CSE CENTRE FOR STRATEGIC EDUCATION
Leading educational thinking and practice

IARTV

YEAR 12

CSE TEST: MAY 2010

PHYSICS

Written test 1

ANSWERS & SOLUTIONS BOOK

Mark allocations: As a guide, suggested mark allocations for each answer are shown within square brackets [ ].

Additional information: With some answers, to enhance student understanding, additional information is shown as a **Note** within curly brackets { }.

Q	Marks	Answer	Solution

SECTION A – AREA OF STUDY 1 – MOTION IN ONE AND TWO DIMENSIONS

1 2 1.3 m s^{-2}

Acceleration is given by the gradient of the graph of velocity against time. The graph shows the gradient is constant for the first 3 s. It can be obtained from:

$$\begin{aligned}\text{gradient} &= a \\ &= \frac{\Delta v}{\Delta t} \\ &= \frac{4-0}{3} \qquad \text{[1 mark]} \\ &= 1.33 \\ &= 1.3 \text{ m s}^{-2} \text{ (to 2 sig figs)} \qquad \text{[1 mark]}\end{aligned}$$

2 1 0 N

The graph shows that 4.0 s after starting Sam is travelling at constant velocity. So his acceleration is zero. Therefore the net force on him, which is directly proportional to his acceleration, must also be zero.

3 1 Sam's weight is the gravitational force exerted by the Earth on Sam. See bottom right of Figure A.

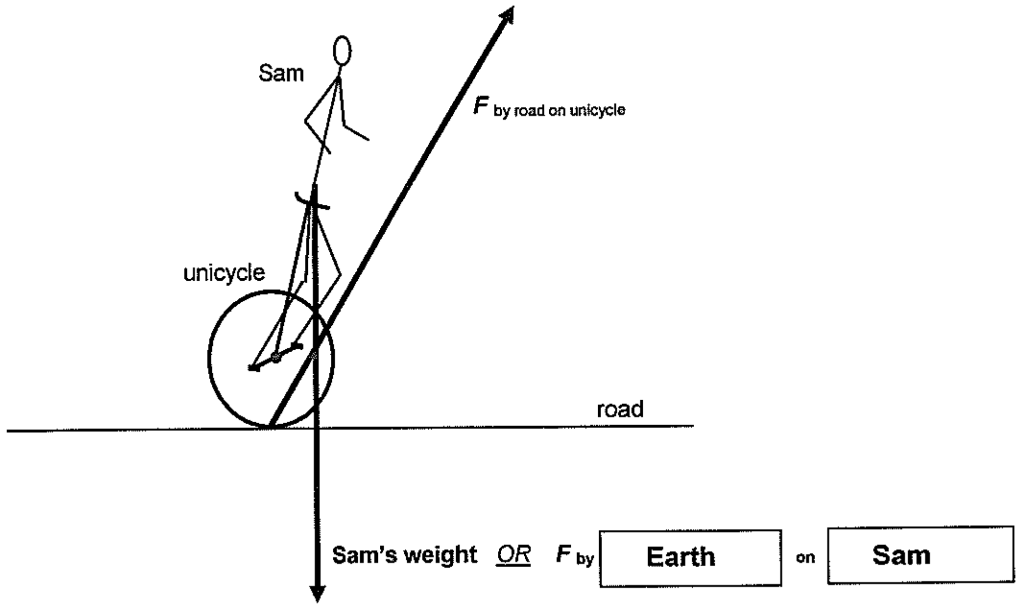

Figure A

4 2 As Sam and his unicycle are **accelerating forward**, they must be experiencing a **forward net force** [1 mark]. Of the three forces acting on them,

- their **weight** being vertical will have no horizontal component,
- **air resistance** will oppose their movement and will therefore be horizontally backwards, and
- the **force from the road**, $F_{\text{by road on unicycle}}$, (shown in Figure A) must have a **forward component** greater than the backward air resistance for there to be a forward net force on them. Therefore $F_{\text{by road on unicycle}}$ must be 'leaning forward'.

[1 mark for effectively covering the second and third dot points.]

Q Answer Solution

11 D Because the load and the zener diode in Figure 7 are in parallel, the current in the load,

$$I_{load} = I_{400\,\Omega} - I_{zener}$$
$$= \frac{V_{400\,\Omega}}{R_{400\,\Omega}} - 2.0\times10^{-3}$$
$$= \frac{6.2-5.0}{400} - 2.0\times10^{-3}$$
$$= 3.0\times10^{-3} - 2.0\times10^{-3}$$
$$= 1.0\times10^{-3}\ \text{A}$$
$$= 1.0\ \text{mA}$$

12 B The voltage regulator ensures that the voltage across the load resistor is 5 V, just as it was in Question 11 when V was 6.2 V. Hence the current in the load will be the same, independent of the variation of the input voltage V to the regulating device, which at this instant is 5.8 V.

13 D Heat sinks are used where electrical power is absorbed by a device and converted into heat. Regulators absorb excess power to maintain a constant output voltage and hence generate heat. A heat sink is used to remove heat from the regulating device which is designated 4 in the diagram.

