# 2011 VCAA Physics Exam 1 Solutions



## Area of study 1 – Motion in one and two dimensions

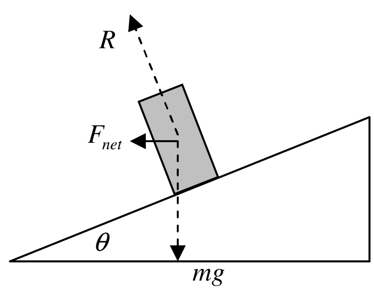
Q1 $|F_{net}| = m|a| = 2500 \times 0.50 = 1250\,\text{N}$

Q2 Consider the motion of the trailer: $F_{net} = ma$,
$T = 2000 \times 0.50 = 1000$ N
The tension in the rope is 1000 N.

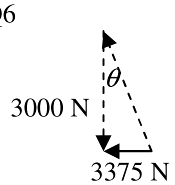
Q3 $u = 0$, $t = 5.0$, $a = 0.50$, $s$?
$s = ut + \frac{1}{2}at^2$, $s = \frac{1}{2}(0.50)5.0^2 = 6.25$ m
The tractor moves 6.25 m in the first 5.0 s.

Q4 $|F_{net}| = \frac{mv^2}{r} = \frac{300 \times 15^2}{20} = 3375$ N

Q5 Vector addition of the two forces gives the net force.




Q6




$\theta = \tan^{-1}\left(\frac{3375}{3000}\right) = 48.4°$

Q7 Consider blocks A and B together as an item exerting a downward force on block C. The magnitude of this force is equal to the magnitude of the force of gravity on the combined mass of A and B, $(0.050 + 0.10)g = 1.5$ N. According to Newton's third law block C exerts an upward force of 1.5 N on block B (A and B combined).

Q8 When the blocks are in free fall, they experience no forces other than the force of gravity, i.e. they exert zero force on each other.

Q9 At position A, $F_{net} = ma$, $mg + R = \frac{mv^2}{r}$.
The reaction force $R$ on the car must be $\geq 0$ for the car not to leave the rail. Let $R = 0$ to find the minimum speed.
.: $v = \sqrt{gr} = \sqrt{10 \times 15} = 12.2$ m s$^{-1}$.

Q10 When the car (and Melanie) travels at the minimum speed at position A, both are in free fall and the reaction force of the car on Melanie is zero. Hence Melanie's apparent weight is zero at position A.

Q11 At position B, $-mg + R = \frac{mv^2}{r}$.

$-600 + R = \frac{60 \times 5.5^2}{15}$, $R = 721\,\text{N}$
Melanie's apparent weight is 720 N approximately.

Q12 Vertical component: $u = {}^{+}24\sin 37°$, $a = {}^{-}10$, $s = 0$, $t$?
Use $s = ut + \frac{1}{2}at^2$ to find $t \approx 2.89$ s.

Q13 Vertical component: $u = {}^{+}24\sin 37°$, $a = {}^{-}10$, $v = 0$, $s$?
Use $v^2 = u^2 + 2as$ to find $s \approx {}^{+}10.4$ m. .: $h \approx 10.4$ m

Q14
Conservation of energy: Total energy at A = total energy at C
.: $\frac{1}{2}mv^2 = mgh$, $v = \sqrt{2gh} = \sqrt{2 \times 10 \times 12.8} = 16$ m s$^{-1}$ at C
Momentum at C $= mv = 60 \times 16 = 960$ kg m s$^{-1}$ towards D.

