Neap:

Trial Examination 2010

VCE Physics Unit 3

Written Examination

Suggested Solutions

SECTION A – CORE

Area of study 1 – Motion in one and two dimensions

Question 1

Momentum is conserved and needs to be treated first in order to find the common speed after the collision.

$\Sigma \text{momentum}_{\text{before}} = \Sigma \text{momentum}_{\text{after}}$ (Let motion to the right be positive)

$P_{\text{before}} = P_{\text{combined after}}$

$(60.0 \times 2.00) + (12 \times -1.00) = (60.0 + 12.0)\ \text{V}_{\text{common}}$ 2 marks for correct method

$120 - 12 = 72 V_{\text{common}}$

$V_{\text{common}} = \frac{108}{72.0} = 1.50 \text{ m s}^{-1} = 1.50 \text{ m s}^{-1}$ right 2 marks

1 mark for correct velocity
1 mark for correct direction

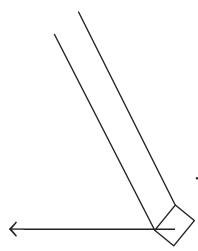
Question 2

The total momentum of the system is conserved independently of whether the collision is elastic or inelastic. 1 mark

Thus, John's statement is incorrect. Momentum is conserved before the collision is determined to be elastic or inelastic. 1 mark

Thus, Selena's statement is also incorrect as momentum is conserved before the collision is determined to be elastic or inelastic. In any case, the collision is inelastic which contradicts Selena's statement. 1 mark

Question 3



1 mark

Question 4

$F_{\text{net}} = \frac{m4\pi^2 r}{T^2}$

$F_{\text{net}} = \frac{60.0 \times 4\pi^2 \times 10.2}{(5.11)^2}$ 1 mark

$F_{\text{net}} = 925 \text{ N or } 9.25 \times 10^2 \text{ N}$ 1 mark

Question 5

At the highest point on the track,

Method 1

ΣForces (horizontally) = Net Force = Answer Q4

$\text{Tension} \times \sin(\theta) = 925 \text{ N}$

$\text{Tension} \times \sin(57) = 925 \text{ N}$ 1 mark for method

$\text{Tension} = \dfrac{925}{\sin(57)}$

$\text{Tension} = 1103 \text{ N}$

$T = 1.10 \times 10^3 \text{ N}$ (consequential answer to Question 4)

Method 2

$$\Sigma\text{Forces(vertically)} = 0$$

$$\text{Tension} \times \cos(\theta) - (m \times g) = 0$$

$$\text{Tension} \times \cos(57) - (60.0 \times 10) = 0$$

$$\text{Tension} = \frac{600}{\cos 57}$$

$$\text{Tension} = 1102 \text{ N}$$

$$\text{Tension} = 1.10 \times 10^3 \text{ N}$$ 1 mark for answer

Question 6

Work done by net force = net force × distance × $\cos(\theta)$

$W = F_{\text{net}} \times s \times \cos(\theta)$

F_{net} = mass × net acceleration

$F_{\text{net}} = m \times a$

To find acceleration: given u = 0, t = 4.59 sec, s = 10 m

$s = ut + 0.5at^2$

$10 = 0 + 0.5 \times a \times 4.59^2$ 1 mark

$a = 0.949 \text{ m s}^2$

$F_{\text{net}} = 30.0 \times 0.949 = 28.5 \text{ N}$ 1 mark

$W = F_{\text{net}} \times s \times \cos(\theta)$

$W = 28.5 \times 10 \times \cos(0)$

$W = 285 \text{ J or } 2.85 \times 10^2 \text{ J}$ 1 mark

Question 7

Apparent Weight = size of normal reaction.

ΣForces (vertically) = 0, let up be positive

$-\text{Force}_{\text{Fred}} - \text{Weight} + \text{Normal reaction} = 0$ 1 mark

$-F_{\text{Fred}} - W + N = 0$

$-140\sin(23) - (30 \times 10) + N = 0$ 1 mark

$N = 140\sin(23) + 300$

$N = 355$ N

$N = 3.5 \times 10^2$ N 1 mark

Question 8

Energy stored = area beneath force–extension curve up to 15 cm, or use $\text{E} = \frac{1}{2}kx^2$ (k = gradient)

$k = \frac{200}{0.1} = 2000$ N/m

$E_{\text{stored}} = 0.5 \times 2000 \times (0.15)^2$ 1 mark

$E_{\text{stored}} = 22.5$ J

$E_{\text{stored}} = 23$ J 1 mark

Question 9

The maximum height reached occurs when the total energy stored in the slingshot converts to gravitational potential energy.

