Neap

Trial Examination 2022

Suggested Solutions

QCE Physics Units 3&4

Paper 2

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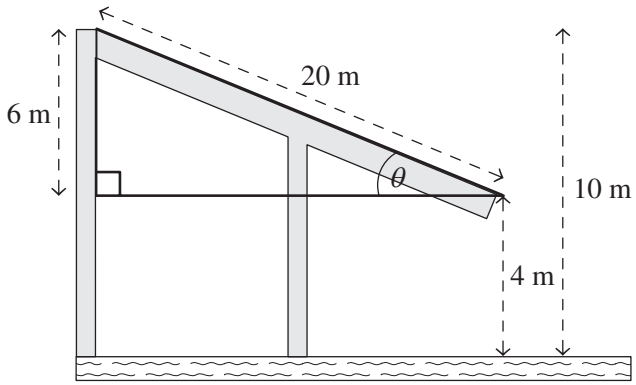
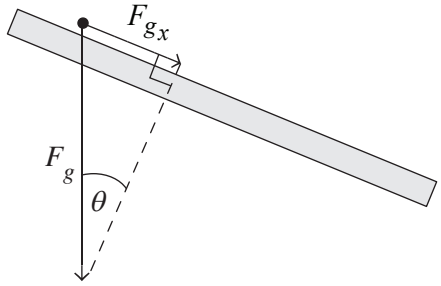
SECTION 1

QUESTION 1 (8 marks)

a)





The angle that the waterslide makes with the pool surface:

$$\sin\theta = \frac{6}{20}$$

$$\theta = \sin^{-1}\frac{6}{20}$$

$$\theta = 17.46° \quad \text{(to 2 decimal places)}$$

[1 mark]
1 mark for determining the angle.
Note: Diagrams are not required to obtain full marks.

b) Component of the weight force parallel to the waterslide (magnitude only):

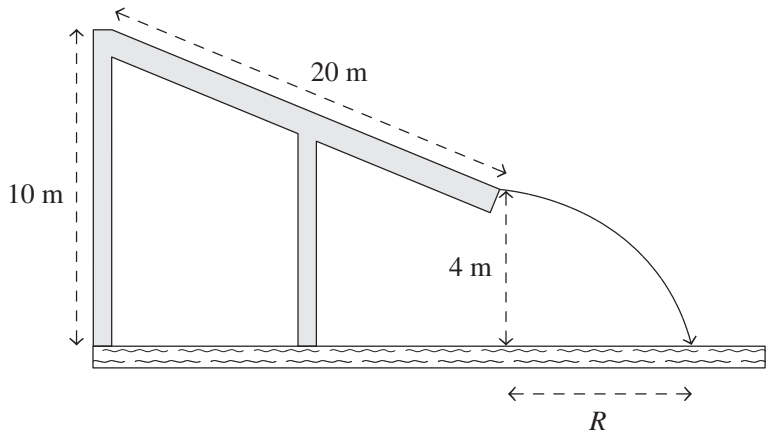
$$\begin{aligned} F_{g_x} &= F_g \cdot \sin\theta \\ &= mg \cdot \sin\theta \\ &= 60 \times 9.8 \times \sin\theta \\ &= 60 \times 9.8 \times \sin 17.46 \\ &= 176.4 \text{ N} \quad \text{(to 1 decimal place)} \end{aligned}$$

[2 marks]
1 mark for using correct trigonometry in working.
1 mark for calculating the magnitude.
*Note: Consequential on answer to **Question 1a**). $\sin\theta$ or cos (90 – θ) are acceptable per the working shown. Accept a positive or negative final answer.*

c) $$\begin{aligned} a_x &= \frac{F_{g_x}}{m} \\ &= \frac{176.4}{60} \\ &= 2.94 \text{ m s}^{-2} \quad \text{(to 2 decimal places)} \end{aligned}$$

[1 mark]
1 mark for providing the correct answer.
*Note: Consequential on answer to **Question 1b**). Accept a positive or negative final answer.*

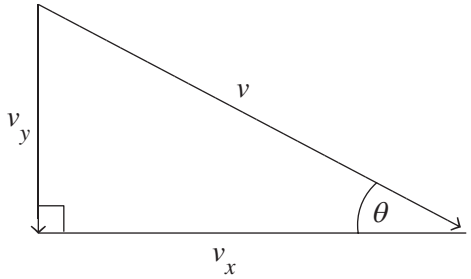
d)



Final velocity of the student at the bottom of the waterslide (linear motion):

$$v^2 = u^2 + 2as$$
$$v^2 = 0^2 + 2 \times 2.94 \times 20$$
$$v = \sqrt{117.6}$$
$$= 10.8444 \text{ m s}^{-1}$$

Horizontal component of this velocity:



$$v_x = v \cdot \cos\theta$$
$$= 10.8444 \times \cos\theta$$
$$= 10.8444 \times \cos 17.46$$
$$= 10.3447 \text{ m s}^{-1}$$

