Neap:

Trial Examination 2014

VCE Physics Unit 3

Written Examination

Suggested Solutions

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SECTION A – CORE

Area of study 1 – Motion in one and two dimensions

Question 1 (8 marks)

a. $g\sin\theta = 1.0\ \text{m s}^{-2}$

$\theta = \sin^{-1}\left(\frac{1}{10}\right)$ 1 mark

$\theta = 5.74°$ 1 mark

$= 5.7°$

b. $s = \frac{1}{2}at^2$

$t = \frac{\sqrt{2 \times 2.0}}{1.0}$ 1 mark

$= 2.0\ \text{s}$ 1 mark

c. The correct answer is **C**. 2 marks

The acceleration is the same for balls of any mass.

d. The correct answer is **C**. 2 marks

$s = \frac{1}{2}at^2$

$\frac{t_{4.0\ \text{m}}}{t_{2.0\ \text{m}}} = \sqrt{\frac{4.0}{2.0}} = \frac{\sqrt{2}}{1}$

Question 2 (6 marks)

a. $\Sigma F = 0$

$F_{\text{ENGINE}} = F_{\text{FRICTION}}$ 1 mark

$= (1500 + 500)\text{kg} \times \frac{1N}{\text{kg}}$

$= 2000\ \text{N}$ 1 mark

b. $F_{\text{TOW BAR}} = F_{\text{FRICTION ON TRAILER}}$ 1 mark

$= (500)\ \text{kg} \times \frac{1N}{\text{kg}}$

$= 500\ \text{N}$ 1 mark

c. $\Sigma F = ma$

$F_{\text{TOW BAR}} - F_{\text{FRICTION}} = 500(3)$ 1 mark

$F_{\text{TOW BAR}} = 2000\ \text{N}$ 1 mark

Question 3 (7 marks)

a. $t = \frac{d}{v}$

$= \frac{90}{45}$

$= 2.0 \text{ s}$ 1 mark

b. At midpoint of flight $V_{\text{VERTICAL}} = 0 \text{ m s}^{-1}$.

$t_{\text{MIDPOINT}} = 1.0 \text{ s}$

$v = u + at$ (vertical)

$\therefore v_{\text{VERTICAL AT BOW}} = 10 \text{ m s}^{-1}$ 1 mark

$\therefore v_{\text{HORIZONTAL AT BOW}} = 45 \text{ m s}^{-1}$ 1 mark

$\therefore \tan\theta = \frac{10}{45}$

$\theta = 12.5°$ 1 mark

c. Reaches maximum height at midpoint.

$s_{EXTRA} = \frac{1}{2}at^2 = 5(1)^2 = 5 \text{ m}$ 2 marks

$\therefore$ maximum height = 6.8 m 1 mark

Question 4 (5 marks)

a. Call the tension in the string *T*.

$T\sin\theta = \frac{mv^2}{R}$

$T\cos\theta = mg$ 1 mark

$\tan\theta = \frac{v^2}{Rg} = \frac{16}{(0.5)(10)} = 3.2$ 1 mark

$\theta = 72.6°$ 1 mark

b. $T\cos\theta = mg$ 1 mark

$T = \frac{20}{\cos(72.6°)}$

$T = 66.9 \text{ N}$ 1 mark

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Question 5 (4 marks)

a. The correct answer is **B**. 1 mark

$\therefore \text{PE}_{\text{BOTTOM}} = 0 \text{ J}$

$\text{KE}_{\text{BOTTOM}} = \text{KE}_{\text{TOP}} + \text{PE}_{\text{TOP}}$

b. $\text{KE}_{\text{TOP}} = \frac{1}{2}mv^2 = \frac{1}{2}m(5)^2$

$\text{KE}_{\text{BOTTOM}} = \frac{1}{2}m(50)^2$

$\text{PE}_{\text{TOP}} = mgh$

$\therefore mgh = \frac{1}{2}m(50)^2 - \frac{1}{2}m(5)^2$ 1 mark

$h = \frac{2500 - 25}{20}$ 1 mark

$= 123.75 \text{ m}$ 1 mark

Question 6 (5 marks)

a. [✓ spring P] 1 mark

Spring P is stiffer as it has a greater spring constant (which is given by the gradient of the force versus extension graph). 1 mark

b. $F = 800 \text{ N} = 40 \text{ N}$ per spring 1 mark

From graph, $40 \text{ N} \Rightarrow \Delta x = 0.08 \text{ m}$.