Q Marks Answer Solution

{**Note:** As they have zero **vertical** acceleration, the net force on them in the vertical direction must be zero. Therefore the only two vertical forces, the downward weight and the **upward component** of $F_{\text{by road on unicycle}}$ must be equal in magnitude and opposite in direction.}

5 2 2.5×10^{2} N

As he is moving in a circular path at constant speed, the net force on Sam and his bike can be found from the relation:

$$F_{net} = ma$$
$$= m\frac{v^2}{r}$$
$$= (77+3)\frac{4.0^2}{5.1} \quad \text{[1 mark]}$$
$$= 250.98$$
$$= 2.5\times10^{2}\ \text{N (to 2 sig figs)} \quad \text{[1 mark]}$$

6 1 See Figure B. [To gain the mark the arrow must be directed horizontally inward. Its tail could start near the centre of Sam and his bike or where the tyre contacts the track.]

{**Note:** Figure C shows the two forces acting on Sam and his bike:

- The total downward gravitational force by the Earth on Sam and his bike (their combined weight), and
- The force by the track on the tyre. This must be perpendicular to the track, as the question stated that there was no sideways force from the track up or down the slope.

The sum of these two forces gives the net force on Sam. This net force has to be directed towards the centre of the horizontal circular path. Hence the vector sum of these two forces would be as shown in Figure D.}

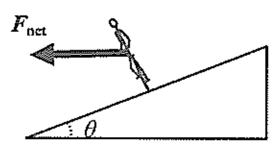

Figure B

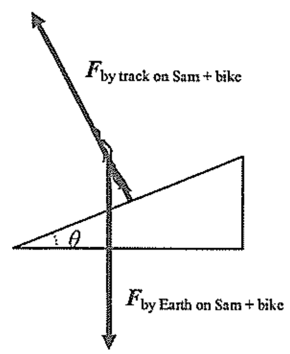

Figure C

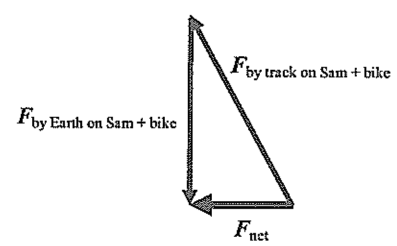

Figure D

7 2 17°

Using the force from the track, $F_{\text{by track on Sam+bike}}$ (see Figure C) and resolving this force into its horizontal and vertical components, as in Figure E:

- The vertical component F_{vert} must balance the gravitational downward force on Sam and his bike (i.e. their combined weight), as there must be no **net** vertical force, since they are not accelerating up or down. So $F_{vert} = mg$
- The horizontal component F_{hor} is the only other force they experience and is therefore the net force F_{net} on them. We already have its value from Answer 5.

Q Marks Answer Solution

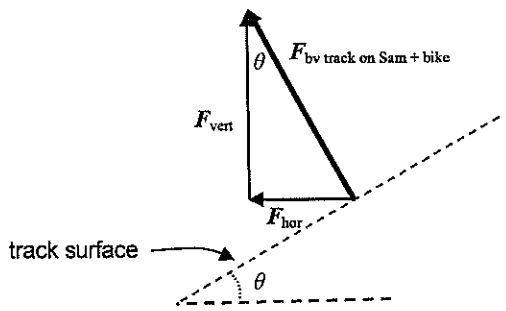

Figure E

Using the triangle in Figure E,

$$F_{hor} = F_{vert}\tan\theta$$

$$F_{net} = mg\tan\theta$$

$$2.5\times10^2 = (77+3)\times10\times\tan\theta \quad \text{[1 mark]}$$

$$\tan\theta = \frac{2.5\times10^2}{80\times10}$$

$$= 0.3125$$

$$\theta = 17.35$$

$$= 17^\circ \text{ (to the nearest degree)} \quad \text{[1 mark]}$$

Consequential answer: $\tan^{-1}\frac{\text{Ans5}}{800}$

8 3 If a car of mass m, travelling at a velocity v, crashes into an object and stops, its change in momentum equals the impulse of the force from the object exerted back on the car, i.e. $m\Delta v = F\Delta t$. Since the change in momentum to bring the car to rest is mv, the impulse $F\Delta t$ is a definite value. [1 mark] However, if the bumper is softer, e.g. plastic rather than steel, it will crumple more slowly, i.e. the time Δt during which the force acts will be greater [1 mark] and therefore the force F exerted back on the car and occupants will be less [1 mark], reducing the risk of injury.

9 2 1.2 s The time taken can be determined by considering the **vertical components of the flight**. We will take the downward direction as positive.
We know $a = 10 \text{ m s}^{-2}$, $u = 0$, $x = 7.2$ m, and $t = ?$

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

$$7.2 = 0 + \tfrac{1}{2}\times10t^2 \quad \text{[1 mark]}$$

$$5t^2 = 7.2$$

$$t^2 = \frac{7.2}{5}$$

$$= 1.44$$

$$t = 1.2\text{ s} \quad \text{[1 mark]}$$

Q Answer Solution

8 B The period of the full-wave rectified voltage is half that of the secondary voltage, i.e. 5 ms.
The time constant $\tau = RC = 10\text{ k}\Omega \times 1\ \mu\text{F} = 10\times10^3\ \Omega \times 1\times10^{-6}\text{ F} = 10^{-2}\text{ s} = 10$ ms.
This RC circuit has the capability to drop the peak voltage of 7.6 V (as determined in Answer 7) by about 2/3 in one time constant, i.e. by about $^2/_3 \times 7.6$, i.e. 5.1 V in 10 ms. This is best seen diagrammatically in Figure J showing the potential decay after the **first peak**.
As can be seen in Figure J, the ripple voltage, i.e. the decrease in voltage from the first peak to the next rising cycle is about $^1/_3 \times 7.6$, i.e. 2.5 V.

