UNITS: 1 MARK OFF EVERY TIME. (NO LIMIT)

(SECTION B: MORE TOLERANT - CONSISTENCY WILL GIVE $\frac{1}{2}$ MARK OFF.)
ONCE ONLY - IGNORE

# TEE PHYSICS 1988

## DRAFT SOLUTIONS

### SECTION A

NOTE : The maximum loss in marks in Section A due to significant figures is to be 5 marks out of 80. Between 2 and 4 significant figures is acceptable.

1. (a) The zero error is 0.4 mm (either + or - ) (2 marks)
   (b) The true reading is X + 0.4 mm (2 marks)

1 mark for 0.6 mm. (X + 0.6 mm = 2 marks for whole question)

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2. The torque exerted on the nut is given by

$$t = r \times F = 0.305 \times 592 \qquad \text{(2 marks)}$$

$$= 181 \text{ Nm} \qquad \text{(2 marks)}$$

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3.

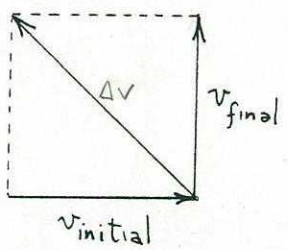


DIAGRAM GETS MARKS - CALCULATION DOESN'T.

$$\Delta v = \text{change in velocity}$$

$$= v_{final} - v_{initial}$$

(diagram 2 marks)
(labels 2 marks)

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4. The maximum force exerted on the pilot is at the bottom of the loop, which is the sum of the centripetal force and the force due to gravity so

$$F = \frac{m v^2}{r} + mg = 6 \, mg$$

(2 marks)

The speed of the plane is

$$v = 900 \times 1000 / 3600$$
$$= 250 \text{ ms}^{-1}$$

From the above $250^2 / r + g = 6 g$

$$r = 62500 / 5 \times 9.8$$
$$= 1280 \text{ m} \qquad \text{(2 marks)}$$

1276 m ACCEPTABLE.

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5. The change in momentum is given by

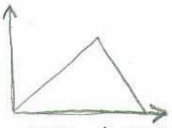
$$p_2 - p_1 = F (t_2 - t_1)$$

$= \text{area under the curve}$ (2 marks)

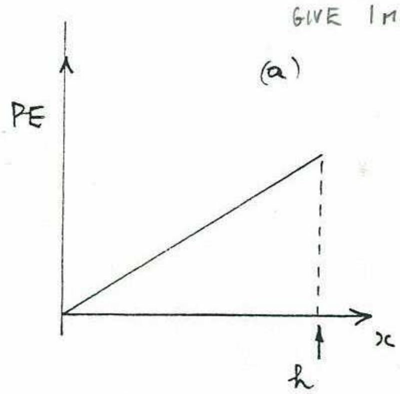
$= \frac{1}{2} \times 10 \times 5$

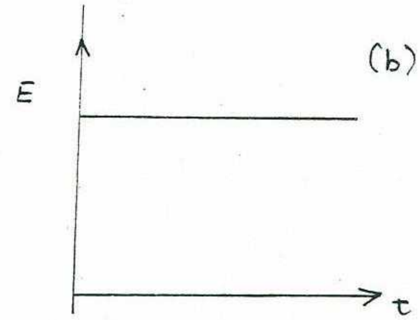
$= 25 \text{ kgms}^{-1}$ (Ns) (2 marks)

NO DIRECTION NEEDED.




6.




(2 marks each)

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7. The absolute refractive index of a medium is given by

$$n = \frac{\text{speed of light in free space}}{\text{speed of light in the medium}}$$ $\left(= \frac{\sin i}{\sin r}\right.$ must mention other medium is a vacuum. $\left.\right)$

(2 marks)

Since the velocity of light in the medium cannot exceed the velocity of light in free space, n can never be less than 1.

(2 marks)

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8. Since the tension in the string is constant,

$$f \propto \frac{1}{\lambda}$$

(2 marks) } FOR THOSE WHO GET NUMBERS WRONG.

For (b) the wavelength is half that in (a), so the frequency is double, i.e. 892 Hzs

(1 mark)

For (c) the wavelength is one third that in (a) so the frequency is tripled, i.e. 1338 Hzs
$(1{\cdot}34 \times 10^3)$

(1 mark)

} NUMBERS ONLY – 4 MARKS.

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9. For a lens,

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$ (1 mark)

$$\frac{1}{50} = \frac{1}{3050} + \frac{1}{v}$$ } 2 MARKS FOR THIS LINE

From this the distance between the lens and the film is

$$v = 50.8 \text{ mm}$$ 1 (~~3~~ marks)

USE 3·05m ⇒ 2 MARK PENALTY

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10. In one half-life the amount of radioactive material decreases to one half its original value.