$\therefore$ energy per spring $= \frac{1}{2}(40)(0.08)$

$= 1.6 \text{ J}$ 1 mark

$\therefore$ energy for 20 springs = 32 J 1 mark

Question 7 (5 marks)

a. $\frac{R^3}{T^2} = \frac{GM}{4\pi^2} \qquad T = \sqrt{\frac{R^3 4\pi^2}{GM}}$ 1 mark

$$T = \sqrt{\frac{(6.97 \times 10^6)^3 4\pi^2}{(6.97 \times 10^{-11})(5.98 \times 10^{24})}}$$

$= 3.47 \times 10^5 \text{ s}$ 1 mark

$= 1.6 \text{ hr}$ 1 mark

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b. $F = mg = \dfrac{mGM}{R^2}$

$= \dfrac{(1.1 \times 10^4)(6.67 \times 10^{-11})(5.98 \times 10^{24})}{(6.97 \times 10^6)^2}$ 1 mark

$= 9.0 \times 10^4$ N 1 mark

Area of study 2 – Electronics and photonics

Question 1 (6 marks)

a. The 30 Ω and 60 Ω resistor are in parallel and, using the parallel resistance formula, have an equivalent resistance of 20 Ω. 1 mark

Using the series formula gives a total resistance of 30 Ω. 1 mark

b.

The current through the parallel equivalent 20 Ω and the 10 Ω resistor is the same. 1 mark

Therefore using $V = IR$, if $V_{10\Omega} = 6.0$ V then $V_{20\Omega} = 12.0$ V. 1 mark

c. The current in the 60 Ω resistor is I. Therefore the current in the 30 Ω resistor is $2I$, as the voltage drop across the parallel components is the same but the resistance is halved. 1 mark

The total current running through the 10 Ω resistor is $3I$ (the sum of the two currents from the parallel combination). 1 mark

Note: possible consequential on the first part.

Question 2 (5 marks)

a. The resistance versus temperature graph for a thermistor used as a temperature control device is non-linear, 1 mark

as the graph shown in Figure 2 is a non-linear graph (i.e. it is not a straight-line graph). 1 mark

b. From the resistance versus temperature graph the temperature is 70°C (allow a few degrees tolerance) when the resistance is 1000 Ω. 1 mark

c. The minimum value that the variable resistor is required to be set at so that the buzzer sounds when the thermistor is at a temperature of 20°C can be determined using the voltage divider formula. As $V_{XZ} = 9.0$ V and $V_{YZ} \geq 6.0$ V, then $V_{XY} \leq 3.0$ V.

At 20°C the resistance of the thermistor is 2.7 kΩ (reading the information from the resistance versus temperature graph shown in Figure 2). 1 mark

$$\frac{V_{YZ}}{V_{XZ}} = \frac{6.0}{3.0} = \frac{R_{YZ}}{2700} \Rightarrow R_{YZ} = 5.4 \text{ k}\Omega.$$ 1 mark

Question 3 (6 marks)