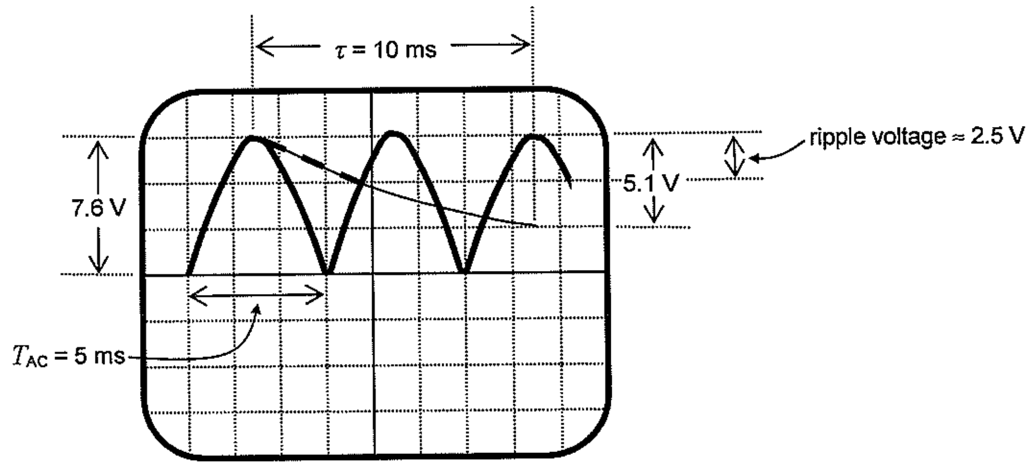

Figure J

9 D Increasing the capacitance of the capacitor increases the time constant giving rise to a smaller ripple voltage and a smoother output signal. See Figure K.

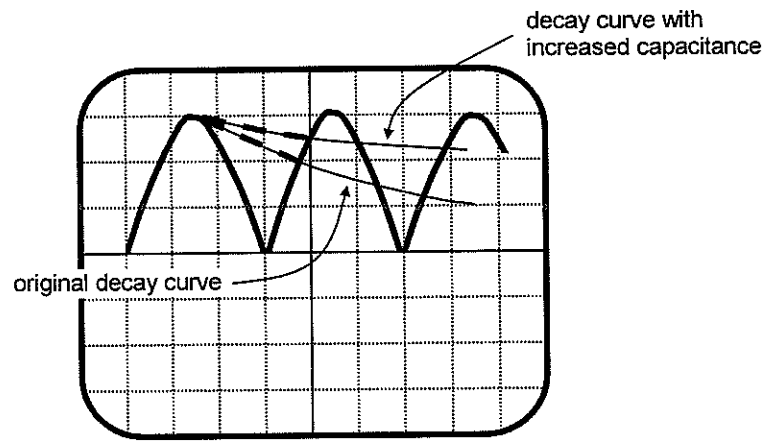

Figure K

10 A Current is directed through diode 2 to the load and then through diode 3 back through the secondary coil of the transformer. Only response A correctly states this.

Q Answer **Solution**

SECTION B – DETAILED STUDY 3 – FURTHER ELECTRONICS

1 A Using the turns ratio relation and RMS voltages,

$$\frac{V_{\text{secondary}}}{V_{\text{primary}}} = \frac{N_{\text{secondary}}}{N_{\text{primary}}}$$

$$\frac{V_{\text{secondary}}}{110} = \frac{1}{20}$$

$$V_{\text{secondary}} = \frac{110}{20} = 5.5\text{ V}$$

This is the RMS secondary voltage. The peak-to-peak voltage can be found using

$$V_{\text{RMS}} = \frac{1}{2\sqrt{2}}V_{\text{p-p}}$$

$$5.5 = \frac{1}{2\sqrt{2}}V_{\text{p-p}}$$

$$V_{\text{p-p}} = 2\sqrt{2}\times 5.5 = 15.6\text{ V}$$

2 B In one time constant, the capacitor charges to approximately 2/3 of it fully charged state. Using the equation for the time constant, $\tau = RC$, with $\tau = 2.7$ s and $R = 385\ \Omega$,

$$C = \frac{\tau}{R} = \frac{2.7}{385} = 7.0\times10^{-3}\text{ F} = 7.0\text{ mF}$$

3 C The appropriate meter is a multimeter set to AC voltage mode so that the RMS value of the voltage can be measured.
A CRO is used to measure either peak voltage V_{peak} or peak-to-peak voltage $V_{\text{p-p}}$ and to observe the shape of a signal. So A is incorrect. Responses B and D use a multimeter for purposes other than intended in the question.

4 D Diodes conduct one way only and hence they rectify an AC voltage.

5 A Points K_1, L_1 and M_1 are points on the active line with no resistance between them, and points K_2, L_2 and M_2 are points on the earth line (sometimes referred to as the earth rail) with no resistance between them. So the voltage between each pair (K_1 and K_2, etc) must be the same at any instant, which in this case is half-wave rectified and (partially) smoothed. Location J is prior to the diode and consequently would have a voltage variation that is AC and sinusoidal.

