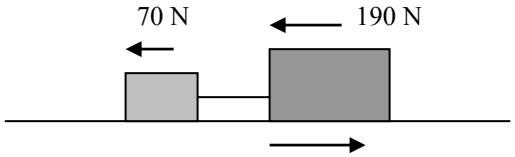
2006 VCAA Physics Exam 1 Solutions

SECTION A – Core
Area of study 1 – Motion in one and two dimensions

Q1

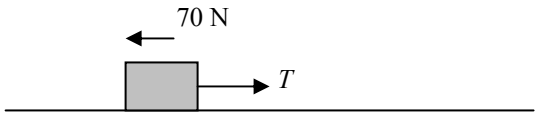


F (driving force on the rear tyre by the road)

Constant speed, no acceleration, $\therefore F_{net} = 0$,

$^{+}F + ^{-}70 + ^{-}190 = 0$, $\therefore F = 260$ N, $\therefore$ driving force on the road by the rear tyre is 260 N.

Q2



Constant speed, no acceleration, $\therefore F_{net} = 0$, $^{+}T + ^{-}70 = 0$,
$\therefore T = 70$ N.

Q3 When the cyclist stops pedalling, driving force = 0.
Work done by opposing forces = ΔE_K,

$(70+190)x = \frac{1}{2}(90+40)\times 6.0^2$, $x = 9.0$.

Distance travelled during slowing = 9.0 m.

Q4 Friction force F = weight force W $= mg = 60\times 10 = 600$ N

Q5 $F_{net} = ma$, $C = m\frac{v^2}{r} = 60\times\frac{11^2}{7.5} = 9.7\times 10^2$ N

Q6 $F_{net} = {}^{+}22 + {}^{-}0.5\times 10 = {}^{+}17$ N, resultant force = 17 N.

Q7 $a = \frac{F_{net}}{m} = \frac{^{+}17}{0.5} = {}^{+}34$ ms^{-1} (constant upward acceleration),
$u = 0$, $t = 1.5$ s, $s = ?$

$s = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2}\times 34\times 1.5^2 = 38.25$. Height = 38 m.

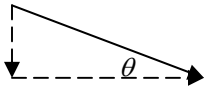
Q8 Horizontal momentum = horizontal impulse
$= 22\times 1.5 = 33$ kgms^{-1}.

After 1.5 s, horizontal velocity $= \frac{p}{m} = \frac{33}{0.5} = 66$ ms^{-1}.

Vertical component: $u = 0$, $a = -10$, $t = 1.5$, $v = u + at = -15$.

$\therefore$ speed $= \sqrt{15^2 + 66^2} = 68$ ms^{-1}

$\theta = \tan^{-1}\left(\frac{15}{66}\right) = 13^o$.



Q9 Relative to Mary, the ball has a horizontal velocity component to the rear of the train. **E**.

Q10 Conservation of momentum:
$6000\times^{+}5.00 + M\times 0 = (6000+M)\times^{+}0.098$, $\therefore M = 3.0\times 10^5$ kg.

Q11 Shuttle: impulse = change in momentum,
$\vec{F}_{av}\times 20 = 6000\times^{+}0.098 - 6000\times^{+}5.00$, $\therefore \vec{F}_{av} = {}^{-}1471$.
Average force on shuttle $= 1.5\times 10^3$ N.

Q12 Total work done on Sam = heat energy generated due to friction + increase in Sam's gravitational potential energy.
$22720 = 300\times L + 13720$, $\therefore L = 30$ m.

Q13 Increase in gravitational potential energy $= mgh$,
$\therefore 13720 = 70\times 10\times h$, $\therefore h = 19.6$ m.

Q14 Change in elastic potential energy = change in gravitational potential energy, i.e. $\frac{1}{2}kx^2 = mgh$,

$\therefore \frac{1}{2}k8^2 = 70\times 10\times 18$, hence $k = 3.9\times 10^2$ Nm^{-1}.

Q15 $a = g \propto \frac{M}{r^2}$, $\therefore a = 10\times\frac{1}{10}\times\frac{1}{\left(\frac{1}{2}\right)^2} = 4$ ms^{-2}.

Q16 Since $a = g$ in orbit, $\therefore \frac{4\pi^2 r}{T^2} = \frac{GM}{r^2}$,

$\therefore T = \sqrt{\frac{4\pi^2 r^3}{GM}} = 1.6\times 10^5$ s.