Horizontal range while in free fall:

$$R = v_x \cdot t$$
$$= 10.3447 \times 0.63$$
$$= 6.5 \text{ m} \quad \text{(to 1 decimal place)}$$

[4 marks]
1 mark for substituting into the formulas.
1 mark for calculating the final velocity at the bottom of the waterslide. (Note: The square root is technically '±'; however, this question only considers magnitudes, not directions, so accept positive or negative values.)
1 mark for calculating the horizontal component of the velocity.
1 mark for calculating the horizontal range.
Note: Consequential on answer to ***Question 1c****). Diagrams are not required to obtain full marks.*

QUESTION 2 (5 marks)

a) The energy level diagram shows a number of energy states in an atom. When an electron transitions from a higher energy state to a lower energy state, a quantum of light in the form of a photon is emitted. The energy of this photon corresponds to the difference in energy between levels. This photon has a specific energy, which corresponds to a specific wavelength.

[3 marks]

1 mark for explaining that the energy level diagram shows energy states and how electron transitions result in photon emission.

1 mark for explaining that photon energy corresponds to difference in energy between levels.

1 mark for explaining that the photon has specific energy.

Note: Responses should use appropriate wording and phrasing to obtain full marks.

b) As the jump to the lower energy state of $n = 1$ is a larger jump ($n = 1$ is lower than $n = 2$), the photon released has a greater amount of energy. A greater amount of energy results in a shorter wavelength per $E = \frac{hc}{\lambda}$.

[2 marks]

1 mark for explaining that the photon released has greater energy.

1 mark for stating that a greater amount of energy results in a shorter wavelength.

Note: Responses are not required to include the formula to obtain full marks.

QUESTION 3 (4 marks)

For example, any four of:

- The photoelectric effect is the emission of electrons from a material due to incident photons.
- A photon of sufficient energy (f > threshold frequency or E > work function) is absorbed by an electron and the electron is ejected from the material; the ejected electron is a photoelectron.
- A photon of insufficient energy (f < threshold frequency or E < work function) does not eject an electron from the material.
- Increasing the frequency of a photon, and thereby its energy, increases the maximum velocity (or kinetic energy) of the ejected electron.
- If the threshold frequency (or work function) is met or surpassed, then increasing the intensity of the incident photons increases the amount of ejected photons; that is, the photocurrent increases.
- If the threshold frequency (or work function) is not met or surpassed, then increasing the intensity of the incident photons produces no photoelectrons, even for very intense light.
- The threshold frequency differs depending on the material.
- One photoelectron absorbs one photon only.

[4 marks]

1 mark for each correct characteristic.

Note: Responses should use appropriate wording and phrasing to obtain full marks.

QUESTION 4 (5 marks)

a) $a_c = \dfrac{v^2}{r}$

$\dfrac{1}{r} = \dfrac{a_c}{v^2}$

$\dfrac{1}{r} = 0.002$ (gradient of trendline $a_c = 0.002v^2$)

$r = 500$ m (to the nearest whole number)

[2 marks]
1 mark for recognising that the gradient is equal to the reciprocal of the radius (may be implied by working).
1 mark for determining the radius.
Note: The question states to use the trendline equation; therefore, responses that only use a single data point from the graph can only obtain one mark for determining the correct answer.

b) From the equation of the trendline, $0.002v^2 = 7.2$. So, $v = 60$ m s^{-1}.

$v = \dfrac{2\pi r}{T}$

$T = \dfrac{2\pi r}{v}$

$= \dfrac{2 \times \pi \times 500}{60}$

$= 52$ s (to the nearest whole number)

[3 marks]
1 mark for determining the value of v (may be implied by working).
1 mark for substituting into the formula.
1 mark for calculating the period of rotation.
*Note: Accept follow-through errors. Consequential on answer to **Question 4a)**.*

QUESTION 5 (8 marks)

a) $t_0 = 20$ years

$t = \dfrac{t_0}{\sqrt{\left(1 - \dfrac{v^2}{c^2}\right)}}$

$= \dfrac{20}{\sqrt{\left(1 - \dfrac{0.866^2 c^2}{c^2}\right)}}$

$= 40$ years (to the nearest whole number)

[2 marks]
1 mark for identifying t_0.
1 mark for determining the time elapsed from twin A's perspective.

b) $t = 20$ years

$$t = \frac{t_0}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$$

$$20 = \frac{t_0}{\sqrt{\left(1 - \frac{0.866^2 c^2}{c^2}\right)}}$$

$t_0 =$ 10 years (to the nearest whole number)

[2 marks]
1 mark for identifying t.
1 mark for determining the time elapsed from twin B's perspective.

c) Twin A, who remained on Earth, cannot have aged both 10 years and 40 years when the twins meet again.