6 C The single diode gives half-wave rectification of the AC voltage.

7 C When a sinusoidal signal is full-wave rectified, its period halves and hence it's frequency doubles, in this case to 200 Hz. To full-wave rectify an AC voltage, 2 diodes are employed at any given instant. This results in a voltage decrease of (2 × 0.7) V, i.e. 1.4 V. Thus the peak voltage across the output will be (9 – 1.4) V, i.e. 7.6 V.

Q Marks Answer **Solution**

10 2 14 m The horizontal distance covered can be found using the **horizontal components of the flight.**
We know $a = 0$, $u = 12$ m s^{-1}, $t = 1.2$ s (from Answer 9), and $x = ?$

$$x = ut + \tfrac{1}{2}at^2$$
$$= 12\times1.2 + 0 \quad \text{[1 mark]}$$
$$= 14.4$$
$$= 14\text{ m (to 2 sig figs)} \quad \text{[1 mark]}$$

Consequential answer: 12 × Ans9

11 3 Higher [1 mark]

{**An introductory note:** During the flight the force by the air on Derwen and his bike $F_{\text{by air on D+b}}$ will vary in **magnitude** (increasing with the speed) and **direction** (opposite to the instantaneous velocity). $F_{\text{by air on D+b}}$ can be thought of as equivalent to two components F_{vert} and F_{hor} as shown in Figure F.}

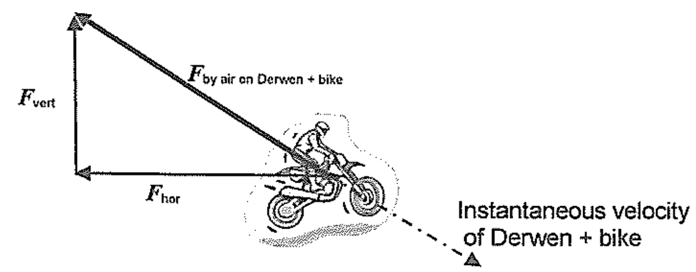

Figure F

Two possible approaches to an explanation (among others):

(1) A conceptual reasoning approach:
Considering the **vertical** aspects of the flight, in addition to the downward force of gravity on Derwen and the bike, there would be an upward force on them by the air (which would vary with speed and is shown as F_{vert} in Figure F), meaning the net downward force would be less and therefore their downward acceleration would be reduced. This would cause them to take **longer** to reach the ground.

(2) A mathematical approach:
In the equation used in Answer 9,

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

x (7.2 m) and u (0 m s^{-1}) would still be the same, giving

$$7.2 = 0 + \tfrac{1}{2}at^2$$

So ½at^2 will still be 7.2. But now a would be less than 10 m s^{-2} due to the drag from air. So the value of t will be **higher** than before.

[1 mark for the value of t being higher, and mark out of 2 for adequate reasoning.]

12 1 The impulse of the AWD on the minibus and the impulse of the minibus on the AWD are equal in magnitude **and** opposite in direction.
[Both ideas need to be given to gain the mark.]

Q	Marks	Answer	Solution
13	2	$1.6\ \text{m s}^{-1}$	Using conservation of momentum in this 'closed' system, $p_{\text{AWD initial}} + p_{\text{bus initial}} = p_{\text{AWD final}} + p_{\text{bus final}}$ $m_{\text{AWD}}u_{\text{AWD}} + m_{\text{bus}}u_{\text{bus}} = m_{\text{AWD}}v_{\text{AWD}} + m_{\text{bus}}v_{\text{bus}}$ $(1.9\times10^3 \times 4.8)+0 = (1.9\times10^3\ v_{\text{common}}) + (3.8\times10^3\ v_{\text{common}})$ [1 mark] $9120 = 5.7\times10^3\ v_{\text{common}}$ $v_{\text{common}} = \frac{9120}{5.7\times10^3}$ $= 1.6\ \text{m s}^{-1}$ [1 mark]

14   3   **Inelastic** collision [1 mark]

$$\text{Initial kinetic energy of system} = \tfrac{1}{2}m_{\text{AWD}}u_{\text{AWD}}^2 + \tfrac{1}{2}m_{\text{bus}}u_{\text{bus}}^2$$
$$= \tfrac{1}{2}(1.9\times10^3)\times4.8^2 + 0$$
$$= 2.19\times10^4\ \text{J} \quad \text{[1 mark]}$$
$$\text{Final kinetic energy of system} = \tfrac{1}{2}m_{\text{AWD}}v_{\text{AWD}}^2 + \tfrac{1}{2}m_{\text{bus}}v_{\text{bus}}^2$$
$$= \tfrac{1}{2}(1.9\times10^3)\times1.6^2 + \tfrac{1}{2}(3.8\times10^3)\times1.6^2$$
$$= 2.43\times10^3 + 4.86\times10^3$$
$$= 7.29\times10^3\ \text{J} \quad \text{[1 mark]}$$
$$= 0.729\times10^4\ \text{J}$$

As the final kinetic energy of the system is less than the initial kinetic energy, the collision is inelastic.