Total mechanical energy before firing = Total mechanical energy after firing.

$\frac{1}{2}kx^2 = mgh$ 1 mark

$22.5 = 0.020 \times 10 \times h$ (consequential to Question 8)

$h = \frac{22.5}{10 \times 0.020}$ 1 mark

$h = 112.5$

$h = 113$ m or 1.1×10^2 m 1 mark

Question 10

Time of flight = 2 × time taken to get to the maximum height
Vertically, let upwards be positive

$a = -10$

$v = 0$

$s = 18$

Use $s = vt - 0.5at^2$

$18 = 0 - 0.5 \times 10 \times t^2$ 1 mark

$t^2 = 3.6$

$t = 1.897$ sec 1 mark

$\therefore$ time in air = 2 × 1.897 = 3.8 sec 1 mark

Question 11

Horizontally, $u\cos(\theta) \times$ time of flight = range (u = initial speed)

$54.0 = u\cos(\theta) \times 3.79$ 1 mark

$u\cos(\theta) = \dfrac{54.0}{3.79} = 14.248$ consequential upon Question 10

Vertically, $v = u\sin(\theta) + at$

$0 = u\sin(\theta) - 10 \times 1.897$ 1 mark

$u\sin(\theta) = 18.97$

thus $\dfrac{u\sin(\theta)}{u\cos(\theta)} = \dfrac{18.97}{14.248}$ 1 mark

$\tan(\theta) = 1.331$

$\theta = \text{INVtan}(1.331) = 53°$ 1 mark

Question 12

At position *A*, the ball experiences friction, which opposes its velocity and it experiences its weight force.

Thus the forces acting are $\swarrow$ and $\downarrow$. The net force is the sum of these $\downarrow + \swarrow = \swarrow$

Thus the answer is **D**.

2 marks

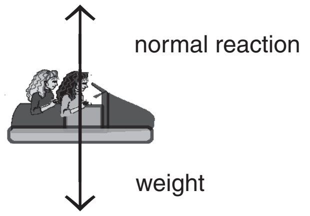
Question 13

The feeling of weightlessness occurs when the human body makes no contact with any surfaces and so that the normal reaction equals zero. The occupants will feel weightless if the normal reaction acting on them at the top of the ride becomes zero. 1 mark

Let's take the downwards towards the centre of the circular track as positive.

Σ Forces (vertically) = centripetal force

Weight – Normal reaction = centripetal force.



1 mark

$$W - N = \frac{mv^2}{r}$$

$$N = mg - \frac{mv^2}{r}$$

$$N = (60 \times 10) - \frac{(60 \times 12^2)}{14.4}$$ 1 mark

$N = 600 - 600 = 0$

Yes, the occupants will feel weightless. 1 mark

Question 14

Given:

Period = $T = 102 \times 60 = 6120$ seconds

Mass of the Earth = 5.98×10^{24} kg

Universal gravitational constant = 6.67×10^{-11} Nm^2 kg^{-2}

Radius of Earth = 6.38×10^6 m

Use $\dfrac{r^3}{T^2} = \dfrac{GM_{\text{Earth}}}{4\pi^2}$

$$\frac{r^3}{(6120)^2} = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{4\pi^2}$$ 1 mark

$$r^3 = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24} \times (6120)^2}{4\pi^2}$$

$r^3 = 3.78 \times 10^{20}$ 1 mark

$r = (3.78 \times 10^{20})^{\frac{1}{3}}$

$r = 7.23 \times 10^6$ m

altitude = orbital radius – radius of Earth 1 mark

altitude = $7.23 \times 10^6 - 6.37 \times 10^6$

altitude = 8.53×10^5 m

altitude = 8.53×10^2 km or 853 km 1 mark

Area of study 2 – Electronics and photonics

Question 1

The two resistors are in parallel, so the parallel resistance formula is used

$\frac{1}{R_P} = \frac{1}{6.0} + \frac{1}{3.0} = \frac{3}{6} = 0.5$ 1 mark

$R_P = 2.0\ \Omega$ 1 mark

Question 2

As the two resistors are in parallel with the battery, they both have a 6.0 V drop across them. 1 mark

Therefore the current through the 3.0 Ω resistor can be determined using Ohm's Law

