2025 DHS Prelim Paper 3 Suggested Solutions

1 **(a)** Gravitational field strength at a point is defined as the gravitational force exerted per unit mass placed at that point. **B1**

(b) Since gravitational field strength g is the gravitational force F exerted per unit mass, **M1**

$$g = \frac{F}{m}$$

and the gravitational force exerted by the point mass on another body with mass m is $F = \frac{GMm}{r^2}$ **M1**

A0

$$g = \frac{F}{m} = \frac{\left(\frac{GMm}{r^2}\right)}{m} = \frac{GM}{r^2}$$

Note: Do not accept answers with just working but no explanations.

Marker's Comment:
Credit requires explanation of the physics steps. Candidates must state Newton's law, reference the field strength definition from part (a), and explain the substitution process. Simply writing equations and algebra without explaining the reasoning shows mathematical manipulation but not physics understanding.

(c) (at surface,) lines (of force) are radial **B1**

Earth has large radius / height above surface is small, so lines are (approximately) parallel **B1**

and equally spaced **B1**

Marker's Comment:
Candidates must answer the question as asked. The requirement is to explain using lines of gravitational force (field lines), not mathematical expressions. Credit requires describing how field lines near the surface appear parallel and uniformly spaced, showing constant field strength. Using $g = GM/r^2$ arguments ignores the specified approach.

2 **(a)** The rate of change of momentum of a body is directly proportional to the resultant force acting on the body and occurs in the direction of the resultant force. **B1**

Marker's Comment:

Many did not write the correct Newton's 2nd law of motion. A few stated the force is ma.

(b) **(i)** $p = \Delta(mv)$

$= -65 \times 10^{-3}\ (5.2 + 3.7)$ **C1**

$= -0.58$ N s **A1**

(ii) $F = (0.58) / (7.5 \times 10^{-3}) = 77$ N **A1**

(c) **(i)** **1.** Force on the wall from the ball is equal to the force on ball from the wall **B1**

but in the opposite direction **B1**

(general statement of Newton's third law only score 1 mark)

2. momentum change of ball is equal and opposite to momentum change of the wall **B1**

OR since there is no external resultant force acting on the system (ball and wall), the total momentum of the system is conserved

OR total change in momentum of ball and wall is zero

Marker's Comment:
Common mistakes such as the word 'resultant' was missed out in stating Principle of Conservation of Linear Momentum. Change in momentum was wrongly calculated without considering momentum as a vector.

(ii) kinetic energy (of ball and wall) is reduced / not conserved, inelastic. **B1**

(allow relative speed of approach does not equal to relative speed of separation)

Marker's Comment:

Kinetic energy was 'different/not equal' will not be credited.

3 **(a)** The moment of a force about a point is the product of the force and the perpendicular distance from that point to the line of action of the force. **B1**

(b) **(i)** Taking moments about point A and since the sum of the clockwise moments must equal the sum of the anticlockwise moments,

$$8.0(9.81)\left(\frac{7.5}{2}\right)\cos 37^0 + 12.0(9.81)(7.5\cos 37^0) = T(3.8)$$ **C1**

A1

Hence $T = 2.5 \times 10^2$ N (to 2 s.f.)

(ii) Since net horizontal force must be zero, $F_H = 2.5 \times 10^2$ N
Since net vertical force must be zero,

$F_V = 8.0\times 9.81 + 12.0\times 9.81 = 2.0 \times 10^2$ N

$F = 3.2\times10^2$ N **A1**

$\tan\theta = F_V / F_H$ **C1**
 = 39°, anticlockwise above horizontal. **A1**

Marker's Comment:
Most were unable to give the right definition of moment. Quite a number were also unable to take moments of forces correctly and solve for the value of the tension.