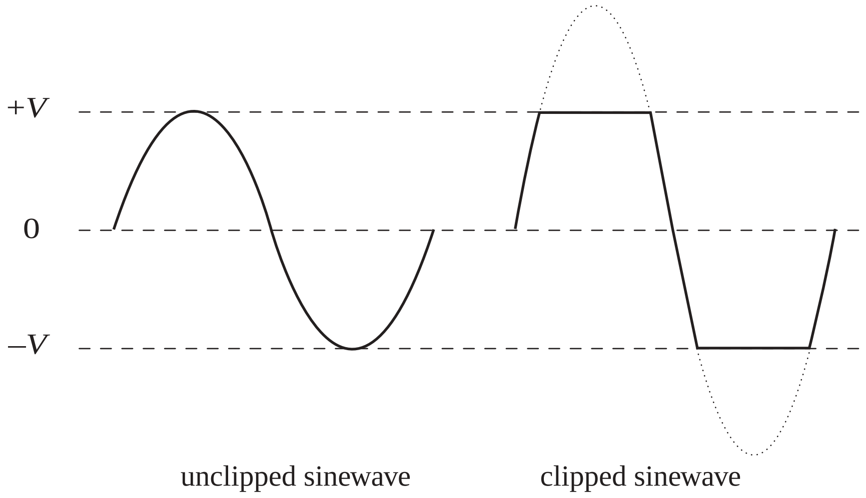
a. Figure 4 shows a peak-to-peak voltage for the output voltage of 50 V. 1 mark

$$V_{PP} = 2\sqrt{2}V_{RMS}$$

Therefore $V_{RMS} = 17.7$ V. 1 mark

b. gain of the voltage amplifier $= \frac{V_{\text{OUT}}}{V_{\text{IN}}} = \frac{50 \text{ V}}{500 \text{ mV}} = 100$ 2 marks

c. Clipping occurs when the input voltage ranges outside the linear amplification region of the V_{IN} versus V_{OUT} characteristic graph for the voltage amplifier. This results in a distorted output signal (see diagram below) – output voltage is constant outside the linear amplification region. 2 marks



Question 4 (6 marks)

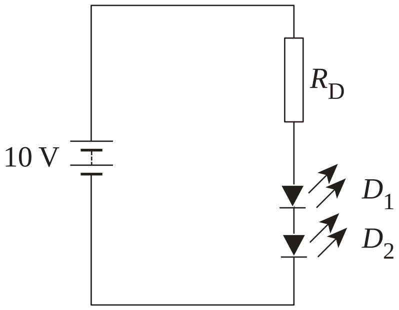
a. The current in the resistor R_D = 3.5 mA.

V_{LED} = 3.0 V

Therefore V_{RD} = 7.0 V. 1 mark

$V = IR$ so $I = \frac{7}{2000}$ = 3.5 mA. 1 mark

b. Placing both LEDs in series with the resistor R_D gives the circuit arrangement shown below.



2 marks

c. When both LEDs are in series with the resistor R_D the voltage drop across the combined LEDs is 4.5 V. Therefore 5.5 V will drop across R_D. 1 mark

$V = IR$ so $I = \frac{5.5}{2000}$ = 2.75 mA. 1 mark

Question 5 (5 marks)

a. The acronym LDR stands for light-dependent resistor. The resistance varies as a function of the amount of light illuminating the LDR. 1 mark

b. $V_{PQ} = 8.0\ \text{V}$ when the illuminance is 6 lux.

At 6 lux the resistance of the LDR is 20 kΩ. 1 mark

This is two-thirds of the total resistance in the voltage divider circuit shown in Figure 8.

$12\ \text{V} \times \frac{2}{3} = 8.0\ \text{V}$ 1 mark

c. The illuminance in the room goes down to 0.2 lux. This means that the resistance of the LDR is now 200 kΩ. 1 mark

For the lights to come on $V_{PQ} \geq 10.5\ \text{V}$.

Using the voltage divider formula:

$$V_{\text{OUT}} = \frac{200\ \text{k}\Omega}{210\ \text{k}\Omega}V_{\text{IN}}$$

$$= 11.4\ \text{V}$$

As $11.4\ \text{V} > 10.5\ \text{V}$ the lights will come on. 1 mark

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SECTION B – DETAILED STUDIES (2 marks for each correct answer)

Detailed study 2 – Materials and their use in structures

Question 1 C

Reading the σ information from the graph it can be seen that *X* has about twice the ultimate tensile strength of *Z* (that is, the stress at the endpoint at the fracture point).