(2 marks) } FOR WRONG ANSWER BUT REASONING

Since 15 years is 5 half lives, the fraction remaining after 15 years is

$$p = 1 / 2^5 = 1/32 \quad (\text{or } 0.0312)$$

(2 marks)

FULL MARKS FOR NUMBER

ACCEPT 1 SIG. FIG.

– no mass.
– penetrates paper, alfoil, etc.

11. Four distinct properties of gamma radiation are:
- it is electromagnetic radiation
- it can cause pair production
- it has a very short wavelength (or very high frequency)
- the photons have a very high energy
- it is not deflected by electric or magnetic fields ← 2 DISTINCT PROPERTIES.
- it can expose photographic film
- it can ionize atoms (1 mark each)
- no charge

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12. The work function of a metal is the amount of energy (WORK DONE) required to just remove an electron from the metal. (4 marks)

IMPORTANT (2 MARKS FOR NOT MENTIONING "JUST" OR "MINIMUM")

FORMULA ONLY (OMI... LACKS EXPLANATION
– MUST DEFINE AND EXPLAIN EQUATION (2 MARKS ONLY)

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13. The efficiency is

$$= 100 \times \frac{\text{(useful energy produced)}}{\text{(total energy consumed)}}$$ ← 1 MARK

$$= 100 \times 1 \times 10^9 / ( 2 \times 10^9 + 1 \times 10^9 )$$
$$= 33.3\%$$

(2 marks)

The mass consumed in a year is found from $E = \Delta mc^2$
Here

$$E = \text{power} \times \text{time}$$
$$= 3 \times 10^9 \times 365 \times 24 \times 3600 \quad (\doteq 9.4608 \times 10^{16}\ \text{J})$$

from which

$$\Delta m = E / c^2$$
$$= 1.05\ \text{kg}$$

(2 marks)

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14. The force is given by Coulomb's law

k MUST BE DEFINED

$$F = \frac{q_1 q_2}{4\pi\epsilon_o r^2} = \frac{(3 \times 10^{-6})^2}{4\pi\epsilon_o\ r^2}$$ (1 MARK) (2 MARKS)

(1 mark)

Substituting 1.5 N for F gives $r = 232$ mm. This is the distance between the two charges. (1 MARK)

(3 marks)

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15. The force on wire A is given by

WRONG FORMULA – 0 MARKS
DIRECTION – 1 MARK.

$$F = i_1 l B_2 \qquad \text{where } B = \frac{\mu_o i_2}{4\pi r}$$

(1 mark)

Thus the force per unit length is

1 MARK FOR SCALE READING

$$\frac{F}{l} = \frac{\mu_o i_1 i_2}{2\pi r} = 4\pi \times 10^{-7} \times 2 \times 3.5 / ( 2\pi \times 0.0472 )$$

0.0470 – 0.0475 ACCEPTABLE

$$= 29.7\ \mu\text{Nm}^{-1} \quad 2.97 \times 10^{-5}\ \text{Nm}^{-1}$$ (2 marks)

The direction is to the left, parallel to the rule. (1 mark)

16. The power dissipated by the bulb is $P = VI$ so the current is

$$I = P/V = 48/12$$
$$= 4.00\ A$$ (2 marks)

The current is given by $I = V/R$ so the resistance of the headlamp is

$$R = V/I = 12/4$$
$$= 3.00\ \Omega$$ (2 marks)

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17. The charge on one electron is $1.602 \times 10^{-19}$ C ← REASONING (1 mark)

Thus the number of excess electrons is

$$n = Q/e = 4 \times 10^{-9} / 1.602 \times 10^{-19}$$ ← 2 MARKS
$$= 2.50 \times 10^{10} \text{ electrons}$$ (3 marks)

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18. (a) ADCB } DCBA — MUST MENTION ELECTRON FLOW IF REVERSED ANSWERS. (1 mark)
(b) ABCD (1 mark)
(c) repel (2 marks)

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19. If the wire was not wound back on itself, it would form a coil. Because of this, every time there was a change in current, an emf would be generated. By winding back the coil on itself, the magnetic field generated by one half of the coil cancels out the magnetic field generated by the other half, so that there is no emf generated.

NON-INDUCTIVE RESISTOR – 4 MARKS.
CANCELLING MAGNETIC FIELD – " " (4 marks)

INDUCTION IMPORTANT CHANGING CURRENT CHANGE MAGNETIC FIELD PRODUCING EMF.