4 (a) (i) The internal energy of a substance is the sum of the random distribution of kinetic and potential energies associated with the molecules of a system. **B1**

Marker's Comment:
Many responses were not specific enough to associate internal energy with the molecules of a system. A handful stated the first law of thermodynamics rather than the definition of internal energy

(ii) At the same temperature, water vapour and water have the same total kinetic energy of molecules but water vapour has higher total potential energy of molecules (due to weaker intermolecular forces of attraction) **B1**

Hence the internal energy per unit mass of water vapour is higher than that of water **B1**

Marker's Comment:
Not very well done, many misconceptions were surfaced. Most common misconception was reasoning that having stronger intermolecular forces of attraction would result in higher potential energy.

Another common misconception was to compare the particle motion of liquid vs solid (molecules sliding past each other vs moving around at high speeds). Students would often reason that because of this difference, water vapour molecules would have higher kinetic energy instead of linking it to the concept of temperature.

(b) (i)

$$\frac{pV}{T} = nR = \text{constant}$$

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$

$$\frac{101000(15000)}{288} = \frac{890 \times V_2}{228}$$ **C1**

$$V_2 = 1.3476 \times 10^6$$

$$= 1.35 \times 10^6 \text{ m}^3$$ **A1**

Marker's Comment:
Most common error was not realising that T is not a constant, and using $p_1V_1 = p_2V_2$ for the calculation instead.

(ii)

$$KE_{avg} = \frac{3}{2}kT$$

$$= \frac{3}{2}(1.38 \times 10^{-23})(228)$$

$$= 4.72 \times 10^{-21} \text{ J}$$ **B1**

(iii)

$$\Delta U = U_f - U_i$$

$$= \frac{3}{2}p_fV_f - \frac{3}{2}p_iV_i$$

$$= \frac{3}{2}\left[890(1.3476 \times 10^6) - (101000)(15000)\right]$$ **C1**

$$= -\ 4.7345 \times 10^8$$

$$= -\ 4.73 \times 10^8 \text{ J}$$ **A1**

Marker's Comment:
(b)(ii) was well done in general. However, (b)(iii) was not, with a fairly wide range of errors. Common errors include:

- Using (initial – final) to compute change.
- Using wrong formula (e.g. $\Delta U = p_1V_1 - p_2V_2$)
- Finding difference between average *KE* rather than *U*

5 (a) (i) Constant phase difference **B1**

Marker's Comment:
Many did not know the definition with many different variants of wrong answers. These include comparing the frequency, wavelength, type of wave, speed or stated that the sources must always be in / have the same phase for coherence.

(ii) The vapour <u>produces photons when electrons de-excite</u> from a higher energy state to a lower energy state. **B1**

The de-excitation of electrons is a <u>random process</u>. **B1**

The photons emitted are produced at <u>random time intervals</u> and therefore the <u>phase difference between the emitted photons is not constant.</u> **B1**

<u>Note:</u> Mechanism must be correct to be awarded the last two B1 marks.

> **<u>Marker's Comment:</u>**
> Poorly done despite being very lenient. Most tried to smoke their way through by using the explanation for absorption/emission spectra wholesale to explain. (e.g. vapour absorbs white light to undergo excitation and re-emits photon in all directions during de-excitation)
>
> Most did not understand that monochromatic meant only 1 wavelength is being seen/produced, which led to subsequent explanations contradicting monochromatism (e.g. different wavelengths / frequencies produced)
>
> More serious misconceptions include:
> - Associating the low pressure of the vapour to the production of light.
> - Associating the motion of the vapour molecules to the production of light. (e.g. photons are emitted when vapour molecules move around at high speeds)
> - Diffraction occurred which caused a difference in phase.
> - Using X-ray production or photoelectric effect to explain the production of photons.

(b) (i) **<u>Any 2 of the following:</u>** **B2**

- Waves have equal or approximately equal amplitude
- The slit separation must be of the same order of wavelength as the wave
- The distance between the two slits must be small compared to the distance between the source and screen.
- The waves from the two sources must be unpolarised or polarised in the same plane

> **<u>Marker's Comment:</u>**
> Not very well done. Many gave conditions for superposition to occur rather than for two source interference to be observable or repeated conditions that would be implied by coherence (e.g. same frequency).

