Neap:

Trial Examination 2012

VCE Physics Unit 3

Written Examination

Suggested Solutions

SECTION A – CORE

Area of study 1 – Motion in one and two dimensions

Question 1

a. $N = mg\cos\theta = 1800 \times 10 \times \cos(18)$ 1 mark

$N = 1.7 \times 10^4$ N 1 mark

b. $\Sigma F = ma = T - \text{friction} - mg\sin\theta$

Since speed is constant $\Sigma F = 0$ 1 mark

$0 = T - 300 - (700 \times 10 \times \sin(18))$ 1 mark

$T = 2.5 \times 10^3$ N 1 mark

c. For whole system, $\Sigma F = 0 = F_D - 850 - 300 - (2500 \times 10 \times \sin(18))$

$F_D = 8.9 \times 10^3$ N 1 mark

$\text{Power} = \frac{W}{t} = \frac{Fd}{t} = (8.9 \times 10^3) \times \frac{15}{8}$ 1 mark

$\text{Power} = 1.7 \times 10^4$ W 1 mark

Question 2

a. $r = 0.8\sin(15) = 0.21$ m 1 mark

$v = \frac{2\pi r}{T} = \frac{(2 \times \pi \times 0.21)}{1.7}$ 1 mark

$v = 0.77$ m s^{-1} 1 mark

b. Vertically, $\Sigma F = 0$ so $mg = T\cos\theta$

$m \times 10 = 5.6\cos(15)$ 1 mark

$m = 0.54$ kg 1 mark

$F_c = \frac{mv^2}{r} = \frac{(0.54 \times (0.77)^2)}{0.21}$ 1 mark

(Note: give consequential mark if mass calculated is used here)

$F_c = 1.5$ N 1 mark

OR

$F_c = T\sin 15°$

$= 5.6\sin 15°$

$= 1.5$ N

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

$T = \frac{mg}{\sin(15)}$ so if m increases, T will increase.

$F_c = \frac{mv^2}{r}$ so if m increases, F_c will increase.

d. At the top, when the ball is travelling at its minimum speed $T = 0$

$\Sigma F = \frac{mv^2}{r} = mg$

$0.54 \times \frac{v^2}{0.8} = (0.54 \times 10)$ 1 mark

$v = 2.8\ \text{m s}^{-1}$ 1 mark

OR

At top of flight, $v = \sqrt{rg} = \sqrt{(0.8 \times 10)}$ 1 mark

$v = 2.8\ \text{m s}^{-1}$ 1 mark

Question 3

a. Kinetic energy of ball = elastic potential energy stored in spring

$E_k = 0.5mv^2 = 0.5(0.02)(12^2) = 1.4\ \text{J}$ 1 mark

$U_e = 0.5kx^2$ so $1.4 = 0.5k(0.08^2)$ 1 mark

$K = 450\ \text{N m}^{-1}$ 1 mark

b. Vertically to the highest point: $u = 12\sin(35)$, $v = 0$, $a = -10$, $x = ?$

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

$0 = (12\sin(35))^2 + (2 \times (-10) \times x)$ 1 mark

$x = 2.4\ \text{m}$ 1 mark

c. To find the speed of ball when it lands:

$u = 12\sin(35)$, $a = -10\ \text{m s}^{-2}$, $x = 1.2\ \text{m}$, $v = ?$

$(v^2 = u^2 + 2ax = (12\sin(35))^2) + (2 \times -10 \times 1.2)$ 1 mark

$v = 4.8\ \text{m s}^{-1}$ or $-4.8\ \text{m s}^{-1}$ so on the way down it will be $-4.8\ \text{m s}^{-1}$ 1 mark

To find the time of flight:

$v = u + at$

$-4.8 = 12\sin(35) + (-10)t$ so $t = 1.17$ seconds 1 mark

Note: the time of flight can also be found by solving a quadratic equation but this method is not required.

To find the range, $x = ut = 12\cos(35) \times 1.17 = 11.5\ \text{m}$ 1 mark

Question 4

a. $P_i = P_f$

$(600 \times 5) + (m \times -2) = 1(m + 600)$

1 mark

$3000 - 2m = m + 600$

$m = 800\ \text{kg}$ 1 mark

b. $m\Delta v = \Sigma Ft$

$600 \times (1 - 5) = \Sigma F \times 0.2$ 1 mark

$\Sigma F = 1.2 \times 10^4\ \text{N}$ 1 mark

c. The change in kinetic energy for each car is a fixed quantity, this is equal to the work done. 1 mark

The rigid metal bumper bar will compress less than the rubber bumper bar, hence the car will stop in a shorter distance. 1 mark

Since $W = Fx$, if W is constant and x is decreased, the Force (F) will increase. 1 mark

Note: do not accept answer if it is in terms of momentum change and time rather than energy change and distance.