$V = IR$

$I = \frac{6.0}{3.0}$

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

Question 3

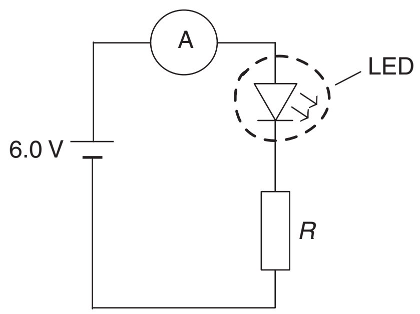
The power dissipated in the 6.0 Ω resistor is found using the power formula: $P = IV$.
As the two resistors are in parallel with the battery, they both have a 6.0 V drop across them.
Therefore the current through 6.0 Ω resistor is 1.0A ($V = IR$) 1 mark

$P = IV$

$= (1.0)(6.0)$

$= 6.0\ \text{V}$ 1 mark

Question 4



2 marks

1 mark for identifying correct component (circled)
1 mark for label (LED or Light Emitting Diode)

Question 5

From the current–voltage characteristic graph the voltage drop across the LED is 1.5 V.

Therefore the voltage drop across the resistor, $R = 6.0 - 1.5 = 4.5$ V 1 mark

$V = IR$

$4.5 = I(450)$

$I = 1.0 \times 10^{-2}\ \text{A}$

$= 10\ \text{mA}$ 1 mark

Question 6

6.0 V 1 mark

When the optoelectronic device is reversed in the circuit it means that no current flows through the circuit. 1 mark

This means that the potential difference across the resistor is 0.0 V and across the diode 6.0 V. 1 mark

Question 7

The value of the resistance of the thermistor when the temperature in the room is 30°C is $100\ \Omega$ (read from graph). 1 mark

Question 8

R_1 and the thermistor (R_2) form a voltage divider circuit.

$$V_{\text{OUT}} = \text{V}_{\text{IN}}\frac{R_2}{(R_1 + R_2)}$$

$$= \frac{9.0 \times 100}{(200 + 100)}$$ 1 mark

$$= 3.0\ \text{V}$$ 1 mark

Question 9

When the room reaches 18°C the thermistor resistance is 200 Ω (read from graph).

$$V_{\text{OUT}} = \frac{R_2}{(R_1 + R_2)} \times V_{\text{IN}}$$

$$= \frac{200}{(200 + 200)} \times 9.0$$ 1 mark

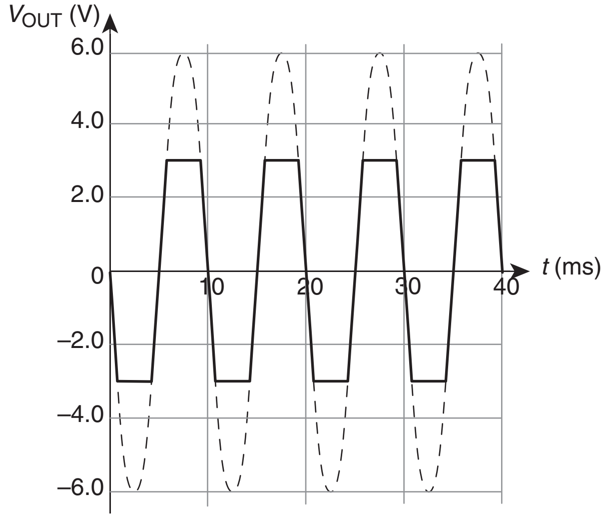
$$= 4.5\ \text{V}$$ 1 mark

Question 10

The gain of the amplifier (taken from the linear region of the graph) is given by

$$\text{Gain} = \left|\frac{V_{\text{OUT}}}{V_{\text{IN}}}\right| = \left|\frac{-3\ \text{V}}{6\ \text{mV}}\right| = \frac{3}{6 \times 10^{-3}} = 500$$ 2 marks

Question 11



3 marks

1 mark for indicating the inverting nature of the amplifier

1 mark for the correct minimum and maximum values of V_{OUT} (3 V and –3 V respectively)

1 mark for showing that the wave form has been clipped

Note: Dashed line is not required

Question 12

The beam's brightness varies through a range of values in carrying the information – this is a characteristic of analogue information.

1 mark

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

Detailed study 1 – Einstein's special relativity

Question 1 **B**

Travelling at 0.9 c there would be significant contraction of length in the direction of travel so the square would appear as in **B**.