A handful brought in Rayleigh's Criterion as a condition for observable interference pattern. There were also quite a number that could not distinguish between slit width vs slit separation.

(ii)

$$x = \frac{\lambda D}{a}$$

$$= \frac{590 \times 10^{-9} \times 2.3}{1.2 \times 10^{-3}}$$ **C1**

$$= 1.1308 \times 10^{-3}$$

$$= 1.1 \times 10^{-3} \text{ m (to 2sf)}$$ **A1**

[-1 m] if students did not use or arrive at formula to get the final answer. (i.e. used *a* sin*θ* = *nλ* in conjunction with tan*θ* = *x* / *D* without arriving at *x* = *λD* / *a*.

Marker's Comment:

Generally well done. Note for students that used first principles that they should arrive at the stated formula in the syllabus via the use of small angle approximation before solving for the final answer.

(iii) Since $I \propto A^2$,

$$\frac{I_A}{I_B} = \frac{A_A^{\ 2}}{A_B^{\ 2}}$$

$$\frac{I}{\frac{1}{3}I} = \frac{A_A^{\ 2}}{A_B^{\ 2}}$$

$$A_B = \frac{1}{\sqrt{3}} A_A$$ **M1**

By principle of superposition, the amplitude of a dark fringe near P is

$$A = A_A - A_B$$

$$= A_A - \frac{1}{\sqrt{3}} A_A$$

$$= \left(1 - \frac{1}{\sqrt{3}}\right) A_A$$ **M1**

Therefore, intensity of dark fringe is:

C1

$$\frac{I_{fringe}}{I} = \frac{A^2}{A_A{}^2}$$

A1

$$I_{fringe} = \left(\frac{A^2}{A_A{}^2}\right) I$$

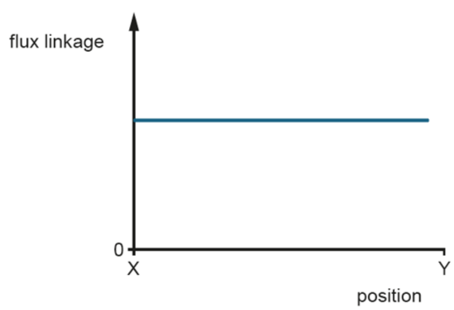
$$= \left(1 - \frac{1}{\sqrt{3}}\right)^2 I$$

$$= 0.17863\ I$$

$$= 0.18\ I$$

Marker's Comment:
Students found this challenging. Many left this blank or did not know where to start from. A handful got values of more than I for dark fringe, this is impossible. Common misconception was to merely do a subtraction of the intensities from slit A and B to get the intensity of the dark fringe.

6 (a) (i) non-zero horizontal straight line from X to Y **B1**



(ii) constant flux density (inside coil) **B1**

either (magnetic) flux linkage proportional to flux density **B1**

or $\Phi = BAN$ and B, A and N are all constant

Marker's Comment:
Very few were able to explain the constant flux linkage even though the correct line was drawn.

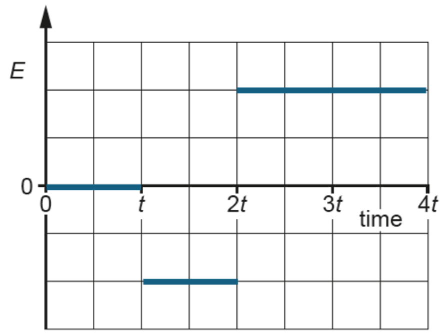
(iii) $\Phi = BAN$ **C1**

$= 0.080 \times 0.71 \times 10^{-4} \times 64$

$= 3.6 \times 10^{-4}$ Wb **A1**

(iv) sketch showing:

- *E* is zero from time 0 to time *t* and non-zero after time *t* **B1**
- *E* has constant non-zero magnitude between time *t* and time 4*t* **B1**
- *E* has same constant non-zero value of one sign between time *t* and time 2*t*, and opposite sign between time 2*t* and time 4*t* **B1**



(b) current in spring creates a magnetic field around the spring **B1**

either (magnetic) fields around adjacent turns interact to cause a force to be exerted (between the turns) **M1**

or current in one turn interacts with (magnetic) field due to adjacent turns to cause force to be exerted (between the turns)

(magnetic force) is attractive so distance (between turns) decreases **A1**

> **Marker's Comment:**
> Faraday's Law was applied to explain the change in distance which was wrong. A few managed to explain this part well.

7 **(a)** number of cycles per unit time **B1**

> **Marker's Comment:**
> Poorly done. Common errors include referring frequency to the number of times the current changes direction, not being able to distinguish between an oscillation, wave or rotation with cycles, and also using the period as a base to define frequency (e.g. inverse of period, time taken for one complete oscillation etc.)

(b) **(i)** period = 2π / 40π = 0.050 s = 50 ms **A1**

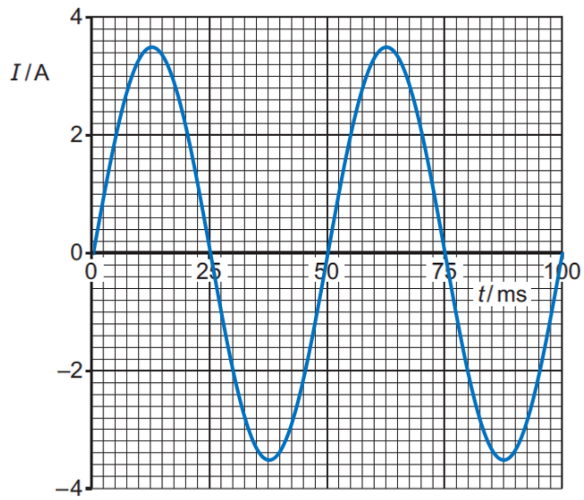
> Marker's Comment:

Small handful needs to be mindful of their use of variables. There is a difference between what is meant by period T vs time t.

(ii) sinusoidal curve, starting at (0, 0) and initially increasing from there **B1**

periodic line showing 2 cycles with period 50 ms from $t = 0$ to $t = 100$ ms **B1**

all peaks shown at I = +3.5 A and all troughs shown at I = –3.5 A **B1**



(iii) $I_{\text{r.m.s}} = 3.5/\sqrt{2}$

$= 2.5$ A **A1**

(c) $P = I^2R$

$P_0 = 3.5^2 \times 680 \ (= 8330 \text{ W})$ **M1**

$P_{avg} = I_{rms}{}^2R = \left(\frac{3.5}{\sqrt{2}}\right)^2(680) \ (= 4165 \text{ W})$ **M1**

$\frac{P_{avg}}{P_0} = \frac{4165}{8330} = \frac{1}{2}$ therefore, $P_{avg} = \frac{1}{2}P_0$ **A1**

Note: full working with substitution of values shown to get credit. Explicit comparison with calculation must be made to obtain last A1 mark.

Marker's Comment:
Generally parts (b) and (c) were well done. Some read off the scale wrongly which usually resulted in them drawing a graph with amplitude 3.0 A instead of 3.5 A.

Students should also be mindful of the requirements of a "show" question. They are required to show their workings fully, including making explicit mathematical comparison to show the result by calculation. A number jumped to the conclusion after finding the values of P_0 and P_{avg} without doing a proper mathematical comparison.

8 **(a)** **(i)**

$$a = \omega^2 r = \left(\frac{2\pi}{24 \times 60 \times 60}\right)^2 (6370 \times 10^3)$$ **C1**

$$= 3.37 \times 10^{-2} \text{ m s}^{-2}$$ **A1**

> **Marker's Comment:**
> The question asks for centripetal acceleration, not gravitational acceleration. Some using $g = GM/r^2$ are calculating the wrong quantity.