Question 5

a. $\dfrac{r^3}{T^2} = \dfrac{GM}{(4\pi^2)}$

$$\frac{r^3}{(24.6 \times 3600)^2} = \frac{(6.67 \times 10^{-11}) \times (6.37 \times 10^{23})}{4\pi^2}$$ 1 mark

$r = 2.04 \times 10^7\ \text{m}$ 1 mark

Altitude = r – radius of Mars = $(2.04 \times 10^7) - (3.43 \times 10^6)$

Altitude = $1.7 \times 10^7\ \text{m}$ 1 mark

b. Apparent weight = 0 N 1 mark

The only force acting on the satellite is gravity, so it is in ‘freefall’ and the apparent weight is zero (there is no ‘normal’ force which is the apparent weight). 1 mark

c. $g = \dfrac{GM}{r^2} = \dfrac{(6.67 \times 10^{-11}) \times (6.37 \times 10^{23})}{(3.43 \times 10^6)^2}$ 1 mark

$g = 3.6\ \text{N kg}^{-1}$ 1 mark

Note: no marks to be given unless calculations are shown.

Area of study 2 – Electronics and photonics

Question 1

a. $4.0\,\Omega$

Resistors *Y* and *Z* are in series and equivalent to $12.0\ \Omega$.

The *YZ* resistor combination is in parallel with resistor *X* which is $6.0\ \Omega$

Using the parallel resistance formula,

$\frac{1}{R_p} = \frac{1}{12} + \frac{1}{6} = \frac{1}{4}$, 1 mark

which means $R_p = 4.0\,\Omega$. 1 mark

b. 1.0 A

Resistors *Y* and *Z* are in series and equivalent to $12.0\ \Omega$ and the current through each resistor will be the same as they are in series. The total voltage drop across the *YZ* combination is 12 V.

$I = \frac{V}{R} = \frac{12}{12} = 1.0\ \text{A}$ 2 marks

c. 24 W

The power dissipated in resistor *X* is given by $P = IV$.

$I = \frac{V}{R} = \frac{12}{6} = 2.0\ \text{A}$ 1 mark

$P = IV = 2.0 \times 12 = 24\ \text{W}$. 1 mark

Question 2

a. YES 1 mark

b. Because the LED is in forward bias. 1 mark

c. 22.5 mA

From the graph the voltage across the LED is 1.5 V.

Therefore the voltage across the resistor is 6.0 – 1.5 = 4.5 V. 1 mark

The current through the LED will be the same as the current through the resistor.

$I = \frac{V}{R} = \frac{4.5}{200} = 22.5\ \text{mA}$ 1 mark

d. **A**

If the $200\ \Omega$ resistor is replaced with a $300\ \Omega$ resistor, the current through the LED-resistor series combination will be smaller and therefore the LED will glow less brightly than before. 2 marks

Question 3

a. $5.0\ \text{k}\Omega$

The value of the resistance of the thermistor when the temperature in the oven is $100\ °\text{C}$ is read directly from the graph. 1 mark

b. $750\ \Omega$

The value of the resistance of the thermistor when the temperature in the oven is $400\ °\text{C}$ is read directly from the graph (allow a range of $700\ \Omega$–$800\ \Omega$). 1 mark

c. 6.0 V

$$V_{OUT} = \left(\frac{R_T}{R_T + R_V}\right)V_{IN}$$

$$= \left(\frac{5}{5+5}\right)12\ \text{V}$$

$$= 6.0\ \text{V}$$

2 marks

d. 10.4 V

$$V_{OUT} = \left(\frac{R_V}{R_T + R_V}\right)V_{IN}$$

$$= \left(\frac{5}{5+0.75}\right)12\ \text{V}$$

$$= 10.4\ \text{V}$$

2 marks

Note that there will be a small allowable range based on consequentials from ***Question 3****.*

Question 4

a. **C**

The gain of the amplifier is given by $\frac{V_{OUT}}{V_{IN}} = \frac{3}{0.03} = 100$. 2 marks

Note 30 mV = 0.03 V

b. Inverting amplifier.