Area of study 2 – Electronics and photonics

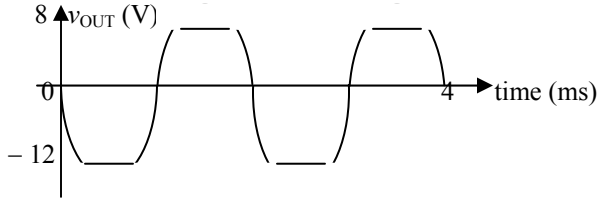
Q1

Point	Voltage (V)
1	20
2	$\frac{1}{1+4}\times 20 = 4$
3	20 – 8 mA × 1 kΩ = 12

Q2 $\Delta v_{OUT} = -200\times\Delta v_{IN} = -200\times 50$ mV $= -10$ V,

$\therefore \Delta v_{R_C} = +10$ V. $\therefore \Delta i_C = \frac{\Delta v_{R_C}}{R_C} = \frac{+10}{1000} = +0.01$ A $= +10$ mA$_{\text{p-p}}$.

Q3 v_{IN} is too large and clipping occurs. No change in period.



Q4 A decoupler separates AC and DC components of signals in a transistor amplifier. For a correctly biased transistor amplifier only AC signals are fed to the input. To ensure this a capacitor (C_{IN}) acts as a decoupler to filter out the DC component from a signal. Another capacitor (C_{OUT}) ensures only amplified AC signals at the output. Capacitor C_E filters out the AC component across R_E to maintain a constant biased DC voltage at the input.

Q5 Voltage across the 100-ohm resistor = 5.0 – 0.7 = 4.3 V,
$\therefore I = \dfrac{V}{R} = \dfrac{4.3}{100} = 0.043 \text{ A} = 43 \text{ mA}.$

Q6 Read from graph, 100Ω.

Q7 At $T = 10^o$ C, $R_{THERM} = 400\ \Omega$, $V_{THERM} = V_{OUT} = 4.0$ V,
$\therefore V_R = 12 - 4.0 = 8.0$ V.
Since $\dfrac{R}{R_{THERM}} = \dfrac{V_R}{V_{THERM}}$, $\therefore R = \dfrac{8.0}{4.0} \times 400 = 800\ \Omega.$

Q8 Modulation is a particular form of coding. Information signal (sound signal) is used to modulate the light signal, which is then transmitted through the fibre-optic cable. Demodulation is the reverse process of modulation in which information carried by the modulated light signal is recovered and decoded.

Q9 At P, LED; at Q, LDR.

SECTION B – Detailed studies
Detailed study 1 – Einstein's special relativity

Q1 The experimenters did not detect any difference in the speeds of two light beams (one parallel and one perpendicular to the direction of the rotation of the Earth). One of the possible explanations for the null result was that ether does not exist.

Q2 An inertial frame of reference is one in which Newton's first law (the law of inertia) is valid.

Q3 L is the proper length because it was measured by Kris who was at rest in her rocket ship.

Q4 $L' = L\sqrt{1 - \dfrac{v^2}{c^2}}$, $\therefore L = \dfrac{L'}{\sqrt{1 - \dfrac{v^2}{c^2}}}$. **B**

Q5 Lee: $340 - 30 = 310\ \text{ms}^{-1}$; Sung: $340 + 30 = 370\ \text{ms}^{-1}$.

Q6 Light propagates through empty space with a definite velocity $c = 3.0 \times 10^8\ \text{ms}^{-1}$ independent of the velocity of the source and/or observer. **A**

Q7 Dilated time $= \dfrac{2.2\mu s}{\sqrt{1 - \left(\frac{0.995c}{c}\right)^2}} = 22\ \mu\text{s}$

Q8 Contracted height $= 2627\sqrt{1 - \left(\dfrac{0.995c}{c}\right)^2} = 262$ m

Q9 $L' = L\sqrt{1 - \dfrac{v^2}{c^2}}$, $\therefore \dfrac{L'}{L} = \sqrt{1 - \dfrac{v^2}{c^2}} = 99\% = 0.99$,
$\therefore 1 - \dfrac{v^2}{c^2} = 0.9801$, $\therefore v = \sqrt{0.0199} \times c = 4.23 \times 10^7\ \text{ms}^{-1}.$

Q10 As the electron is accelerated to greater and greater speeds close to c, its mass becomes larger and larger approaching infinity. **B**

Q11 $mc^2 = m_o c^2 + E_K$. **C**

Detailed study 2 – Investigating materials and their use in structures

Q1 **B**

Q2 Polyethylene – it absorbs more energy before breaking (larger area under σ-ε graph).