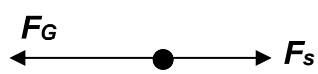
(ii)

$$F_G = \frac{GMm}{r^2}$$

$$= \frac{(6.67 \times 10^{-11})(5.98 \times 10^{24})(1.00))}{(6370 \times 10^3)^2}$$ **C1**

$$= 9.83 \text{ N}$$ **A1**

(b) **(i)**



B2

B1: Correct Magnitude
B1: Correct Direction

> **Marker's Comment:**
> Draw forces in the radial direction: gravitational force towards Earth's centre (leftward) and spring tension away from centre (rightward). Ensure vector lengths show relative magnitudes and show only the object - force diagrams should not include Earth, spring, or other objects.

(ii) *F* = *ma*

$\boldsymbol{F_G} - \boldsymbol{F_s} = ma$

$9.83 - \boldsymbol{F_s} = 1.00 \times 3.37 \times 10^{-2}$ **C1**

$\boldsymbol{F_s} = 9.80$ N (no ECF) **A1**

(iii) At the equator, part of the gravitational acceleration provides centripetal acceleration for Earth's rotation. **B1**
Hence, the measured free fall acceleration would be slightly less than the true gravitational acceleration alone. **B1**

> **Marker's Comment:**
> Part of gravity's "effort" goes into maintaining the circular motion, leaving less available to accelerate objects downward:
> true gravitational acceleration (9.83 m s^{-2}) = centripetal acceleration at equator (0.037 m s^{-2}) + apparent gravitational acceleration measured (9.80 m s^{-2})

(c) (i) When the tension in the rope is less than the weight of the person, the resultant force acting on the person is in the same direction as his velocity, causing the person to speed. When the tension in the rope is more than the weight of the person, the resultant force acting on the person is opposite in direction to his velocity, casing the person is slow down. **B1**

Consequently, the person will achieve maximum speed when the resultant force acting on him is zero, accompanied by a corresponding acceleration of zero. **B1**

(ii) Man is moving at maximum speed when resultant force acting on him is zero.

$$mg = ke$$

$$\Rightarrow e = \frac{mg}{k} = \frac{80.0 \times 9.81}{120} = 6.54 \text{ m}$$ **C1**

Applying Principle of Conservation of Energy:
total energy before stepping off = total energy at maximum speed v

$$0 + 0 + mg(L + e) = \frac{1}{2}mv^2 + \frac{1}{2}ke^2 + 0$$ **C1**

where L is the natural length of the rope.

$$v = \sqrt{\frac{2mg(L+e) - ke^2}{m}}$$

$$= \sqrt{\frac{2 \times 80.0 \times 9.81 \times (25.0 + 6.54) - 120 \times (6.54)^2}{80.0}}$$

$$= 23.6 \text{ m s}^{-1}$$ **A1**

(iii) Let x to be the extension when the person is at the lowest point **C1**

Applying Principle of Conservation of Energy:
GPE at highest point = EPE at lowest point