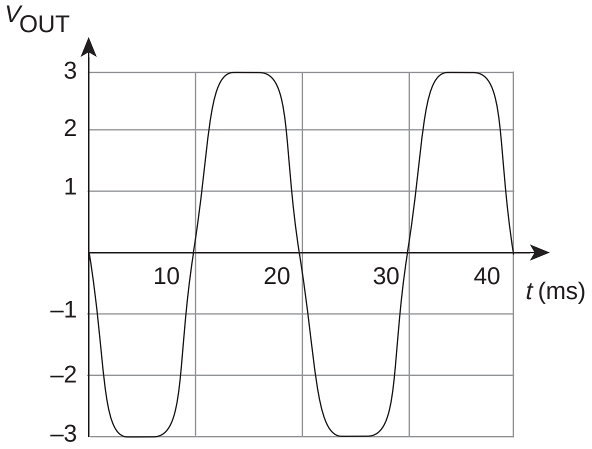
The gradient of the graph is negative. 1 mark

c. The graph of the output voltage versus time graph is marked as follows:

1 mark for correct voltage values and correct period.

1 mark for showing inverting nature of amplifier.

1 mark for showing clipping at the +3 V and –3 V marks.



3 marks

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

Detailed study 1 – Einstein's special relativity

Question 1

The correct answer is **D**.

An inertial reference frame is one which is absolutely stationary or which is moving with constant velocity.

Question 2

The correct answer is **D**.

The Lorentz factor, $\gamma = \dfrac{1}{\sqrt{1 - \dfrac{v^2}{c^2}}}$

$$\gamma = \frac{1}{\sqrt{1 - \dfrac{(0.95c)^2}{c^2}}}$$

$$= 3.2$$

Question 3

The correct answer is **C**.

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

Question 4

The correct answer is **B**.

A nuclear power station best relates to Einstein's concept that mass can be converted to energy

Question 5

The correct answer is **C**.

Using the Lorentz equation, $\gamma = \dfrac{1}{\sqrt{1 - \dfrac{v^2}{c^2}}}$

$$1.10 = \frac{1}{\sqrt{1 - \dfrac{v^2}{c^2}}}$$

Therefore solving for v gives v = 0.4166 c.

An increase of 50% means the new speed is v = 0.6249 c.

Substitution into the γ equation gives γ = 1.28.

Question 6

The correct answer is **A**.

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

Question 7

The correct answer is **A**.

The effect of the proton being accelerated in a new 1.5 GeV circular particle accelerator is that it will increase its mass (it will also increase its speed but not to the speed of light as in answer **C**).

Question 8

The correct answer is **C**.

The time dilation factor would be large as the proton travels around the 1.5 GeV circular particle accelerator because it increases its speed significantly enough in this high energy accelerator and $t = \dfrac{t_0}{\sqrt{1 - \dfrac{v^2}{c^2}}}$.

Question 9

The correct answer is **B**.

The equivalent energy of an electron of mass 9.1×10^{-31} kg is given by $E = mc^2$.

$$E = (9.1 \times 10^{-31})(3.0 \times 10^8)^2$$
$$= 8.2 \times 10^{-14}\text{J}$$

Question 10

The correct answer is **C**.

$$\frac{L}{L_0} = \frac{1}{\gamma}$$

$$\frac{20}{50} = \frac{1}{\gamma}$$

$$\gamma = 2.5$$

Question 11

The correct answer is **D**.

James Clerk Maxwell's equations demonstrated the existence of electromagnetic waves that can travel at $3.0 \times 10^8 \text{m s}^{-1}$.

Question 12

The correct answer is **B**.

A *tau meson* which has a Lorentz factor of 20 has a speed 0.998749 c.

Use the formula $\gamma = \dfrac{1}{\sqrt{1 - \dfrac{v^2}{c^2}}}$ and solve for v

Detailed study 2 – Materials and their use in structures

Question 1

The correct answer is **D**.

The maximum tensile strength is the stress at the point where the material fractures. From the graph, this is equal to 1.8×10^{6} N m^{-1}.

Question 2

The correct answer is **B**.

The material is ductile as it has a non linear region, indicating that it undergoes plastic deformation. This means that it cannot be brittle. Options **C** and **D** are not correct as there is no data which states what defines a tough or strong material.

Question 3

The correct answer is **B**.

Strain = 2.0×10^{-3} so stress = 8.0×10^{5} N m^{-2} (from graph)

Stress = $\frac{F}{A}$ so $8.0 \times 10^{5} = \frac{(1.0 \times 10^{4})}{A}$

$A = 1.3 \times 10^{-2}$ m^{2}

Question 4

The correct answer is **D**.

Young's modulus = gradient of linear section of graph.

$$Y = \frac{(16 \times 10^{5})}{(4 \times 10^{-3})} = 4.0 \times 10^{8} \text{ N m}^{-2}$$

Question 5

The correct answer is **A**.

