Neap:

Trial Examination 2011

VCE Physics Unit 3

Written Examination

Suggested Solutions

SECTION A – CORE

Area of study 1 – Motion in one and two dimensions

Question 1

At 5.0 m, speed is constant so $\Sigma F = 0$. Therefore F_d (driving force) is equal to the frictional force at 5.0 m, and so is equal to 20 N. 1 mark

At 2.0 m, $\Sigma F = 20 - 9 = 11\ \text{N}$. 1 mark

$\Sigma F = ma$

$11 = 2.0a$ 1 mark

$a = 5.5\ \text{m s}^{-2}$

Question 2

$\Delta E_k =$ work done on car – work done to overcome friction

Work done to overcome friction = area under graph = 53 squares $\times$ 1 = 53 J (accept 52.5 – 53.5 J) 1 mark

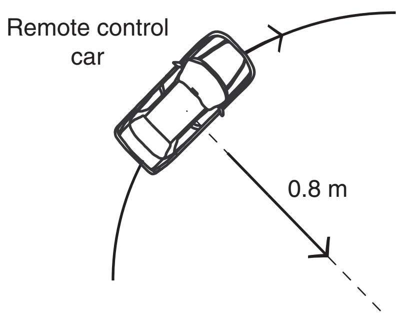
$\Delta E_k = \frac{1}{2}mv^2 = (Fxd) - 53$

$\frac{1}{2} \times 2 \times v^2 = (20 \times 5) - 53$ 1 mark

$v = 6.9\ \text{m s}^{-1}$ 1 mark

Question 3

Centripetal force will act towards the centre of the circle. 1 mark



Question 4

$F_c = \frac{mv^2}{r}$

$4.5 = \frac{(2 \times v^2)}{0.8}$ 1 mark

$v = 1.3\ \text{m s}^{-1}$ 1 mark

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Question 5

Since $F_c = \frac{mv^2}{r}$ by the maximum speed at which the car can travel in a circle of radius r can be increased by increasing F_c. 1 mark

If the curve is banked, there is a component of the normal force acting towards the centre of the circle. 1 mark

Centripetal force will be equal to the sum of the sideways frictional force and the component of the normal towards the centre of the circle, and hence increase the speed at which the car can travel in the circular path. 1 mark

Question 6

Apparent weight is equal to the normal force acting on the car.

At the top of the speed hump, $F_c = \frac{mv^2}{r} = mg - N$.

$N = (2 \times 10) - \frac{(2 \times 2.5^2)}{1.5}$ 1 mark

$N = 12$ N 1 mark

Question 7

Conservation of momentum: $p_i = p_f$

$(2.5 \times 2) = (-1.2 \times 2) + (1 \times m)$ 1 mark

$m = 7.4$ kg 1 mark

Question 8

$m\Delta v = \Sigma Ft$

$2(-1.2 - 2.5) = \Sigma F(0.05)$ 1 mark

$\Sigma F = 148 \text{ N} = 1.5 \times 10^2 \text{ N}$ 1 mark

Direction is West 1 mark

Question 9

Initial kinetic energy $= \frac{1}{2}mv^2$

$= \frac{1}{2} \times 2 \times 2.5^2$

$= 6.25$ J 1 mark

Final kinetic energy $= \left(\frac{1}{2} \times 2 \times 1.2^2\right) + \left(\frac{1}{2} \times 7.4 \times 1^2\right)$

$= 5.14$ J 1 mark

Since kinetic energy has been lost, the collision is inelastic. Therefore Matilda is not correct. 1 mark

Question 10

Horizontally, $x = ut\cos\theta$

$= 2 \times 0.43 \times \cos(37°)$ 1 mark

$x = 0.67$ m 1 mark

Question 11

Vertically to the top of the flight, $u = 2\sin(37°)\ \text{m s}^{-1}$, $v = 0$ and $a = -10\ \text{m s}^{-2}$.

$v^2 = u^2 + 2ax$

$0 = (2\sin(37°))^2 + (2 \times -10)x$ 1 mark

$x = 0.07$ m 1 mark

Question 12

Vertically for the whole flight, $u = 2\sin(37°)\ \text{m s}^{-1}$, $t = 0.43$ sec and $a = -10\ \text{m s}^{-2}$. 1 mark

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

$= (2\sin(37°) \times 0.43) + \left(\frac{1}{2} \times -10 \times 0.43^2\right)$ 1 mark

$x = -0.4$ m, therefore the height of the ramp is 0.4 m. 1 mark

Question 13

From the graph, $k = \frac{1}{0.01} = 100\ \text{N m}^{-1}$. 1 mark

$U_e = E_k$ hence $\frac{1}{2}kx^2 = \frac{1}{2}mv^2$.