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20. From the expression given,

1 MARK ← 2 MARKS (kg, m, s acceptable)

$$r^x = \frac{8\eta l v}{\pi t \Delta p} = \frac{1.M\ L\ T^{-1}.L.L^3}{1.T.M\ L\ T^{-2}L^{-2}} = L^4$$ (3 marks)

Hence r is raised to the power 4. ← 1 MARK (1 mark)

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MULTIPLE CHOICE

| | | | | |
|---|---|---|---|---|
| 21. A | 23. B | 26. C | 28. C | 30. C |
| 22. C | 24. A | 27. A | 29. E | |
| | 25. B | | | |

1 MARK EACH.

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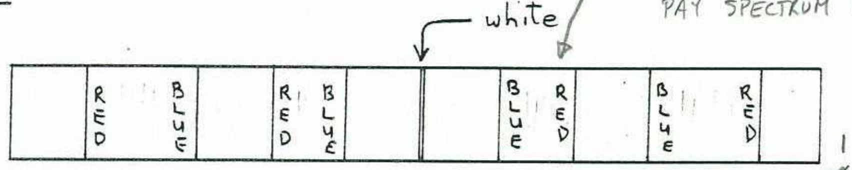
NO MARKS FOR SPECTRUM REVERSED

PAY SPECTRUM AS WELL

QUESTION 1

(a)




(~~2~~ 1 marks)

(b) For the most energetic ultra-violet photon, the energy is

$$E = +\ 13.58\ \text{eV} = hc/\lambda \quad \longleftarrow \text{1 MARK.}$$

Hence

$$\lambda = 6.63 \times 10^{-34} \times 3 \times 10^{8} / 13.58 \times 1.602 \times 10^{-19}$$
$$= 91.4\ \text{nm} \quad 9.14 \times 10^{-8}\ \text{m}$$

(2 marks)

(c) For the least energetic visible photon

$$\lambda = hc / (3.39 - 1.51) \times 1.602 \times 10^{-19}$$
$$= 660\ \text{nm} \quad 6.60 \times 10^{-7}\ \text{m.}$$

(~~1~~ 2 mark)

(d) Hydrogen burns with a blue flame because most of the lines in the Balmer series, which are the only ones lying in the visible region, are in the blue portion of the spectrum.

BAND EMISSION SPECTRA (BAND MOLECULAR SPECTRA)

(1 mark)

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QUESTION 2

SPLIT IN HALF – 1 MARK

OR MORE (NEUTRONS)

(a) Fission is the process wherein one heavy nucleus falls apart into two pieces; fusion is the process where two light nuclei join together into one. — 1 MARK

2 MARKS FOR PRINCIPLE.

(2 marks)

(b) The energy arises from the difference in mass between the initial and the final particles. The mass difference is

$$m = (\ 2 \times 2.014102 - 3.016049 - 1.008665\ )$$
$$= 0.00349\ \text{amu}$$

(1 mark)

Thus the energy obtained from all the molecules in 1 litre of water is

$$E = mc^2 \times \text{number of molecules}$$

$$= 0.00349 \times 1.661 \times 10^{-27} \times (3 \times 10^{8})^2 \times 5.02 \times 10^{21}$$

$$= 2.619 \times 10^{9}\ \text{J}$$

(2 marks)

EXPRESSION OF THIS PER DAY – 0 MARKS.

ANSWER NOT NECESSARY BUT SHOULD BE INVOLVED IN FINAL CALCULATION

Therefore the power produced if this mass is consumed in one day is

$$P = E/t = 2.619 \times 10^{9} / (24 \times 3600)$$
$$= 30.3\ \text{kW}$$

(1 mark)

$3.03 \times 10^{4}\ \text{W}$

QUESTION 3 1 MARK FORMULA
1 MARK ANSWER.

(a) The emf generated in the wire is given by

$$\text{emf} = lvB = 72.4 \times 10^{-3} \times 1.5 \times 2.58$$
$$= 0.280 \text{ V}$$

(2 marks)

(b) The power dissipated in the resistor is

$$P = I^2R = V^2/R = 0.280^2/5$$
$$= 15.7 \text{ mW}$$ $1.57 \times 10^{-2}$ W

(1 mark)

(c) The rate at which work is being done on the wire is 15.7 mW and this is equal to Fv. Hence

$$F = P/v = 15.7 \times 10^{-3} / 1.5$$
$$= 10.5 \text{ mN}$$ $1.05 \times 10^{-2}$ N. ALTERNATIVE METHODS.