Q	Marks	Answer	Solution
15	2	24 J	Work W done on the car equals the product of the downward force F exerted on the car and the car's downward displacement x, i.e. $W = Fx$ = total weight of the adults × downward displacement $= m_{\text{total}}\, g \times x$ $= (75\times4)\times10 \times (8.0\times10^{-3})$ [1 mark] $= 300\times10 \times 8.0\times10^{-3}$ = 24 J [1 mark]
16	2	$9.4\times10^4\ \text{N m}^{-1}$	The force F exerted on the spring equals the product of the force constant of the spring k and the compression produced Δx, i.e. $F = k\,\Delta x$ For one modelled spring, the force F will be one quarter of the total downward force exerted by the four adults. $\frac{m_{\text{total}}}{4}\times g = k\,\Delta x$ $\frac{300}{4}\times10 = k(8.0\times10^{-3})$ [1 mark] $k = \frac{300}{4}\times\frac{10}{8.0\times10^{-3}}$ $= 9.375\times10^4$ $= 9.4\times10^4\ \text{N m}^{-1}$ (to 2 sig figs) [1 mark]

Q	Answer	Solution
5	A	Stress σ can be determined from the stretching force F and the cross-sectional area A using: $\sigma = \frac{F}{A}$ $= \frac{F}{\pi r^2}$ $= \frac{450}{\pi(1.5\times10^{-3})^2}$ $= 6.37\times10^7$ $= 63.7\times10^6$ = 63.7 MPa
6	D	Young's modulus = gradient of stress-strain graph $E = \frac{100\times10^6}{0.0005}$ $= 2\times10^{11}$ Pa
7	A	The stored potential energy per unit volume of the material is represented by the 'area under stress-strain graph'. So the total stored potential energy in the cable is equal to the 'area under the graph' multiplied by the volume of the cable. So when σ = 60 MPa, E_p = 'area under graph' × volume of cable $= \tfrac{1}{2}\sigma\varepsilon \times \pi r^2 l$ $= \tfrac{1}{2}\times(0.0003)\times(60\times10^6)\times\pi(1.5\times10^{-3})^2\times3.07$ = 0.195 J
8	C	Concrete is much weaker than steel under tension. Concrete does not add tensile strength to steel in steel-reinforced concrete.
9	A	The most brittle material will fracture under the least strain.
10	B	Toughness is a measure of the amount of energy that can be absorbed per unit volume under tension without fracture and is represented by the area under the stress-strain graph up to the point of fracture. This refers to the ability to absorb energy without fracturing.
11	C	A plastic shopping bag undergoes plastic deformation prior to fracture and may even experience an increased strain under a decreased stress, i.e. the graph may develop a negative gradient. A material able to be drawn out in this way such as a wire is said to be ductile.
12	B	The permanent strain of the material is indicated on the strain axis where the 'unloading line' returns to the strain axis, i.e. 0.01% of the original length. So final length = original length + increase in length = 3.0000 + 0.01% × 3.0000 = 3.0000 + 0.0003 = 3.0003 m
13	A	The 'area under the graph' represents the energy transferred per unit volume of material in loading (to the material) or unloading (from the material). The difference in the area under the two lines (area K) represents the difference between these two magnitudes of energy which is the energy per unit volume lost as heat.

Q Answer **Solution**

SECTION B – DETAILED STUDY 2 - MATERIALS AND THEIR USE IN STRUCTURES

1 D Compression due to the Earth's gravitational forces pulling down on Malcolm's body, compressing mainly cartilage, during the day when his body will be mostly in a vertical position.

2 C Under the weight of Alistair the top of the cantilever bends further than the bottom. The molecules across the top of the cantilever are pulled apart whereas the molecules along the bottom actually move closer together under compression.

3 D The top of the pole is being pulled down by the force from cable R and the bottom is being pushed up by the force from the ground. So the pole is under compression.
Wire P is being stretched horizontally by the forces from the cables pulling outwards on the two poles. So it is under tension.

4 B Figure I shows the four forces acting on the pole; F_P, F_Q, F_R, and F_G, the force on the pole by the ground, although the actual direction of F_G is unknown. (The weight of the pole is to be disregarded as it is insignificant by comparison.)

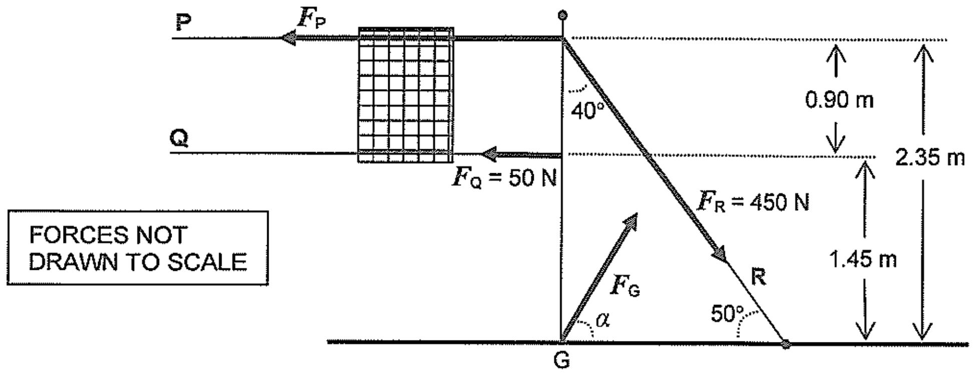

Figure I

To find F_P we could use translational equilibrium (2 equations) and rotational equilibrium (1 equation) as we have 3 unknowns, F_P, F_G and angle α (see Figure I).
A simpler method is to use rotational equilibrium and eliminate F_G and α by taking torques about the point G.
The net torque on the pole about G is zero.