$$mg(L + x) = \frac{1}{2}kx^2$$

$$80.0 \times 9.81(25.0 + x) = \frac{1}{2}(120)x^2$$

$$60x^2 - 784.8x - 19620 = 0$$

$$x = 25.8 \text{ m}$$ **A1**

(iv) 1. At highest point,

$$GPE = mg(L + x) = 80.0 \times 9.81 \times (25.0 + 25.8)$$

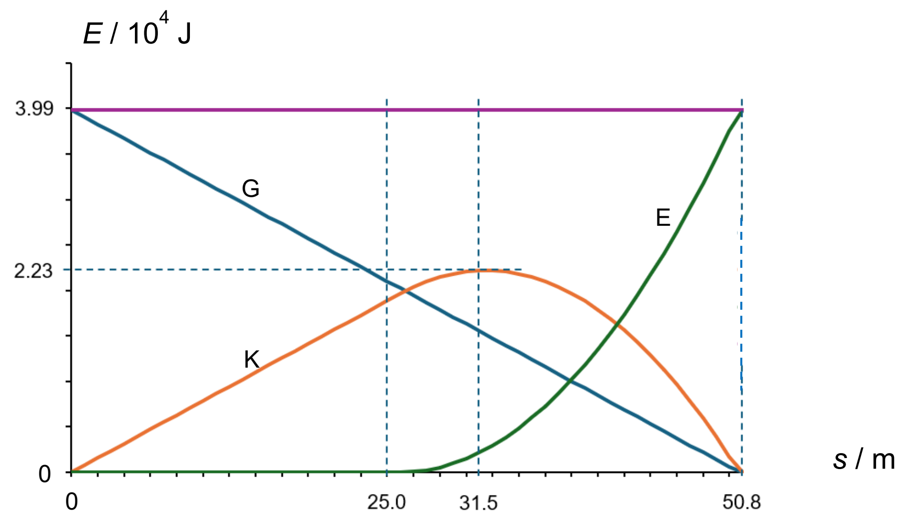
$$= 3.99 \times 10^4 \text{ J}$$ **C0**

Straight GPE line with correct labels on y-axis and x-axis. **B1**

2. Quadratic EPE curve with correct start and end points (s = 25.0 m & s = 50.8 m respectively). **B1**

3. $$KE_{max} = \frac{1}{2}mv^2 = \frac{1}{2}\times 80.0\times 23.6^2 = 2.23\times 10^4 \text{ J}$$ **C0**

Straight line from s = 0 m to s = 25.0 m. **B1**
Curve from s = 25.0 m to s = 50.8 m, with correct label on y-axis



Marker's Comment:
Energy graphs must show correct curvature direction. EPE varies as ½kx^2, giving a concave up (U-shaped) curve, not concave down, and KE changes in a curved manner once the rope stretches. Include numerical energy values and key displacement markers (natural length, at maximum KE, and maximum extension).

9 **(a)** By varying the resistance of the variable resistor R <u>from its maximum resistance to zero</u> **B1**

(b) **(i)** False, because the resistance values are not constant. Each point on the graph represents a different resistance setting. To test Ohm's law ($V \propto I$ for constant R), the resistance must remain fixed while voltage is varied. **B1**

OR

False. To test Ohm's law, the same resistance value must be used throughout the experiment. Here, the variable resistor is set to different values at each measurement, so we cannot conclude it doesn't obey Ohm's law from this data.

OR

False. To test Ohm's law, the current through a fixed resistance is measured as the p.d. across it is varied. In this experiment, the resistance itself is being changed, not the applied voltage, so this is not a valid test of Ohm's law.

(ii) False. The battery does not supply electrons - the electrons are already in the conductor. Instead, the battery acts as an electrical 'pump' that provides e.m.f./electric field to make these existing free electrons drift through the circuit, producing current. **B1**

(c) (i) The graph is a plot of $V = E - Ir$
Hence, the V-intercept is $\underline{E = 3.00\text{ V}}$. **A1**

(ii)

$$\text{Gradient} = -r = \frac{3.00 - 0.20}{0.0 - 4.0} = \frac{2.80}{-4.0} = -0.70\ \Omega$$ **C1**

So $r = 0.70\ \Omega$ **A1**

Deduct 1 mark if gradient is positive or if r is negative.

> **Marker's Comment:**
> Reading accuracy from graph is crucial. Select two widely spaced points that lie exactly on grid intersections to minimise reading errors when calculating internal resistance. Poor coordinate estimation, especially for points between grid lines, leads to significant errors in the final answer. Use clear intersection points wherever possible.