(2 marks)

(d) The rate at which the applied force does work is exactly equal to the rate at which energy is dissipated in the resistor, i.e.

$$P = 15.7 \text{ mW}$$ $1.57 \times 10^{-2}$ W MUST SHOW WORKING (REASONING) IF ANSWER WRONG

(2 marks)

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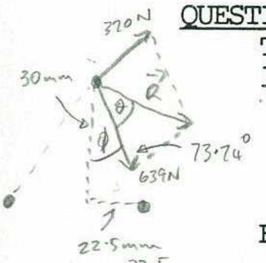
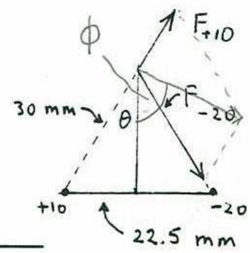
QUESTION 4




The force exerted by the 10 μC charge is found from Coulomb's law:

$$F = \frac{q_1 q_2}{4\pi\epsilon_o r^2}$$




tan φ = $\frac{22.5}{30.0}$ ⇒ φ = 36.87°

From the diagram,

$$r^2 = 0.03^2 + 0.0225^2$$

So

$$F = \frac{10 \times 10^{-6} \times 5 \times 10^{-6}}{4\pi \times 8.85 \times 10^{-12} \times (0.03^2 + 0.0225^2)}$$ $1.406 \times 10^{-3}$
$$= 320 \text{ N}$$

$\vec{R} = \sqrt{(320)^2 + (639)^2 - 2(320)(639)\cos 73.74}$

$= \sqrt{3.962 \times 10^5}$

$= 6.295 \times 10^2$ N

This force is repulsive. The force exerted on the 5 μC charge by the -20 μC charge is found similarly, and this must be exactly twice this or 639 N, except that here the force is attractive.

(2 marks)

$\frac{320}{\sin\theta} = \frac{6.295 \times 10^2}{\sin 73.74°}$

The net force is the sum of these. In the diagram, the angle θ is given by

$$\theta = \text{artan}(0.0225/0.03) = 36.87°$$

⇒ θ = 29.21°

The vertical components of the two forces are 320 cos θ and 639 cos θ; thus the net vertical component is

$\vec{R} = 6.30 \times 10^2$ N at 66.1° to vertical

$$F_v = (320 - 639)\cos\theta$$
$$= -256 \text{ N}$$

The net horizontal component is

$$F_h = (320 + 639)\sin\theta$$
$$= 575 \text{ N}$$

(2 marks)

Thus the net force is

$$F = \sqrt{(256^2 + 575^2)}$$
$$= 630 \text{ N}$$

(1 mark)

The net force F acts at an angle Φ to the vertical where

$$\Phi = \text{artan}\,\frac{575}{256}$$
$$= 66.0°$$

ANY DIRECTION RELATIVE TO THE DIAGRAM USED. (1 MARK)

(~~2~~ 1 marks)

QUESTION 5

(a) The angle ABE is found from Snell's law

$$n_1 \sin \theta_1 = n_2 \sin \theta_2 \qquad (1 \text{ mark})$$

Hence

$$\sin \theta_2 = 1.33 \sin 0.295^\circ / 1$$ ← 1 MARK.

$$\theta_2 = 0.392^\circ \qquad (2 \text{ marks})$$

(b) From the diagram

$$\tan(90 - \theta_1) = NC / BN$$
$$\tan(90 - \theta_2) = NP / BN \qquad (2 \text{ marks})$$

$n_{1\to 2} = \frac{n_2}{n_1} = \frac{\text{real}}{\text{apparent}}$. ACCEPTABLE.

Dividing these two equations,

$$NP = NC \tan(90 - \theta_2) / \tan(90 - \theta_1)$$
$$= 0.395 \text{ m}$$

This is the apparent distance of the coin from the surface of the water. (2 marks)

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ACCEPT EITHER ANSWER.

QUESTION 6

(a) The average time of fall is 1.64222 s (1.5588 s). Hence the acceleration due to gravity is

$$g = \frac{2s}{t^2} = \frac{2 \times 11.8}{1.64222^2} \qquad \left[ = \frac{2 \times 11.8}{1.5588^2} \right]$$

NEEDS COMMENT → $$= 8.75 \text{ ms}^{-2} \qquad \left[ = 9.71 \text{ ms}^{-2} \right]$$ ← NO COMMENT NEEDED (1 mark)

(REASON WHY IT SHOULD BE LEFT OUT)

Some comment on the fact that the recorded time of 2.31 s is quite different form all the others.