$$0 = (50 \times 1.45) + (F_P \times 2.35) - (450 \times 2.35 \times \sin 40°)$$
$$0 = 72.5 + 2.35F_P - 679.75$$
$$2.35F_P = 607.25$$
$$F_P = 258.4 \text{ N}$$

Q Marks Answer **Solution**

17 2 24 J

Two possible approaches:

(1) The total additional strain potential energy ΔE_s in the four springs can be calculated from the work done by the adults on the car (already found in Answer 15) [2 marks]
Consequential answer: Ans15

(2) Their loss in gravitational potential energy $mg\Delta h$, as they move the car body down the 8 mm.

$$\Delta E_s = m_{\text{total}} g \Delta h$$
$$= 300 \times 10 \times (8 \times 10^{-3}) \quad \text{[1 mark]}$$
$$= 24 \text{ J} \quad \text{[1 mark]}$$

{**Note:** If you obtained an answer of 3.25 J, you probably used the relation:
$$E_s = \tfrac{1}{2}kx^2$$
But E_s is the **actual** strain potential energy stored in the spring when its compression is x, and we are not told what the actual compression of the spring system of the car is before the adults get in. Refer to Figure G.

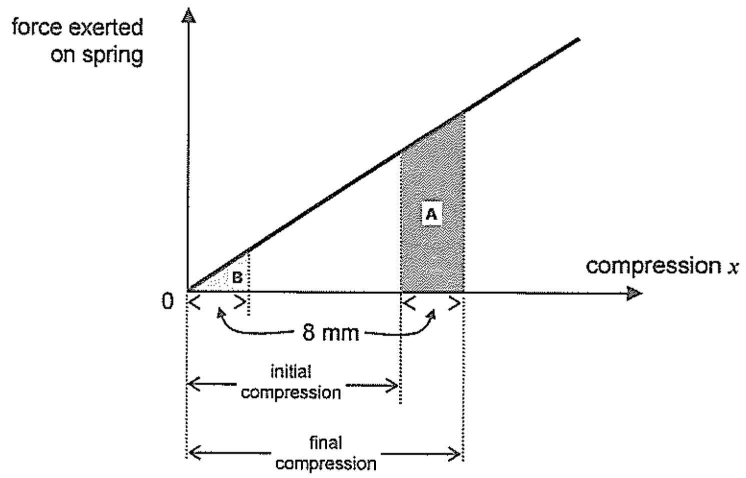

Figure G

The **additional** strain energy or work done on the springs is represented by the additional area under the force-compression graph, i.e. the shaded area **A** in Figure G. The incorrect answer 3.25 J is represented by the area **B**, which would have been correct if the springs were not already compressed by the weight of the body of the car.}

18 2 1.68×10^3 N

The gravitational force on the LRO from the Moon is given by the relation:

$$F = \frac{GM_{\text{Moon}}M_{\text{LRO}}}{r^2}$$
$$= \frac{(6.67 \times 10^{-11}) \times (7.34 \times 10^{22}) \times (1.10 \times 10^3)}{(1.79 \times 10^6)^2} \quad \text{[1 mark]}$$
$$= 1.6808 \times 10^3$$
$$= 1.68 \times 10^3 \text{ N (to 3 sig figs)} \quad \text{[1 mark]}$$

Q	Marks	Answer	Solution

{**Note:** Actually the mass of the LRO, which we took as constant here as an approximation, is not constant but is gradually decreasing as it uses fuel to adjust its position.}

19 | **2** | $1.53\ \text{m s}^{-2}$

Knowing the net force on the LRO from Answer 18, Newton's second law can be used to find its acceleration.

$$F_{\text{net}} = ma$$

$$1.68\times10^{3} = 1.10\times10^{3}\,a \qquad \text{[1 mark]}$$

$$a = \frac{1.68\times10^{3}}{1.10\times10^{3}}$$
$$= 1.5279$$
$$= 1.53\ \text{m s}^{-2}\ \text{(to 3 sig figs)} \qquad \text{[1 mark]}$$

Consequential answer: $\dfrac{\text{Ans18}}{1.1\times10^{3}}$

20 | **1** | $1.53\ \text{N kg}^{-1}$ (*or* m s^{-2})

The net force on the LRO is the gravitational force on it as there are no other forces on the probe.

$$F_{\text{net}} = ma$$
$$mg = ma$$
$$g = a$$
$$= 1.53\ \text{m s}^{-2},\ \text{from Answer 19}$$
$$= 1.53\ \text{N kg}^{-1}\ \text{(to 3 sig figs)} \qquad \text{[1 mark]}$$

Consequential answer: Ans19

SECTION A – AREA OF STUDY 2 – ELECTRONICS AND PHOTONICS

1 | **2** | 7.8×10^{-2} W

The power developed in a load is given by $P = I^2R$. In this case $I = 36$ mA and $R = 60\ \Omega$. Thus:

$$P = 0.036^2 \times 60 \qquad \text{[1 mark]}$$
$$= 0.07776$$
$$= 7.8\times10^{-2}\ \text{W (to 2 sig figs)} \qquad \text{[1 mark]}$$