$\frac{1}{2} \times 100 \times (5.0 \times 10^{-3}) = \frac{1}{2} \times 0.3 \times v^2$ 1 mark

$v = 0.09\ \text{m s}^{-1}$ 1 mark

Question 14

$T = 2 \times 60 \times 60 = 7200$ seconds

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

$\frac{r^3}{7200^2} = \frac{(6.67 \times 10^{-11} \times 5.98 \times 20^{24})}{4\pi^2}$ 1 mark

$r = 8.1 \times 10^6$ m 1 mark

Altitude = r – radius of earth

$= (8.1 \times 10^6) - (6.37 \times 10^6)$

$= 1.7 \times 10^6$ m 1 mark

$1.7 \times 10^6\ \text{m} = 1.7 \times 10^3\ \text{km}$ 1 mark

Question 15

The apparent weight of the satellite is equal to 0 N. 2 marks

This is because the only force acting on the satellite in orbit is the force of gravity, and so the satellite is in 'free fall' and its apparent weight is zero.

Question 16 A

The area under the graph shows the increase in gravitational potential energy and corresponding decrease in kinetic energy as the object moves from position A to position B. 2 marks

Area of study 2 – Electronics and photonics

Question 1

An ammeter is a device that has a very low internal resistance. The ammeter is connected in series and not connected in parallel with the LED and resistor R as it will short circuit the LED and resistor R combination when placed in parallel. This will normally burn out the fuse in the ammeter. 2 marks

Question 2

15 mA

The LED has 1.5 V maximum across it (read information from the graph) and therefore the resistor has 4.5 V across it – the supply voltage minus voltage across LED (6.0 V – 1.5 V). 1 mark

Using $V = IR$

$I = \frac{4.5}{300} = 1.5 \times 10^{-2}$ A = 15 mA 1 mark

Question 3

0.0 mA

When the LED is reversed in the circuit, the current through the LED will be zero. 1 mark

This is because the LED is now in reverse-bias. 1 mark

Question 4

40 kΩ

The resistance of the LDR when the light intensity is 100 Lux is 40 kΩ (read the information directly from the graph). 1 mark

Question 5

12.0V

When the light intensity is 300 Lux, the resistance of the LDR is 10 kΩ (read the information directly from the graph). 1 mark

As the variable resistor and the LDR form a voltage divider circuit we can use the voltage divider formula. $V_{\text{OUT}} = \frac{20}{(20 + 10)18 \text{ V}} = 12.0$ V 1 mark

Question 6

The output voltage V_{OUT} decreases when the light intensity decreases to 100 Lux. 1 mark

The resistance of the LDR when the light intensity is 100 Lux is $40\ \text{k}\Omega$.

$V_{\text{OUT}} = \frac{20}{(20+40)18\ \text{V}} = 6.0\ \text{V}$ 1 mark

When the light level reaches 100 Lux, the change in voltage (from 12.0 V to 6.0 V) can be used to trigger a circuit to make the lighting turn on. 1 mark

Question 7

300

The gain of the amplifier is given by the gradient of the graph in the linear region.

$$\frac{V_{\text{OUT}}}{V_{\text{IN}}} = \frac{9\ \text{V}}{-30\ \text{mV}} = -300$$

(Note: the gain is normally given as the magnitude of the gradient of the graph.) 2 marks

Question 8

The amplifier is an inverting amplifier as the gradient is negative. 1 mark

Question 9

In reference to amplifiers clipping means the flattening of the output signal when the input signal is too large. When the amplitude of the input signal is too large, the amplifier is not physically capable of giving the normal voltage gain. 1 mark

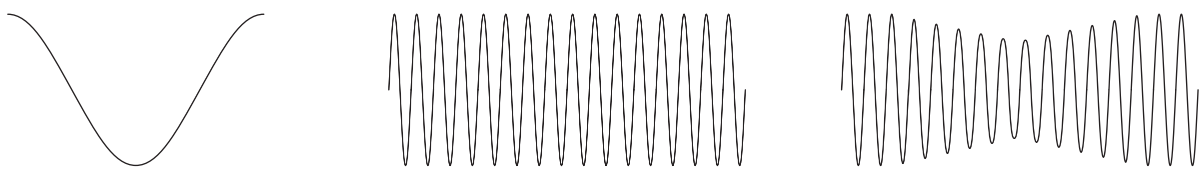
For the amplifier shown in Figure 6 the input voltage ranges which would be clipped would be those shown as flat straight lines from –30 mV to –50 mV and +30 mV to +50 mV. 1 mark