Q15 $u = {}^{+}16$, $t = 6.0$, $v = 0$, $a$?
Use $v = u + at$ to find $a = \frac{{}^{-}8}{3}$

$|F_{friction}| = m|a| = 60 \times \frac{8}{3} = 160\,\text{N}$

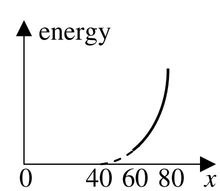
Q16 When the 1.0-kg mass is attached, with the spring and mass stationary, the extension of the spring is
$x = 0.70 - 0.40 = 0.30$ m.
Hooke's law: $F = kx$, $k = \frac{F}{x} = \frac{mg}{x} = \frac{1.0 \times 10}{0.30} \approx 33.3$ N m$^{-1}$

Q17 The 1.0-kg mass starts from rest at $x = 80$ and comes to rest momentarily at $x = 60$. It passes through $x = 70$ at maximum speed. .: zero kinetic energy at $x = 80$ and $x = 60$, maximum kinetic energy at $x = 60$. D

Q18 The total energy of the system is constant. C

Q19 Gravitational potential energy is positive when the 1.0-kg mass is above the lowest point which is taken as zero energy. Also $E_{gravity} \propto h$, i.e. linear. B

Q20 Extension $= x - 40$ cm
*Strain potential energy* $= \frac{1}{2}k(extension)^2$
.: *strain potential energy* $\propto (x - 40)^2$
F



Q21 $Weight = mass \times g$ , $g = \dfrac{weight}{mass}$ , the same weight and the same mass, .: $g$ must be the same, $g = 10\,\text{N kg}^{-1}$

Q22 $g = \dfrac{GM}{r^2}$ , $10 = \dfrac{(6.67\times10^{-11})M}{(30\times10^3)^2}$ , $M = 1.35\times10^{20}$ kg

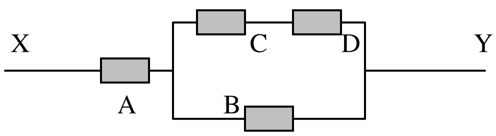
Q23 The visitor's home planet is in free fall,

$a = g$ , $\dfrac{4\pi^2 r}{T^2} = \dfrac{GM}{r^2}$ .

.: $T = \sqrt{\dfrac{4\pi^2 r^3}{GM}} = \sqrt{\dfrac{4\pi^2(1.0\times10^9)^3}{(6.67\times10^{-11})(5.7\times10^{25})}} = 3.2\times10^6$ s

## Area of study 2 – Electronics and photonics

Q1




Total resistance $= 2 + \dfrac{1}{\frac{1}{2+2}+\frac{1}{2}} = \dfrac{10}{3} \approx 3.3\,\Omega$

Q2 $I_{battery} = \dfrac{V_{XY}}{R_{total}} = \dfrac{10}{\frac{10}{3}} = 3$ A, .: $I_B + I_C = 3$

$V_B = V_C + V_D$

.: $I_B R_B = I_C R_C + I_D R_D = I_C(R_C + R_D)$ , since $I_C = I_D$

.: $I_B = 2I_C$

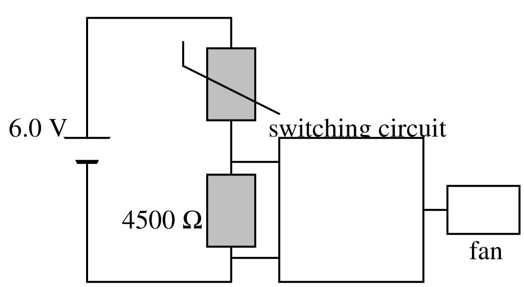
Hence $I_B = 2$ A

Q3 $V_A = I_A R_A = 3\times2 = 6$ V

Q4 $P_D = {I_D}^2 R_D = 1\times2 = 2$ W

Q5 Read from graph, $R_{thermistor} = 1500\,\Omega$ at $20°$ C

Q6




At $20°$ C the thermistor resistance is 1500 Ω. The voltage across the resistor $= \dfrac{4500}{1500+4500} = 4.5$ V. At higher temperature the thermistor resistance is lower than 1500 Ω. .: the voltage across the resistor (input of the switching circuit) will be greater than 4.5 V.