2 | **2** | $1.4\times10^{2}\ \Omega$

Considering the parallel group of the 240 Ω and 120 Ω resistors,

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$$
$$= \frac{1}{240} + \frac{1}{120}$$
$$= \frac{1+2}{240}$$
$$= \frac{3}{240}$$
$$= \frac{1}{80}$$
$$R_T = 80\ \Omega \qquad \text{[1 mark]}$$

Q	Answer	Solution

8 | **D**

Energy $= m_0c^2$
$= (9.1\times10^{-31})\times(3.0\times10^{8})^2$
$= 8.19\times10^{-14}$ J

9 | **C**

10 | **B**

The preamble to Question 9 gives the total mass energy of the electron, $mc^2 = 1.23\times10^{-13}$ J
The rest mass energy, $m_0c^2 = E_0$

$$m = m_0\gamma$$
$$\gamma = \frac{m}{m_0}$$
$$= \frac{mc^2}{m_0c^2}$$
$$= \frac{1.23\times10^{-13}}{E_0}$$

11 | **A**

The mass will increase with speed. This increase in mass is given by:

$$\Delta m = m - m_0$$
$$= m_0\gamma - m_0$$
$$= (9.1\times10^{-31}\,\gamma\ -\ 9.1\times10^{-31})\ \text{kg}$$

12 | **D**

The speed v of the protons can be found from the relation

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$
$$1.4 = \frac{1}{\sqrt{1-\frac{v^2}{(3\times10^8)^2}}}$$
$$1.96 = \frac{1}{1-\frac{v^2}{(3\times10^8)^2}}$$
$$1.96 - \frac{1.96v^2}{(3\times10^8)^2} = 1$$
$$0.96 = \frac{1.96v^2}{(3\times10^8)^2}$$
$$v^2 = \frac{0.96\times(3\times10^8)^2}{1.96}$$
$$v = 2.099\times10^{8}$$
$$\approx 2.1\times10^{8}\ \text{m s}^{-1}$$

13 | **A**

The length L as observed in the proton's frame of reference can be found from the relation:

$$L = \frac{L_0}{\gamma}$$
$$= \frac{300}{1.4}$$
$$= 214\ \text{m}$$

Q	Answer	Solution

SECTION B – DETAILED STUDY 1 – EINSTEIN'S SPECIAL RELATIVITY

1 C

$t_{\text{Andrew}} = t_0 = 1$ min

$t_{\text{Brenda}} = t_0\gamma$

$$= 1\,\text{min} \times \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$= 1\,\text{min} \times \frac{1}{\sqrt{1-\frac{(0.995c)^2}{c^2}}}$$

= 10.01 min. C is the closest answer.

2 D The transverse nature of the electromagnetic waves was not a problem, So not A.
Interference had been widely observed and documented. Not B.
The experimental values for the speed of light were very close to that predicted by Maxwell. So not C.
The real concern was that Maxwell was postulating that the speed of light was independent of the speed of the source or medium. So D.

3 B The length of the side of the square perpendicular to the direction of motion is not affected. The 'horizontal' length parallel to the direction of motion is contracted. So B is the only possible answer.
{**Note**: No calculations were necessary to answer this question, but for those who did:
'L_{vertical}' is unaffected, and so remains at 1 m.
'$L_{\text{horizontal}}$' in the direction of motion

$= L_0/\gamma$, i.e. $L_{\text{horizontal}}/\gamma$

$$= \frac{1\,\text{m}}{\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}}$$

$$= \frac{1\,\text{m}}{\frac{1}{\sqrt{1-\frac{(0.5c)^2}{c^2}}}}$$

= 0.87 m}

4 D The prediction was that the light travelling parallel to the movement of the Earth would take longer than the light travelling perpendicular to the earth but their experiment showed it took the same time.

5 C Einstein's second postulate for special relativity states that the speed of light is constant in a vacuum and has the same value for all observers in all inertial frames of reference.
Michelson & Morley did not use their apparatus to measure the speed of light. They already knew it.

6 A Option A is simply a definition of a frame of reference, which was common to both Galilean and Einstein's relativity. None of the other three options are consistent with both.

7 B

Q	Marks	Answer	Solution

Considering the 60 Ω resistor in series with this parallel group,

$R_T = R_1 + R_2$
$= 60 + 80$
$= 140$
$= 1.4 \times 10^2\ \Omega$ (to 2 sig figs) [1 mark]

3 2 5.0 V

Considering the external circuit as a single equivalent resistance:

$V_{\text{supply}} = V_{\text{total circuit}}$
$= I_{\text{total}} R_{\text{total}}$
$= 36 \times 10^{-3} \times 1.4 \times 10^2$ [1 mark]
$= 5.04$
$= 5.0$ V (to 2 sig figs) [1 mark]

Consequential answer: 0.036 × Ans2

4(a) 1 See Table A. [In Column 1, 1 mark for ticking both Y and Z but not X]

4(b) 2 See Table A. [In Column 2, 1 mark for X, 1 mark for Z and -1 mark if Y was selected, with a minimum total mark of zero]

Table A

Globe	Column 1 [Qn 5(a)]	Column 2 [Qn 5(b)]
X		✓
Y	✓	
Z	✓	✓

5 1 Clipping is a word used to describe the distortion resulting when the input signal to an amplifier is too large [1 mark]. This results in the top and/or bottom of the output signal being 'cut-off' as shown in Figure H.