Question 2 B

Materials that fail without demonstrating plastic behaviour are said to be brittle, therefore material *Y*.

Question 3 B

The relative toughness of materials *X*, *Y* and *Z* is given by their respective areas under the stress–strain graphs. Material *Z* has the greatest area, followed by material *X* and then by material *Y*.

Question 4 A

The tension (T) in the wire is 174 N and the vertical components of both sections of the wire support the weight force, which is 200 N.

Therefore $2T\sin\theta = 200$.

$\theta = 35°$

Question 5 D

$$\sigma = \frac{F}{A} = \frac{174\text{ N}}{5.0 \times 10^{-6}\text{ m}^2}$$

The tensile stress in the wire is $34.8 \times 10^6\text{ N m}^{-2}$.

Question 6 C

$$\sigma = \frac{F}{A} = \frac{1.0^5\text{ N}}{0.2\text{ m}^2}$$

The compressive stress in the column $5 \times 10^5\text{N m}^{-2}$.

Question 7 B

The area under a stress versus strain graph gives the energy absorbed per cubic metre (J m^{-3}).

For a straight-line graph this is given by $\frac{\sigma_t \varepsilon}{2}$.

As $Y = \frac{\sigma_t}{\varepsilon}$, a rearrangement of the formula gives $\frac{0.5(\sigma_t)^2}{Y}\text{ J m}^{-3}$.

As the sample cylinder is 0.5 m^3, total energy is $\frac{0.25(\sigma_t)^2}{Y}$.

Question 8 B

Horizontal shear loads require vertical steel reinforcing meshes near the vertical edges of the square column.

Question 9 B

Stone is used to make such a bridge because arches require a material that is strong under compressive stress, and in an arch design all the stones are under compression.

Question 10 C

Taking moments about point *P* gives the following torque equations:

clockwise torque = $(2000)(2.5) + (1000)(3.0)$

anticlockwise torque = $F_Q(5.0)$

As the system is in equilibrium, solving gives $F_Q = 1600$ N.

Question 11 D

As the total force downwards is 3000 N it means $F_P + F_Q = 3000$ N.

But F_Q is 20% larger than F_P.

$F_Q = 1.2F_P$

Therefore $F_Q = 1636$ N.

Call the distance from block *B* to point *P* *x* metres.
Taking moments about point *P* gives the following torque equations:

clockwise torque = $(2000)(2.5) + (1000)(x)$

anticlockwise torque = $(F_Q)(5) = (1636)(5)$

As the system is in equilibrium, solving gives $x = 3.18$ m.

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Detailed study 6 – Sound

Question 1 C

When the loudspeaker produces sound the candle flame will vibrate horizontally, as the sound pressure wave moves back and forth in a horizontal direction.

Question 2 B

As the sound pressure wave moves back and forth in a horizontal direction, the experiment demonstrates that sound is a longitudinal wave (and not a transverse wave).

Question 3 D

Substitution into the wave equation $v = \lambda f$ gives

$$\begin{aligned} 334 &= \lambda(256) \\ \lambda &= 1.30 \text{ m} \end{aligned}$$

Question 4 B

The length of the flute is 0.65 m. The flute is modelled as a simple pipe that is open at both ends. The fundamental frequency corresponds to a resonance where exactly one-half of a wavelength fits into the pipe.