(1 mark)

(b) From the data, the maximum difference between the average time and the measured times is 2.31 - 1.64222 = 0.6678. Thus we can estimate the time as

$$t = 1.64 \pm 0.67 \text{ s} \qquad \left[ = 1.56 \pm 0.13 \text{ s} \right]$$

This represents a percentage uncertainty of 41% (8.3%). We can regard the uncertainty in measuring the distance as ± 0.05 m, which is a percentage uncertainty of 0.4%. Therefore the total uncertainty is 82% (17%) and we can write g as

$$g = 8.8 \pm 7.2 \text{ ms}^{-2} \qquad \left[ = 9.7 \pm 1.6 \text{ ms}^{-2} \right]$$

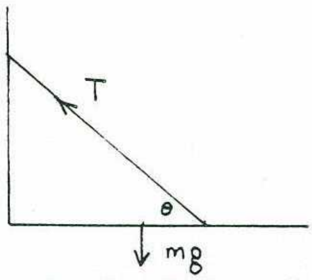
(2 marks)

STANDARD DEVIATION ACCEPTABLE AS UNCERTAINTY

(c) Clearly, the major uncertainty is in the timing. By making the distance the sphere falls larger, we will increase the time and hence reduce the uncertainty. However, this will not achieve a large reduction in uncertainty since to double the time we would have to increase the distance by four times. It would be far more effective to employ an automatic timing mechanism, such as an infra-red beam and an appropriate timer.

(2 marks)

QUESTION 7




(a) Write T for the tension in the chain and θ for the angle as shown in the diagram. Then taking moments about the pivot,

$$\text{clockwise moments} = \text{anticlockwise moments} \quad \leftarrow \text{(1 MARK)}$$
$$3000\ g \times 9 = T \sin\theta \times 13$$

Fom the diagram, $\sin\theta = \dfrac{11}{\sqrt{(11^2 + 13^2)}}$ $\Rightarrow \theta = 40{\cdot}24^{\circ}$ (1 MARK)

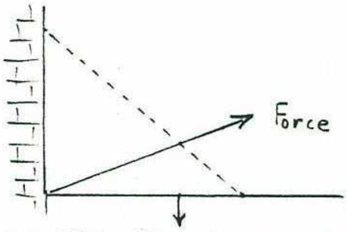
Thus

$$T = \frac{3000 \times 9.8 \times 9}{13 \times 11 / \sqrt{(11^2 + 13^2)}} \quad \leftarrow \text{(1 MARK)}$$

$= 31.5$ kN (3 marks)

$3{\cdot}15 \times 10^4$ N.

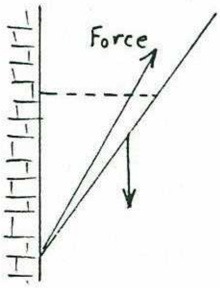
(b)




The diagram shows the force exerted by the wall on the drawbridge. [Naturally the force exerted by the drawbridge on the pivot would be equal and opposite].

(2 marks)

(c)




As the drawbridge is raised, the chain becomes more horizontal and the tension force decreases. Hence the force on the pivot becomes more and more vertical. [Alternatively, it could be stated that the force vector rotates in an anticlockwise direction].

(2 marks)

QUESTION 8

(a) The period of the orbit is T = 24 hours. If r is the radius of the orbit then the velocity of the satellite is

$$v = \frac{\text{distance}}{\text{time}} = \frac{2\pi r}{T}$$

The centripetal force required to keep the satellite in its orbit is provided by the gravitational attraction of the earth. If M is the mass of the earth then

$$\frac{GMm}{r^2} = \frac{mv^2}{r} = \frac{m \quad 4\pi^2 r^2}{r \times (24 \times 3600)^2}$$

$$r^3 = \frac{GMT^2}{4\pi^2}$$ ← (1 MARK)

$$= \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24} \times (24 \times 3600)^2}{4\pi^2}$$ ← 1 MARK

$$r = 42.25 \times 10^6 \text{ m}$$ ← 1 MARK

$(4.22 \times 10^7)$

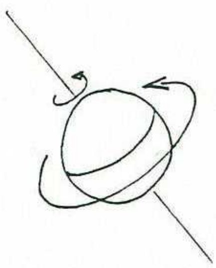
~~(2 marks)~~

Thus the distance above the earth is $(42.25 - 6.37) \times 10^6$

$$= 35.9 \times 10^6 \text{ m}$$ $3.59 \times 10^7$ m

(1 mark)

(b)



MUST SHOW DIRECTIONS SAME.

(1 MARK FOR DIRECTION OF EARTH)

(2 marks)

(c) The satellite must rotate about the centre of mass of the earth. Hence it is possible for the satellite to remain directly above points which lie on the equator only - which means that it is not possible for a satellite to be permanently stationed directly above Perth.

NO - 1 MARK

(~~2~~ marks)
(1 MARK)