Question 2 **C**

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

$$= \frac{1}{\sqrt{1 - \dfrac{(0.9c)^2}{c^2}}}$$

$$= 2.3$$

Question 3 **B**

Postulate one was: No law of physics can identify a state of absolute rest.

Question 4 **A**

Postulate two was: The speed of light is independent of the motion of the light source or observer.

Question 5 **B**

The purpose of the Michelson–Morley Experiment was to determine the existence of the ether.

Question 6 **A**

The results of the Michelson–Morley Experiment demonstrated the ether does not exist.

Question 7 **D**

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

$$= \frac{1}{\sqrt{1 - \dfrac{(0.99999c)^2}{c^2}}}$$

$$= 707$$

Question 8 **D**

Although the space shuttle travels at 28 000 km h^{-1} in its orbit around the earth and seems relatively fast to us, it is slow relative to the 300 000 km s^{-1} speed of light.

Question 9 **C**

The effect of the linear accelerator on the proton's speed and its energy is that the speed increases slightly whilst the energy increases substantially (as you cannot go faster than the speed of light).

Question 10 **C**

The speed of the proton 0.97 c (Lorentz formula).

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

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

$$v = c\sqrt{1 - \frac{1}{4^2}}$$

$$= 0.97\ c$$

Question 11 **A**

The length of the linear section of the accelerator as measured in the proton's frame of reference is 300 m (Lorentz factor).

Question 12 **A**

The GPS receiver measures the satellite clock as running more slowly than itself.

The car represents the moving frame of reference, and so runs more slowly than the satellite clock.

Question 13 **C**

$$m = m_0\gamma = 60 \times 1.9 = 114\ \text{kg}$$

Detailed study 2 – Materials and their use in structures

Question 1 **B**

The ratio of stress to strain defines the Young's modulus which is a measure of the stiffness. For any stress–strain pair, the ratio is less for the cast iron than for the mild steel.

Question 2 **C**

Toughness is measured as the energy absorbed per unit volume of the material which represents the area up to fracture point beneath the stress–strain curve.

Question 3 **A**

At the elastic limit of 280 MPa the strain is 0.017.

$$\text{Young's modulus} = \frac{\text{stress}}{\text{strain}} = \frac{280 \times 10^6}{0.017} = 1.65 \times 10^{10} = 1650\ \text{MPa}$$

Question 4 **D**

The area beneath the graph is required. The area is approximately made up of the area in the elastic region and the area in the plastic region.

Elastic region: Area = $\dfrac{(280 \times 10^6 \times 0.017)}{2} = 2.38 \times 10^6$ J m^{-3}

Plastic region: Area = approximately area of rectangle of height $\dfrac{(280 + 315)}{2}$ and length $0.075 - 0.017$.

$$\text{Area} = \frac{(280 + 315)}{2} \times (0.075 - 0.017)$$

Area = $297.5 \times 0.058 = 1.73 \times 10^7$ J m^{-3}

Total area = 1.96×10^7 J m^{-3}

It is closest to **D**.

A 50.000 m length of the material has a tensile stress of 280 MPa applied to it.

Question 5 **C**

strain = 0.017 at this stress.

$$\frac{\text{change in length}}{\text{original length}} = \text{strain}$$

$$\frac{\text{new length} - 50.000}{50.000} = 0.017$$

new length = $(0.017 \times 50.000) + 50.000 = 50.850$ m

When the 50.000 m length of the material is subjected to the applied stress of 280 MPa, it has a circular cross-sectional area of diameter 1.0 mm, which it maintains throughout the application of the stress. The stress is produced by the hanging of a mass from the length of the material.

Question 6 **D**

$$\text{stress} = \frac{\text{force acting}}{\text{cross-sectional area}}$$

$$\text{cross-sectional area} = \frac{\pi d^2}{4} = \frac{3.14 \times (1.0 \times 10^{-3})^2}{4} = 7.85 \times 10^{-7}\ \text{m}^2$$

$$280 \times 10^6 = \frac{\text{mass} \times 10}{7.85 \times 10^{-7}}$$

$$\text{mass} = \frac{280 \times 10^6 \times 7.85 \times 10^{-7}}{10} = 22\ \text{kg}$$

Question 7 **D**

The 300 MPa loads the material beyond its elastic limit of 280 mPa, which leads to some of the material's internal chemical bonds to be broken and becoming permanently longer than the original length.