Q3 When placed under a tensile stress of 20 MPa,
$\varepsilon = \dfrac{\Delta L}{L} \approx 2\% = 0.02$ (from graph) $\therefore \Delta L = 0.02 \times 5.0 = 0.10$ m.

Q4 Young's modulus $= \dfrac{60}{0.02}$ MPa $= 3000$ MPa.

Q5 $\sigma = \dfrac{F}{A} = \dfrac{mg}{A}$,
$\therefore m = \dfrac{\sigma A}{g} = \dfrac{\left(62 \times 10^6\right)\left(2.0 \times 10^{-4}\right)}{10} = 1.2 \times 10^3$ kg.

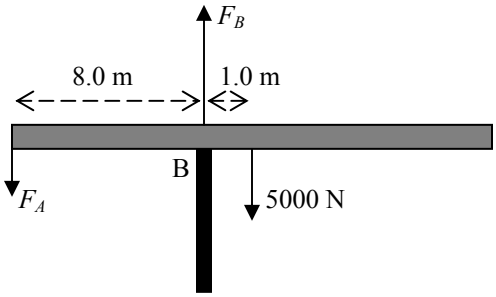
Q6 Work = area under σ-ε graph × volume of material
$= \left(\dfrac{1}{2} \times 62 \times 10^6 \times 0.021\right) \times \left(2.0 \times 2.0 \times 10^{-4}\right) \approx 260$ J.

Q7 Steel rods are strong in tension and used to reinforce concrete under tensile stress.

Q8 **C**

Q9 **D**

Q10



Net torque about point B = 0, $^+F_A \times 8.0 + ^-5000 \times 1.0 + F_B \times 0 = 0$,
$\therefore F_A = 625$ N.

Q11 **D**

Detailed study 3 – Further electronics

Q1 $P = \dfrac{V^2}{R} = \dfrac{12^2}{240} = 0.60 \text{ W}$

Q2 $\dfrac{N_S}{N_P} = \dfrac{V_S}{V_P}, \therefore N_S = \dfrac{18}{240} \times 4800 = 360$

Q3 $V_{peak} = 18\sqrt{2} \approx 25.5 \text{ V}$, period $= \dfrac{1}{f} = \dfrac{1}{50} = 0.02 \text{ s} = 20 \text{ ms}.$

B

Q4 None of the sketches shown. Voltage between points 2a and 2b is the same as that between points 3a and 3b. See Q5.

Q5 The capacitor smooths the voltage. **D**

Q6 The voltage regulator keeps the output voltage at 12 V.

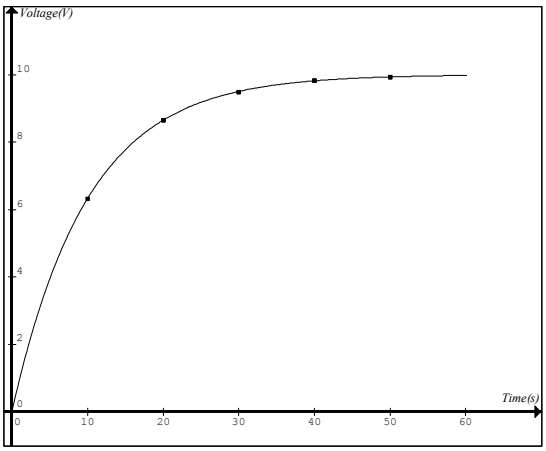
Q7 Output of transformer $= \dfrac{360}{4800} \times 140 = 10.5 \text{ V}_{\text{RMS}} = 14.8 \text{ V}_{\text{peak}}.$
After rectification this peak voltage falls below the voltage required by the voltage regulator to operate in the voltage-regulating region, causing the voltage output of the power supply to fall below 12 V and possibly the appearance of ripples.

Q8 **A**

Q9 Output current increases; output voltage remains the same.

Q10 Time constant $= RC = 2000 \times 10000 \times 10^{-6} = 20 \text{ s}$

Q11



Q12 After 10 s the capacitor discharges by 63% of 10 V, i.e. 6.3 V. Voltmeter reading = 10 − 6.3 = 3.7 V.

Please inform physicsline@itute.com re conceptual, mathematical and/or typing errors