The most common effect of clipping is that the output wave signals do not match the input wave signals to the amplifier and hence there is distortion of the sound output compared to the sound input. 1 mark

Question 10

The process of amplitude modulation is the changing of the amplitude of a carrier wave by superimposing the waveform of the input signal. 1 mark

Waveform of the input signal + Carrier wave = Amplitude modulated signal



1 mark

Note: Some acceptable drawing of how an amplitude modulated signal is created is required for the full two marks.

Question 11

12 Ω

Call the resistance of resistor R_X.

Then, using the parallel resistor formula: $\frac{1}{R_p} = \frac{1}{R_X} + \frac{1}{6} = \frac{1}{4}$ 1 mark

$\frac{1}{R_X} = \frac{1}{12}$

$R_X = 12\ \Omega$ 1 mark

Question 12

12W

The power dissipated by resistor R_X is given by $P = \frac{V^2}{R} = \frac{2(12)}{12} = 12\ \text{W}$. 2 marks

(Note: Only 1 mark for the correct answer without any working and 2 marks for a fully worked consequential from the answer to Question 11.)

Question 13 **A**

The power dissipated by resistor R_{2X} is given by

$$P = \frac{V^2}{R}$$

$$= \frac{(12)^2}{24}$$

$$= 6\ \text{W}$$ 2 marks

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

Detailed study 1 – Einstein's special relativity

Question 1 **D**

An inertial reference frame is a spacecraft travelling at **constant velocity** in outer space.

Question 2 **C**

The γ factor is closest to 1.9 for a spacecraft travelling past a stationary observer on the moon at a speed of 0.85c.

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$= \frac{1}{\sqrt{1-\frac{(0.85c)^2}{c^2}}}$$

$$= 1.9$$

Question 3 **D**

One of the postulates of Einstein's relativity is that the speed of light is constant.

Question 4 **B**

Einstein's concept that mass can be converted to energy does not apply to burning coal as this is a chemical energy reaction, not a nuclear energy reaction.

Question 5 **A**

The Michelson–Morley Experiment of 1887 determined that c is constant.

Question 6 **D**

Proper time is best described as the time recorded in the reference frame at rest with respect to the event.

Question 7 **C**

The mass increase for this electron is 1.42×10^{-27} kg.

$$\Delta m = \frac{\Delta E}{c^2}$$

$$= \frac{(8.00 \times 10^8)(1.6 \times 10^{-19})}{(3.0 \times 10^8)^2}$$

$$= 1.42 \times 10^{-27}$$

Question 8 B

The time dilation for a satellite travelling at 1.0×10^4 m s^{-1} in its orbit around the earth demonstrates that Newtonian physics is a very good approximation to using Einstein's physics, as the speed travelled is very much less than the speed of light.

Question 9 C

The effect of the accelerator on the electron's speed and its energy is that the speed increases slightly whilst the energy increases substantially.

Question 10 A

The length of the spacecraft, as observed from earth, is 40 m. Use Lorentz length contraction formula and a γ factor of 2 to work out length contraction.

Question 11 D

The time noted by the earth-based observer is 60 s. Use Lorentz time dilation formula and a γ factor of 2 to work out time dilation.

Question 12 B

James Clerk Maxwell in 1864 produced equations which demonstrated that the perpendicular magnetic and electric waves can travel at 3.0×10^8 m s^{-1}.

Detailed study 2 – Materials and their use in structures

Question 1 B

Strength is represented by the maximum stress that the material can withstand, toughness is the area under the graph, stiffness is the gradient of the graph and a brittle material has no curved component of its stress–strain graph. The only statement which is correct is thus statement **B**.

Question 2 C

$$\begin{aligned}\text{Youngs modulus} &= \frac{\text{stress}}{\text{strain}}\\ &= \frac{2.0 \times 10^6}{3.0 \times 10^{-3}}\\ &= 6.7 \times 10^8 \text{ N m}^{-2}\end{aligned}$$

Question 3 B

From the graph, the maximum tensile force that material *Y* can withstand is 2.0×10^6 N m^{-2}.