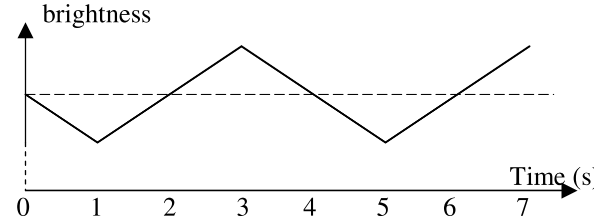
Q7 At full brightness, $I_{R1} = I_{LED} = 0.15$ A, $V_{R1} = 9 - 3 = 6$ V

.: $R_1 = \dfrac{V_{R1}}{I_{R1}} = \dfrac{6}{0.15} = 40\,\Omega$

Q8 At 10 mW light power, $I_{photodiode} = 4.0$ mA $= 0.0040$ A

$V_{R2} = I_{R2} R_2 = I_{photodiode} R_2 = 0.0040\times2000 = 8.0$ V

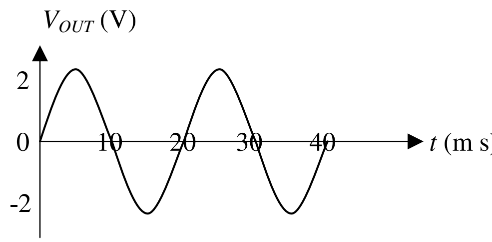
Q9




The above graph (straight-line sections) is based on the assumption that the resistance variation is small relative to the total resistance.

Q10 The carrier wave is the light wave emitted by the LED when the sliding contact is at rest in the middle of the resistance variation range. When the sliding contact moves, variation in the resistance changes the current through the LED and hence the brightness of the LED (light intensity modulation).

Q11




Q12 Clipping occurs when the input signal is outside the range from -10 to 10 mV. The output voltage will be clipped and ranged from -4 to 4 V.

## Detailed study 1 – Einstein's special relativity

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| B | D | C | C | A | A | D | B | D | C | A | D |

Q1 Mass of the Higgs particle

$= 2\left(\dfrac{E_k}{c^2} + m_0\right) = 2\left(\dfrac{1.1\times10^{-6}}{(3.0\times10^8)^2} + 1.6726\times10^{-27}\right)$

$\approx 2.4\times10^{-23}$ kg B

Q2 Since $E = \gamma m_0 c^2$ , $\gamma$ and hence $E$ increases rapidly as $v$ approaches $c$. .: $\Delta E$ is greater at higher speed than at lower speed for the same $\Delta v$ . D

Q3 $E = \gamma m_0 c^2 = \gamma E_0$ , $\Delta E = E_f - E_i = \gamma_f E_0 - \gamma_i E_0 = (\gamma_f - \gamma_i)E_0$

$= (1.10 - 1.05)\times1.50\times10^{-10} = 7.5\times10^{-12}$ J C

Q4 $L = L_o\sqrt{1-\dfrac{v^2}{c^2}}$ , $200 = 300\sqrt{1-\dfrac{v^2}{c^2}}$ , $\dfrac{2}{3} = \sqrt{1-\dfrac{v^2}{c^2}}$ ,

$\dfrac{4}{9} = 1 - \dfrac{v^2}{c^2}$ , $\dfrac{v}{c} = \sqrt{\dfrac{5}{9}}$ , $v \approx 0.75c$ C

Q5 Electromagnetic radiation travels at speed $c$ irrespective of the speed of its source or receiver. A

Q6 Sound travels in the air (the medium). When the air moves (the wind) it carries the sound with it. If the wind and the sound directions are the same, the speed of the sound relative to the ground increases. A

Q7 The Michelson-Morley experiment attempted to prove/disprove the existence of ether by measuring the differences in the speed of light in different directions. D

Q8 An inertial reference frame is a non-accelerating reference frame. B

Q9 The lifetime $t$ of the particle measured by the scientists $= \frac{0.0054}{2.5\times10^{8}} = 2.16\times10^{-11}$ s

The proper lifetime $t_0 = \frac{t}{\gamma} = \frac{2.16\times10^{-11}}{1.81} \approx 1.2\times10^{-11}$ s D

Q10 Infinite amount of energy is required to accelerate particles to the speed of light. Choose the option involving energy. C

