) The reaction force of the cart seat on the rider (*N*) which the rider feels as their apparent weight, will be less than their "regular" weight (*mg*).

$F_{NET} = mg - N$
$N = mg - \frac{mv^2}{r}$
$N = 60 \times 9.8 - \frac{60 \times 8^2}{10}$ (1 mark)
$N = 204$ N (1 mark)

Question 21

Answer: $\mathbf{12.8\ N, left}$

Explanation: Use Coulomb's Law. The force is to the **left** (1 mark) as Q_2 will be attracted to Q_1 due to its opposite charge.

$F = \frac{kQ_1Q_2}{r^2}$

$F = \frac{8.99\times10^9\times1.6\times10^{-6}\times0.8\times10^{-6}}{(0.03)^2}$ (1 mark)

$F = 12.8\text{ N}$ (1 mark)

Question 22

Answer: $\mathbf{112\ V}$

Explanation: Determine the voltage loss in the lines and then step-down to find the voltage at the shed.

$V_{SEC} = 230 \times 5$

$V_{SEC} = 1150\text{ V}$

$I_{PRIM} = \frac{P}{V} = \frac{50000}{230} = 217\text{ A}$

$I_{LINE} = I_{SEC} = \frac{217}{5} = 43.5\text{ A}$ (1 mark)

$V_{LOSS} = IR = 43.5 \times 0.6 = 26.1\text{ V}$ (1 mark)

$V_{PRIM\ STEP-DOWN} = 1150 - 26.1 = 1123.9\text{ V}$

$V_{SHED} = \frac{1123.9}{10} = 112\text{ V}$ (1 mark)