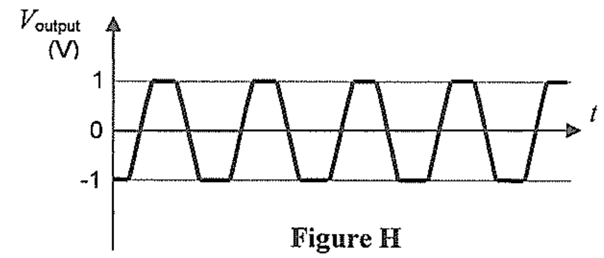

Figure H

6 1 The amplifier is an **inverting** one, as indicated by the signals being exactly out of phase, i.e. differing in phase by 180°.

7 2 20 The linear voltage gain of an amplifier is given by the ratio of the change in output voltage to the corresponding change in the input voltage. Using the first quarter-period of both in Figures 3(a) and 3(b),

$$\text{linear voltage gain} = \frac{\Delta V_{\text{output}}}{\Delta V_{\text{input}}}$$

$$= \frac{0.50}{-0.025}$$ [1 mark]

$$= -20$$

Thus the magnitude of the linear voltage gain is 20. [1 mark]

Q	Marks	Answer	Solution

8   2 $4.2 \times 10^3\ \Omega$

Two possible approaches:

(1) Using the potential divider equation:
The resistance of resistor X in Figure 4 can be determined from the equation,

$$V_{output} = \frac{R_{LDR}}{R_{LDR} + R_X} \times V_{supply},$$

where $V_{output} = 2.0$ V, $R_{LDR} = 1200\ \Omega$ and $V_{supply} = 9.0$ V.

$$2.0 = \frac{1200}{1200 + R_X} \times 9.0 \qquad \text{[1 mark]}$$

$$2400 + 2R_X = 10800$$

$$R_X = \frac{10800 - 2400}{2}$$

$$= 4200$$

$$= 4.2 \times 10^3\ \Omega \text{ (to 2 sig figs)} \qquad \text{[1 mark]}$$

(2) From first principles:
To determine R_X, we need V_X and I_X.

But $V_X = V_{supply} - V_{LDR}$
$= 9.0 - 2.0$
$= 7.0$ V

$I_X = I_{LDR}$, since they are in series

$$= \frac{V_{LDR}}{R_{LDR}}$$

$$= \frac{2.0}{1200}$$

$$= 1.666 \times 10^{-3} \text{ A}$$

So $R_X = \dfrac{V_X}{I_X}$

$$= \frac{7.0}{1.666 \times 10^{-3}} \qquad \text{[1 mark]}$$

$$= 4.2 \times 10^3\ \Omega \qquad \text{[1 mark]}$$

9   2 V_{output} will increase. [1 mark]
When it gets dark, the resistance of the LDR increases. Since the resistance of X remains constant, a larger part of the 9 V supply voltage will be across the LDR (and a smaller amount across X). So V_{output} will increase. [1 mark for correct reasoning]

10   2   90 mW

From the graph, when $I = 30$ mA, $V = 3.0$ V. The power developed in the LED can be calculated using $P = VI$. Thus:

$P = 3.0 \times 0.030$ [1 mark]
$= 0.090$ W
$= 90$ mW (to 2 sig figs)   [1 mark]

Q	Marks	Answer	Solution

11   2 $3.0 \times 10^2\ \Omega$

The resistance can be found using $V_Y = I_Y R_Y$, transposed to make R_Y the subject: $R_Y = \dfrac{V_Y}{I_Y}$. So we need to know V_Y and I_Y.

When the $I_{LED} = 30$ mA, we know
(1) I_Y also = 30 mA, as the LED and resistor Y are in series, and
(2) from the graph that $V_{LED} = 3.0$ V.
But $V_Y = V_{supply} - V_{LED} = 12 - 3 = 9$ V

So $R_Y = \dfrac{V_Y}{I_Y}$

$$= \frac{9}{0.030} \qquad \text{[1 mark]}$$

$$= 300$$

$$= 3.0 \times 10^2\ \Omega \text{ (to 2 sig figs)} \qquad \text{[1 mark]}$$

12   2   D

The amplitude modulation of the carrier wave matches "no, no, yes, not sure" with each code-bit lasting 1 ms.

13   1 4.5×10^{-6} A

The current I_p in the photodiode is the same as the current $I_{1\ M\Omega}$ in the 1.0 MΩ resistor. Thus:

$$I_p = I_{1\ M\Omega}$$

$$= \frac{V_{1\ M\Omega}}{R_{1\ M\Omega}}$$

$$= \frac{4.5}{1.0 \times 10^6} \qquad \text{[1 mark]}$$

$$= 4.5 \times 10^{-6} \text{ A (to 2 sig figs)} \qquad \text{[1 mark]}$$

14   2   A

Increasing the brightness of the light striking the photodiode will increase the current in the photodiode. With a larger current through the two components, the potential difference across the 1 MΩ resistor will increase, resulting in a decrease in the potential difference across the photodiode. The smaller potential difference across the photodiode and the larger current in it means the resistance ($R = \dfrac{V}{I}$) of the diode is decreased.

Answer A has both variables decreasing.