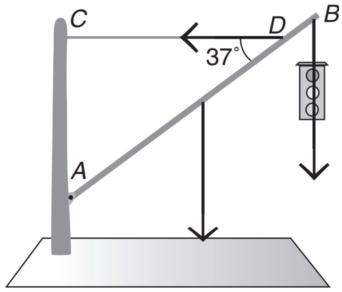
Question 8 **B**

Considering the forces that act on the central object (the pole *AB*),

Torque (due to traffic light) = force × lever arm × $\sin(\theta)$

= 20.0 × 10 × 7.20 × $\sin(53)$

= 1150 Nm



Question 9 **C**

The tension in the cable is unknown and so the sum of torques about *A* equals zero for the central object (the pole) is used to determine the unknown torque. Forces that have torques about point *A* are shown.

Sum of Torques = Torque (Cable Tension) + Torque (pole weight) + Torque (traffic light weight) = 0 (clockwise is positive)

$0 = \text{Torque}_{\text{cable}} - (12.0 \times 10 \times 3.6 \times \sin(53)) - (20 \times 10 \times 7.2 \times \sin(53))$

$0 = (\text{Torque}_{\text{cable}}) - 345.010 - 1150.035$

$\text{Torque}_{\text{cable}} = 345.010 + 1150.030$

$T = 1495.060 = 1495 \text{ Nm}$

Question 10 **B**

Continuing from Question 9,

Tension × 6.31 × $\sin 37°$ = 1495 (Consequential to Question 9)

$$\text{Tension} = \frac{1495}{6.31 \times \sin 37°}$$

Tension = 394 N

Question 11 **A**

The concrete slab will experience bending as shown below.

The top layers of the concrete experience tension and the lower layers experience compression. Reinforcement should occur where the concrete is weakest (in the layers experiencing tension) by a material (iron) that is strong in the way in which the concrete is weak.

Question 12 **B**

The metal rods serve to prevent sideways forces, due to wind or foundation movement, causing shear.

Question 13 **C**

Due to its own weight and the weight of the vehicles, the bridge will bow downwards through its middle, thus Member *X* will be in compression. Given that member *Z* is longer than member *X*, it will deflect downwards by a greater amount, and so member *Y* will be in tension. Member *Z* will experience tension as it is on the base of the bridge.

Detailed study 3 – Further electronics

Question 1 **C**

The frequency of the AC voltage supplied in Australia is 50 Hz.

Question 2 **D**

The peak-to-peak voltage of the main AC voltage supplied in Australia is $480\sqrt{2}$ V.

$V_{\text{peak-to-peak}} = 2\sqrt{2} \times \text{V}_{\text{RMS}}$

Question 3 **D**

The ratio of turns in the primary coils compared to the secondary coils of the transformer is 20 : 1.

$$\frac{V_\text{P}}{V_\text{S}} = \frac{N_\text{P}}{N_\text{S}} = \frac{240\ \text{V}}{12\ \text{V}} = \frac{20}{1}$$

Question 4 **D**

$$\begin{aligned} P &= IV \\ 12\ \text{W} &= I \times 12\ \text{V} \\ I &= 1.0\ \text{A} \end{aligned}$$

Question 5 **C**

The circuit shown in Figure 2 is best described as a full wave rectification circuit.

Question 6 **B**

The peak voltage output of the bridge rectifier circuit is closest to 15.6 V.
At any given time two of the diodes will each have a voltage drop of 0.7 V across them therefore

$$\begin{aligned} V_{\text{OUT}} &= 12\sqrt{2} - 2(0.7) \\ &= 15.6\ \text{V} \end{aligned}$$

Question 7 **B**

The output voltage as seen on a CRO will indicate full wave rectification.

Question 8 **B**

The time constant for the *RC* circuit is 0.15 s

$$\begin{aligned} \tau &= RC \\ &= (1.0 \times 10^4)(1.5 \times 10^{-5}) \\ &= 0.15\ \text{s} \end{aligned}$$

Question 9 **B**

The practical function of the capacitor in the *RC* circuit is best described as being to smooth the output signal.

Question 10 C

The reason the outside casing of the transformer feels very warm when touched is that the transformer is not 100% efficient. Some of the electrical energy converts to heat.

Question 11 B

The Zener diode shown in Figure 4 can be used in an electronic circuit as a voltage regulator by using the Zener diode in reverse bias at –10 V.

Question 12 B

To measure the voltage drop across a resistance component in a functioning low-voltage circuit the multimeter is placed in parallel with the resistance.

Question 13 A

To measure the current through the resistance component in a functioning low-voltage circuit the multimeter is placed in series with the resistance.