Q11 A

Q12 $\gamma = \frac{1}{\sqrt{1-\left(\frac{v}{c}\right)^2}}$, $1.04 = \frac{1}{\sqrt{1-\left(\frac{v}{c}\right)^2}}$, $v \approx 0.2747c$

Double the speed to $v = 2\times0.2747c = 0.5493c$

$\gamma = \frac{1}{\sqrt{1-\left(\frac{v}{c}\right)^2}} = \frac{1}{\sqrt{1-0.5493^2}} \approx 1.20$ D

### Detailed study 2 – Materials and their use in structures

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| C | C | B | B | D | B | D | C | C | A | A | B |

Q1 $\sigma = \frac{F}{A} = \frac{8.0\times10^{3}}{2.0\times10^{-5}} = 4.0\times10^{8}$ N m$^{-2}$ C

Q2 $\varepsilon = \frac{\Delta L}{L} = \frac{5.0\times10^{-4}}{0.10} = 5.0\times10^{-3}$ C

Q3 Young's modulus $= \frac{\sigma}{\varepsilon} = \frac{4.0\times10^{8}}{5.0\times10^{-3}} = 8.0\times10^{10}$ N m$^{-2}$ B

Q4 Energy = area under graph (linear section)

$= \frac{1}{2}\left(8.0\times10^{3}\right)\left(5.0\times10^{-4}\right) = 2.0$ J B

Q5 Toughness of a material is determined by the area under its $\sigma$ - $\varepsilon$ graph, or the area under the *F*-*x* graph divided by its volume.

The estimated area under the *F*-*x* graph

$\approx \left(8.0\times10^{3}\right)\left(17.5\times10^{-4}\right) \approx 14$ J

Volume of material $= \left(2.0\times10^{-5}\right)\left(0.10\right) = 2.0\times10^{-6}$ m$^3$

Toughness $\approx \frac{14}{2.0\times10^{-6}} \approx 7.0\times10^{6}$ J m$^{-3}$ D

Q6 B

Q7 D

Q8 The 40-kg sign pulls the cable with a force of 400 N. C

Q9 Net torques about support A = 0 ,

$^{+}F_B \times 1.0 + ^{-}800\times2.0 + ^{-}1000\times4.0 = 0$, $F_B = 5600$ N C

Q10 Support A prevents the board from rotating clockwise. It exerts a downward force on the board. The downward force of support A, the weights of the board and the diver, and the upward force of support B cause the board to curve downwards. As a result the upper part of the concrete board is in tension and requires placement of steel wires there to reinforce the concrete. A

Q11 The weight of the mass tends to twist the drum. A

Q12 $\varepsilon = \frac{\Delta L}{L}$, $0.010 = \frac{\Delta L}{2.0}$, $\Delta L = 0.020\,\text{m} = 2.0\,\text{cm}$ B

### Detailed study 3 – Further electronics

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| D | D | B | A | A | B | B | A | C | A | B | C |

Q1 $\tau = R_{load}C = \left(5\times10^{6}\right)\left(10\times10^{-6}\right) = 50$ s D

Q2 The time constant >> the period. D

Q3 Power required: $P = \frac{V^2}{R_{load}} = \frac{5000^2}{5\times10^{6}} = 5$ W B

Q4 A

Q5 A

Q6 $\frac{N_s}{N_P} = \frac{V_s}{V_p}$, , $\frac{N_s}{4800} = \frac{10}{240}$, $N_s = 200$ B

Q7 B

Q8 A

Q9 The Zener diode is forward biased, .: voltage across it is 1 V. C

Q10 A

Q11 The capacitor charges up by 63% in 10 s, .: $\tau = RC = 10$ s

$C = \frac{10}{R} = \frac{10}{1\times10^{6}} = 10\times10^{-6}\,\text{F} = 10\,\mu\text{F}$ B

Q12 The capacitor discharges by 63% in 26 s.

.: $\tau = RC = R\left(10\times10^{-6}\right) = 26$ s, .: $R = 2.6\times10^{6}\,\Omega = 2.6\,\text{M}\Omega$

.: resistance of equipment E $= 2.6 - 1 = 1.6$ MΩ C

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