[1 mark]
1 mark for recognising that the time passed on Earth cannot have been two values.

d) One of the frames of reference is inertial, while the other is non-inertial; this is due to Twin B needing to accelerate to turn around and return to the Earth at some point.

[1 mark]
1 mark for suggesting a resolution.
Note: Responses should use appropriate wording and phrasing to obtain full marks.

e) Length contraction occurs.

For example, any one of:

- Twin B, the travelling twin, experiences length contraction as twin A, who remained on Earth, measures proper length.
- Twin B, the travelling twin, experiences length contraction as they experience proper time, which is less than dilated time, and so they need to cover less distance to ensure their velocity remains unchanged.

[2 marks]
1 mark for identifying that length contraction occurs.
1 mark for explaining which twin experiences length contraction.

QUESTION 6 (5 marks)

a) $$\text{emf} = -\frac{n \cdot B \cdot \cos\theta \cdot \Delta A}{\Delta t}$$

$$= -\frac{1 \times 7 \times 1 \times (0.6 - 1.5)}{0.05}$$

$$= 126 \text{ V} \quad \text{(to the nearest whole number)}$$

[3 marks]

1 mark for recognising that $\theta = 0°$ or $\cos\theta = 1$.

1 mark for substituting into the formula.

1 mark for calculating the emf.

Note: Magnitude is required only; accept ΔA as ($0.6\ m^2 - 1.5\ m^2$) or ($1.5\ m^2 - 0.6\ m^2$).

Accept a positive or negative final answer.

b) The direction is out of the page. Lenz's law states that the induced magnetic field will always oppose the change in flux inside the loop of wire. Since the loop is reducing the area and $\Phi = BA$, flux is reduced. Therefore, the induced magnetic field will act to increase the flux inside the loop, and since the external field is pointing out of the page, the induced magnetic field inside the loop will also be out of the page.

[2 marks]

1 mark for identifying that the direction is out of the page.

1 mark for explaining the direction.

Note: Equations are not required to obtain full marks. Responses should use appropriate wording and phrasing to obtain full marks.

QUESTION 7 (5 marks)

$W = 2.36 \text{ eV}$

$= 2.36 \times 1.60 \times 10^{-19}$

$= 3.776 \times 10^{-19} \text{ J}$

$E = hf$

Substituting $f = \dfrac{c}{\lambda}$ gives:

$E = \dfrac{hc}{\lambda}$

$E = \dfrac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{4.5 \times 10^{-7}}$

$= 4.4173 \times 10^{-19} \text{ J}$ (equivalent to 2.76 eV)

$E_k = hf - W$

$= 4.4173 \times 10^{-19} - 3.776 \times 10^{-19}$

$= 6.4133 \times 10^{-20} \text{ J}$

OR

$E_k = hf - W$

$= 2.76 - 2.36$

$= 0.40 \text{ eV}$

$E_k = \dfrac{1}{2}mv^2$

$v = \sqrt{\dfrac{2E_k}{m}}$

$= \sqrt{\dfrac{2 \times 6.4133 \times 10^{-20}}{9.1093835 \times 10^{-31}}}$

$= 375\,242.8375 \text{ m s}^{-1}$

$= 3.8 \times 10^{5} \text{ m s}^{-1}$ (to 2 significant figures)

[5 marks]

1 mark for converting eV to J (either initially with the work function as shown or after finding the energy of the light).

1 mark for converting the wavelength of the light to frequency $\left(f = \dfrac{c}{\lambda} = \dfrac{3 \times 10^{8}}{4.5 \times 10^{-7}} = 6.67 \times 10^{14} \text{ Hz} \right)$.

1 mark for determining the energy of the light.

1 mark for substituting into the formulas.

1 mark for calculating the maximum velocity.

QUESTION 8 (5 marks)

$$n = \frac{N}{L}$$
$$= \frac{100}{0.1}$$
$$= 1000 \text{ turns per metre}$$

$$\text{cross-sectional area} = \pi r^2$$
$$= \pi (0.025)^2$$
$$= 1.9635 \times 10^{-3} \text{ m}^2$$

$$B = \mu_0 nI$$
$$= 4\pi \times 10^{-7} \times 1000 \times 1$$
$$= 1.2567 \times 10^{-3} \text{ T}$$

$$\Phi = BA$$
$$= 1.2567 \times 10^{-3} \times 1.9635 \times 10^{-3}$$
$$= 2.5 \times 10^{-6} \text{ Wb}$$
$$= 2.5 \ \mu\text{Wb} \quad \text{(to 1 decimal place)}$$

[5 marks]
1 mark for calculating the number of turns per metre.
1 mark for calculating the cross-sectional area.
1 mark for calculating the B-field.
1 mark for calculating the magnetic flux.
1 mark for expressing the answer in microwebers.
Note: Accept follow-through errors.