Question 4 D

$$\text{Stress} = \frac{F}{A}$$
$$= \frac{2100}{\pi \times 0.01^2}$$
$$= 6.7 \times 10^6 \text{ N m}^{-2}$$

Question 5 B

From the graph, a stress of 6.7×10^6 N m^{-2} (calculated in Question 4) is in the non-linear region of the compressive stress vs. strain graph for material *X*. This means that the material will undergo plastic deformation and will not return to its original length when the compressive force is removed, i.e. it will be permanently deformed.

Question 6 D

$$\text{Gradient of graph} = \text{Young's modulus} = \frac{\text{stress}}{\text{strain}}$$

$$6.7 \times 10^8 = \frac{\left(\frac{200 \times 10}{A}\right)}{\left(\frac{1.2 \times 10^{-3}}{1}\right)}$$

$$A = 2.5 \times 10^{-3} \text{ m}^2$$
$$= \pi r^2$$
$$r = 2.8 \times 10^{-2} \text{ m}$$

Question 7 A

The toughest material has the greatest area under the graph to fracture. From the graph, this is material *X* when under compression.

Question 8 C

$$\text{Stress} = \frac{F}{A}$$
$$= \frac{6 \times 10^5}{0.1}$$
$$= 6.0 \times 10^6 \text{ N m}^{-2}$$

The energy stored = area under graph for this stress × volume of object

$$\text{Area under graph} = \frac{1}{2} \times (1 \times 10^{-3}) \times (6 \times 10^6)$$
$$= 3000 \text{ J m}^{-3}$$

$$\text{Energy stored} = 3000(0.1 \times 5)$$
$$= 1500 \text{ J}$$

Question 9 A

Concrete is weak in tension and strong in compression, hence the steel rods should be placed in regions of tension.

Tension will occur at the bottom of the platform between the wall and the strut, and at the top of the cantilever section, hence this is where the steel should be placed.

Question 10 B

Vertically, $\Sigma F = 0$.

$$2 \times 590 \sin\theta = 50 \times 10$$
$$\theta = 25°$$

Question 11 B

Horizontally, $\Sigma F = 0$.

$$T_1 \cos(\theta_1) = T_2 \cos(\theta_2)$$
$$T_1 = \frac{T_2 \cos(\theta_2)}{\cos(\theta_1)}$$

Since $\theta_1 < \theta_2$, $\cos(\theta_1) > \cos(\theta_2)$ so $\frac{\cos(\theta_2)}{\cos(\theta_1)} < 1$ and T_1 is smaller than T_2.

Question 12 D

Take torque about chain X.

$$(200 \times 8) + (1000 \times 1.3) = T_Y \times 2.6$$
$$T_Y = 562 \text{ N}$$

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Detailed study 3 – Further electronics

Question 1 D

The peak to peak output voltage (V_{p-p}) for this transformer is $48\sqrt{2}$ V as $V_{\text{PEAK}} = \sqrt{2}\ V_{\text{RMS}}$.

Question 2 A

The ratio of turns in the secondary coils compared to the primary coils of the transformer is 1:10 (24 V:240 V).

The output power (P_S) of the transformer is 24 W.

Question 3 **B**

$P_S = P_P$

Therefore the power in the primary coils of the transformer is 24 W.

Using $P = IV$

$24 \text{ W} = I(240 \text{ V})$

$I = 0.1 \text{ A}$

Question 4 **A**

If the transformer was **not** ideal we would expect $P_S < P_P$.

This is because some of the electrical energy is changed to heat in the transformer and is not available as electrical energy for the secondary output.

Question 5 **D**

The bridge rectification circuit shown in Figure 2 is a full-wave rectifier.

Question 6 **B**

The peak output voltage of the bridge rectifier circuit is 18 V (20 V – 2 V drop across diodes).

Question 7 **C**

This is the only graph that shows full-wave rectification.

Question 8 **B**

The time constant for the *RC* circuit is given by

$$\begin{aligned}\tau &= \text{RC} \\ &= (1.0 \times 10^4)(2.0 \times 10^{-5}) \\ &= 0.2 \text{ s}\end{aligned}$$

Question 9 **B**

To smooth the output voltage the time constant has to be larger. As $\tau = RC$, answer **B** is the only one which creates a larger τ.

Question 10 **B**

A Zener diode is used in an electronic circuit as a voltage regulator by using the Zener diode in reverse bias.

Question 11 **D**

The Zener diode used as a voltage regulator in reverse bias has a magnitude 6.0 V.

Question 12 **C**

The purpose of the radiator fins is to radiate excess heat away from the voltage regulator.