Material *X* has a greater area under the graph than material *Y* so *X* is tougher.

Material *Y* has a greater maximum tensile strength than material *X* so *Y* is stronger.

Question 6

The correct answer is **D**.

Stress = 1.4×10^{6} N m^{-2} so strain = 2.0×10^{-3} (from graph)

Strain = $\frac{\Delta l}{l}$ so $2.0 \times 10^{-3} = \frac{\Delta l}{2}$

$$\Delta l = 4.0 \times 10^{-3} \text{ m} = 4.0 \text{ mm}$$

Question 7

The correct answer is **C**.

Torque = $F.x = (5 \times 10) \times 0.5 = 25$ N m

Question 8

The correct answer is **D**.

Take $\Sigma\tau = 0$ around support *B*.

$(0.9 \times 20 \times 10) + (1.3 \times 5 \times 10) = F_A \times 1.8$

$F_A = 136$ N

Question 9

The correct answer is **A**.

Take $\Sigma\tau = 0$ around support *B*.

$F_A = \dfrac{(180 + 13m_{\text{books}})}{1.8}$ so if m_{books} increases, F_A will increase.

Take $\Sigma\tau = 0$ around support *A*.

$F_B = \dfrac{(180 + 5m_{\text{books}})}{1.8}$ so if m_{books} increases, F_B will increase.

Question 10

The correct answer is **B**.

Section *AB* of the shelf will sag under its own weight. This means that the top part of it will be in compression and the bottom region will be in tension.

From the diagram, the cable will provide an upwards force on the shelf so it must be in tension.

Question 11

The correct answer is **C**.

Take $\Sigma\tau = 0$ around point *A*.

$(10 \times 10 \times 0.6) + (5 \times 10 \times 1.2) = T\sin(40) \times 0.9$

$T = 207$ N

Question 12

The correct answer is **A**.

For the structure to be stable horizontally $F = 0$. Since cable *BC* has a component of force to the left, the wall must exert a force component to the right to balance this.

For the structure to be stable vertically $F = 0$.

Upwards forces = $T\sin(40) = 207 \times \sin(40) = 133$ N

Downward forces = $(10 \times 10) + (5 \times 10) = 150$ N

Since the downward forces are greater than the upward forces, the wall must exert an upwards force component on the shelf.

Detailed study 3 – Further electronics

Question 1

The correct answer is **C**.

The frequency of the AC voltage is given by $f = \frac{1}{T}$

$$= \frac{1}{20} \text{ ms}$$

$$= 50 \text{ Hz}$$

Question 2

The correct answer is **A**.

The RMS voltage of the power supply is given by $V_{\text{RMS}} = V_{\text{PEAK}}\left(\frac{1}{\sqrt{2}}\right)$

$$= \frac{340}{\sqrt{2}} \text{ V}$$

$$= 240 \text{ V}$$

Question 3

The correct answer is **A**.

$$V_{\text{RMS}} = V_{\text{PEAK}}\left(\frac{1}{\sqrt{2}}\right)$$

$$= \frac{4000}{\sqrt{2}} \text{ V}$$

$$\frac{N_p}{N_s} = \frac{V_{\text{IN}}}{V_{\text{OUT}}}$$

$$= 240 \div \frac{4000}{\sqrt{2}}$$

$$= 1:12$$

Question 4

The correct answer is **D**.

$$P = IV$$

$$240 = I \times 240$$

$$I = 1.0 \text{ A}$$

Question 5

The correct answer is **B**.

The circuit shown is a half wave rectification circuit.

Question 6

The correct answer is **D**.

A capacitor in parallel with the R_{LOAD} resistor will smooth the output.

Question 7

The correct answer is **B**.

The time constant for the RC circuit is given by $\tau = RC$

$$= \frac{2 \times 10^{3}}{1 \times 10^{-4}}$$

$$= 0.2 \text{ s}$$

Question 8

The correct answer is **B**.

This circuit models a voltage regulator.

Question 9

The correct answer is **B**.

A Zener diode can be used in an electronic circuit as a voltage regulator by using the Zener diode in reverse bias. This is because in breakdown mode it has a constant voltage across it.

Question 10

The correct answer is **D**.

The value of the resistive load can be found using $V = IR$

$$R = \frac{9.0}{0.15} = 60.0 \ \Omega$$

Question 11

The correct answer is **B**.

One time constant represents a 63% decay in the voltage or a voltage of 7.4 V which is closest to a time value of 0.02 s as determined from the graph.

Question 12

The correct answer is **A**.

Heat adversely affects the performance output of the transistor.