(d) (i) Power output is maximum when $R = r = 0.70\ \Omega$.
Using potential divider rule, $\underline{V = 1.5\text{ V}}$ (allow ECF) **A1**

(ii)

$$P_{\text{max}} = \frac{V^2}{R} = \frac{1.5^2}{0.70}$$ **M1**

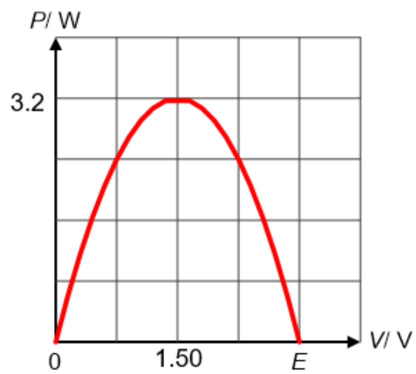
$$= 3.2\text{ W}$$ **A1**

Alternatively:

Draw a line of gradient 0.70 Ω to determine values of V and I at point of intersection (2.1, 1.50) when R is 0.70 Ω. **M1**

Hence, P_{max} = 2.1 A × 1.50 V = 3.2 W (to 2 s.f.) **A1**

(iii)



Quadratic graph opens down. **B1**

Symmetrical about $V = E/2$ (peak is at 1.50 V, 3.2 W). **B1**

(e) (i)

$$\eta = \frac{IV}{IE} = \frac{V}{E} = \frac{1.50}{3.00} = 50\%$$ **A1**

(ii) Maximum efficiency is achieved when value of R is maximum, i.e., 10 Ω. (Reject $R = \infty$.)

Proof: **A1**

$$\eta = \frac{I^2R}{IE} = I\frac{R}{E} = \left(\frac{E}{r+R}\right)\frac{R}{E} = \frac{R}{r+R} = \frac{1}{r/R+1}$$

Hence, for efficiency η to approach 100%, the term r/R in the denominator must approach zero, that is, R must be large (which would mean lower power output) or r must be small (not a marking point here).

(iii) Maximum power transfer is more desirable because the goal is to produce the loudest sound, which requires maximum power delivered to the loudspeaker. **B1**

High efficiency ($R >> r$) minimises energy waste but reduces the actual power delivered to the speaker, whilst maximum power transfer ($R = r$) provides the loudest sound despite being less efficient. **B1**

Note: Both points must be correct. Any contradiction in answers will score 0.

(f) (i)

Using potential divider rule, $V_{PQ} = \frac{6.00}{6.00+4.00} \times 2.00 = 1.20$ V **M1**

$$E' = \frac{0.600}{1.000} \times 1.20 = 0.720 \text{ V}$$ **A1**

(ii)

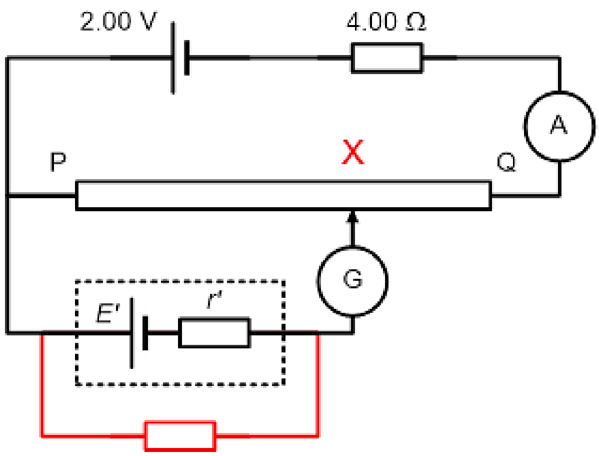


Fig. 9.4

B1

Connect a resistor across the lower branch to allow current to flow through r' so that its value can be determined from $V_{PX} = E' + Ir'$.

(iii) From $Q = It$,

$2000 \times 10^{-3}\,\text{Ah} = (0.080\text{A})\,t$ **C1**

$\Rightarrow t = 25$ h **A1**