$$\begin{aligned} 256 &= \frac{334}{2L} \\ L &= 0.65 \text{ m} \end{aligned}$$

Question 5 C

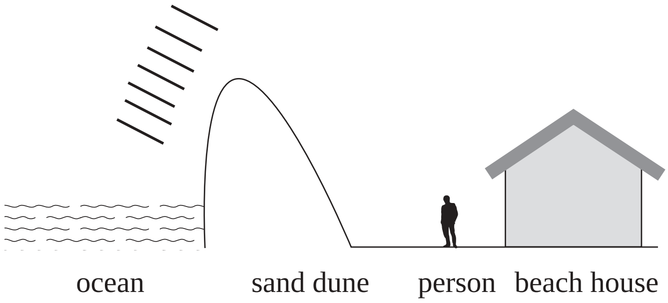
The second overtone is the third harmonic, which means that the frequency will be three times the fundamental frequency.

$$3 \times 256 = 768 \text{ Hz}$$

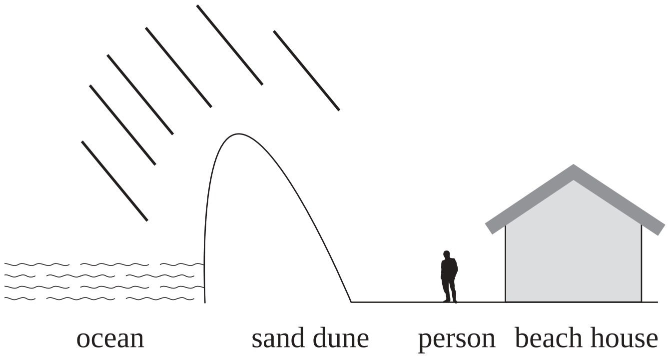
Question 6 **B**

The next three diagrams show **schematically** how high, middle and low-frequency sound waves behave as they encounter the top of the sand dune. Notice that the low-frequency sound waves 'bend' or diffract more than the middle-frequency sound waves, and high-frequency sound waves virtually do not diffract at all around this object.

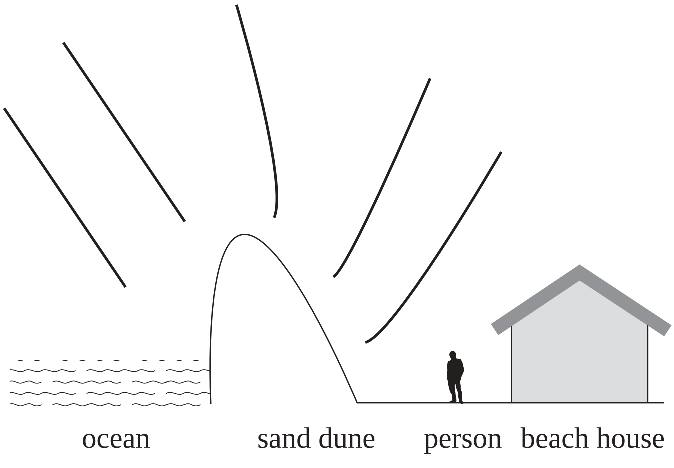
high frequency waves



middle frequency waves



low frequency waves



Question 7 **A**

The reason that you can hear the sounds made by the crashing ocean waves at the beach house is because of diffraction.

Question 8 D

The sound intensity at a distance of 20 m from the truck is 2.0×10^{-4} W m^{-2}. Sound intensity follows an inverse square law, therefore at twice the distance the intensity will be one-quarter of the original sound intensity.

Question 9 C

The decibel reading at a distance of 10 m is 99 dB.

$$L(\text{dB}) = 10\log\left(\frac{8 \times 10^{-3}}{1.0 \times 10^{-12}}\right) = 99\ \text{dB}$$

Question 10 C

The only transducer that does not work on the principle of electromagnetic induction and/or electromagnetic force is the piezoelectric crystal microphone.

Question 11 B

A baffle increases the distance that the sound waves produced at the back of the speaker have to travel to interact with the sound waves produced at the front of the speaker. These sound waves are out of phase, and without a baffle the destructive interference of the sound coming from the front and back of the loudspeaker would lead to very poor quality sound.

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